Nevada Test Site

Routine Radiological Environmental Monitoring Plan

Appendices

December 1998

Prepared for:
U.S. Department of Energy
Nevada Operations Office

Prepared by:

Bechtel Nevada

Post Office Box 98521
Las Vegas, NV 89193-8521

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Environmental Monitoring
Plan**

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Preproduction Review - Final Report November 6, 1998

Work Performed Under Contract No. DE-AC08-96NV11718

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APPENDIX A

QUALITY ASSURANCE, ANALYSIS, AND SAMPLING PLAN FOR NTS AIR

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ACRONYMS and ABBREVIATIONS

ASER	Annual Site Environmental Report
ASL	Analytical Services Laboratory
BN	Bechtel Nevada
cfm	cubic feet per minute
cm	centimeter (0.01 meter)
CT	concentration
DOE	U.S. Department of Energy
EM	Environmental Monitoring Project
EMPM	Environmental Monitoring Project Manager
EPA	U.S. Environmental Protection Agency
ft	feet
L	liter
LCS	Laboratory Control Standard
LDAS	Laboratory Data Analysis System (program used to calculate and record sample results)
m	meter
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
mL	milliliter (0.001 liter)
mm	millimeter (0.001 meter)
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NTS	Nevada Test Site
PC	personal computer
QA/QC	Quality Assurance/Quality Control
QAASP	Quality Assurance, Analysis, and Sampling Plan
WI	Work Instruction
Y	Yield (percent activity detected)

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Environmental monitoring is conducted at the Nevada Test Site (NTS) to monitor concentrations of radioactivity in air, surface water, groundwater, soil, vegetation, and animals; and ambient gamma radiation exposures. This monitoring is done to comply with regulations and address stakeholder issues. This Quality Assurance, Analysis, and Sampling Plan (QAASP) addresses the environmental monitoring that is performed to measure radionuclide concentrations in air.

1.2 SAMPLING OBJECTIVES

The purpose of the radiological sampling on the NTS is to comply with regulatory requirements as described in Chapter 3 of the *Routine Radiological Environmental Monitoring Plan*. The primary objective of the sampling is to perform confirmatory sampling to satisfy concerns of stakeholders that radiation levels in plants and animals are below regulatory action levels and “to show that the radionuclides are behaving in the environment as expected.” Monitoring is also being done to demonstrate that conscientious and cost-effective sampling is being performed on the NTS to detect any breakdown in control measures to contain and manage radionuclides of concern.

1.3 MEDIA TYPES

The media type addressed in this QAASP is air. Sampling is done for particulate radionuclides and tritium in air.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.1 INDIVIDUALS USING THE DATA

Data generated from the implementation of this QAASP will be used primarily by the U.S. Department of Energy (DOE), Bechtel Nevada (BN), and the U.S. Environmental Protection Agency (EPA) to verify compliance with permit requirements and to manage NTS operations based on the principles of ecosystem management. Examples of individuals using the data includes:

- DOE Environmental Monitoring Project Manager.
- BN Environmental Monitoring Project Manager.

Other users of the data include stakeholders, such as the state of Nevada, American Indians, land owners and stewards of adjacent lands, and other interested parties.

2.2 PROJECT OFFICERS

Bechtel Nevada is responsible for project management. Key officers include competent individuals in the following positions:

- Project Manager – provides management direction for the environmental monitoring project.
- Field Activities Supervisor – oversees field work.
- Laboratory Manager – is responsible for laboratory work and data.
- Quality Assurance Manager – provides Quality Assurance/Quality Control (QA/QC) guidance and conducts audits .
- Data Specialists/Reviewers – verify, validate, and report the data.

3.0 DEFINITIONS

ASL (Analytical Services Laboratory) – The radioanalytic laboratory in Building 650, Mercury.

Blank – A sample with none of the analytes of interest.

Data Qualifiers – A letter assigned to a sample result to indicate something about the quality of the data. See paragraphs 9.3.1 and 9.3.2 for the meaning of each data qualifier.

Demarcation Project – A project to better determine surface soil contamination levels and the boundaries of areas with surface soil contamination.

Duplicate Sample – A sample taken at the same location and time as the sample collected for one of the established locations.

EM – Environmental Monitoring Project.

LCS – Laboratory control sample.

LDAS (Laboratory Data Analysis System) – The computer program used by ASL to calculate and record sample results.

MDA – Minimum detectable activity.

MDC – Minimum detectable concentration.

NIST – National Institute for Standards and Technology.

PC – Personal computer.

PLUCKY – The name of the VAX computer on which LDAS resides.

Program Numbers – Three digit numbers used in LDAS by EM to identify the project or program for which the samples are collected or used.

WI – Work Instruction.

4.0 DATA QUALITY OBJECTIVES

Nuclear weapons testing, burial of radioactive waste, and other activities on the NTS have contaminated surface soils and introduced contamination into the vadose zone and water. Currently, airborne contamination results from resuspension of particulates in surface soils, evaporation of tritiated water, and the release of tritiated hydrogen gas. Regulations specify that monitoring is to be performed to evaluate the potential effective dose equivalent to the maximally exposed individual off site. Stakeholder issues include measuring long-term trends in airborne contamination. Because monitoring for airborne radioactivity has been performed for years on the NTS, data from this monitoring has been used to select the current sampling locations. Based on current knowledge and selection criteria, the locations selected are considered to be the best locations for addressing stakeholder issues and meeting regulatory requirements. However, the criteria for selecting sampling locations, both historically and currently, includes accessibility and the availability of electricity. Consequently, not all sampling locations are in the optimal locations. Improvements to sampling locations are anticipated as the current demarcation project identifies locations with the highest airborne potential. Also, as funds become available to power more units using solar photovoltaic panels, samplers will be added or relocated to locations of highest airborne potential. Accessibility to remote locations will continue to prevent the placement of some air samplers in optimum locations.

5.0 SAMPLING STRATEGY

5.1 OBJECTIVE

The objective is to collect samples which will provide good data which can be used to demonstrate compliance with regulatory requirements and satisfactorily addresses stakeholder issues. This objective is to be attained using a program which meets schedules and is fiscally responsible and technically defensible.

5.2 SAMPLING LOCATIONS AND RADIONUCLIDES OF INTEREST

Sampling locations were selected and radionuclides of concern were identified as discussed in Chapter 4.

5.3 SAMPLING AND SAMPLE CHARACTERISTICS

5.3.1 AIR PARTICULATE SAMPLES – PROGRAM CODES 101, 102, 110 (SAMPLES), and 116 (DUPLICATES)

Samples of airborne particulates will be collected routinely from the locations listed in Tables A-1 and A-2, plus two duplicates on a weekly basis. An air sampling unit consisting of a constant volume pump drawing approximately 85 liters per minute (L/min) (3 cubic feet per minute [cfm]) of air through a 9-centimeter (cm) (3.5-inch)-diameter Whatman glass-fiber filter that traps air particulates. The filter is mounted in a plastic, cone-shaped sample holder that faces downwind at a height of 1.5 meter (m) (5 feet [ft]) aboveground. A run-time clock measures the operating time. The clock time multiplied by 85 L/min yields the volume of air sampled, about 860 cubic meters (m³) (30,000 cubic feet [ft³]) during a typical seven-day sampling period. One of the duplicate samplers will be located by a station that historically has had little to no detectable activity above environmental levels; the other sampler will be located by a station that historically is one of the five locations with the highest activity. The duplicate samplers will be moved every three months. It is the objective to keep all the components of the sampling equipment for both the duplicate sampler and the permanent sampler the same (except for filters and filter holders) during the three-month period the duplicate sampler is at one location. Therefore, all routine maintenance or calibration that requires the replacement of one or more of the components is due more than three months after the duplicate sampler is installed.

After the filters are exchanged in the field, the filters are held at least five days to allow radon and thoron progeny to decay before analysis. To ensure sample custody, the samples will be in the custody of EM personnel or stored in a locked container in the EM office until custody is transferred to the ASL.

5.3.2 TRITIUM-IN-AIR SAMPLES – PROGRAM CODES 101, 102, 110 (SAMPLES), and 116 (DUPLICATES)

Tritiated water vapor (“tritium-in-air”) samples are collected routinely from the stations listed in Table A-2, plus two duplicate stations on a biweekly basis. The duplicate samples will be collected within ten feet of one of the permanent sample locations. One of the duplicate samplers will be located by a station that historically has had little to no detectable activity; the other sampler will be located by a station that historically is one of the five locations with the highest activity. The duplicate samplers will be moved every three months. It is the objective to keep all the components of the sampling equipment for both the duplicate sampler and the permanent sampler the same during the three month period the duplicate sampler is at one location. Therefore, all routine maintenance or calibration that requires the replacement of one or more of the components is due more than three months after the duplicate sampler is installed.

Samples are collected at each station by pumping air continuously through two plastic columns connected in series at the rate of approximately 0.8 ft³/hour. Column 1 contains only molecular sieves, and Column 2 has approximately one inch of Drierite at the top and bottom

with molecular sieves between the Drierite. Each column contains approximately 450 grams of material. Both materials are hygroscopic and will absorb essentially all of the moisture from the air which passes through until the material is saturated. Because Drierite changes color when it absorbs water, it is used to determine if Column 1 has become saturated and some moisture has been collected on Column 2, and to determine if Column 2 has also become saturated. If both columns are saturated, the accuracy of results, if the sample is analyzed, are invalid and will be flagged as unusable (X data qualifier). The quantity of the water collected on the columns is determined by weighing each column prior to and after sampling, with the difference in weight being the quantity of water collected.

5.3.3 ASSUMPTIONS

- One gram of water collected in the columns is assumed to have a volume of 1 mL.
- Particulate-in-air and tritium-in-air concentrations in sampled air are homogeneous.
- The radioactivity concentration in sampled air is the same as in air which is breathed.
- The particles in sampled air are of respirable size.
- Funding is available.
- Samples will be analyzed by the ASL.

6.0 FIELD OPERATIONS

6.1 FIELD MEASUREMENTS

6.1.1 PARTICULATE-IN-AIR

Field measurements will be taken and recorded in accordance with Work Instruction (WI) L-E10.601.WEV, “Air Sampling for Particulates and Radioiodines” (BN, 1998a). The following information for the routine weekly samples will be recorded: location, date and time sample collection started and stopped, reading on the sampler timer at the start and stop times, flow rate in cfm as measured by the sampler rotameter, the vacuum in inches of mercury as shown on the sampler vacuum gauge at the end of the sampling period. At least once a month, use a calibrated Magnehelic gauge to measure the flow rate and vacuum in accordance with WI L-E10.601.WEV. Because the scale on the rotameter and the Magnehelic gauge is in 0.5-cfm increments, record the actual reading to one decimal place if the ball or needle is centered on the line of the meter. If the ball or needle is between lines on the meter, record the flow rate in accordance with Table A-4.

6.1.2 TRITIUM-IN-AIR

Field measurements will be taken and recorded in accordance with WI L-E10.603.WEV, “Tritiated Water Vapor Sampling” (BN, 1998b). The following information for the routine biweekly samples will be recorded: location, date sample collection started and stopped,

reading on the dry gas meter at the start and stop times, and flow rate in cubic feet per hour as measured by the sampler rotameter. Adjust the flow rate at the beginning of each sampling period, if needed, to 0.8 ft³/hour. If a sample is to be collected for a shorter period than two weeks, increase the flow rate so the MDC listed in Table A-7, Criterion 3, can be obtained. However, the flow rate is not to exceed 1.2 ft³/hr.

6.1.3 SAMPLE COLLECTION

6.1.3.1 PARTICULATE IN AIR

The particulate-in-air sampling locations are listed in Tables A-1 and A-2 and shown on Figures A-1 and A-2. Siting of these air samplers must conform to the requirements set forth in paragraph 8, Appendix E, Title 40 CFR 58. Particulate-in-air samples will be collected weekly in accordance with WI L-E10.601.WEV, “Air Sampling for Particulates and Radioiodines,” and this QAASP. The filter is at the beginning of the flow path and is a Whatman GF/A glass microfiber filter, or equivalent, 90 millimeters (mm) (3.5 in) in diameter. The filter holder is a yellow plastic conical filter holder made for this purpose. An emptied charcoal filter cartridge is inserted into the holder to provide a backing for the filter and a plastic ring designed to secure the filter is placed in the end of the holder. The outlet end of the holder is designed to fit snugly over the end of a 3/4-inch-diameter galvanized pipe and is held in place by friction. When installed on the sampler, the filter is to be facing the ground, parallel with the ground and between 60 and 65 inches above the ground. The filter must not be near buildings or other obstacles that might interfere with sample collection and there must be unobstructed airflow in an arc of at least 270° around the filter; e.g., if the sampler is near a building, it must be near the corner and not along the side of the building. The equation below is used to calculate the minimum distance, D, between the filter and the nearest obstacle:

$$D \geq 2(O - S)$$

where O is the height of the obstacle and S is the distance from the filter to the ground.

Other sampling equipment includes a 115 VAC 1/3-horsepower electric motor. In most locations, electricity is provided from a nearby building, substation, or transformer. In a few of the locations, electricity is provided by solar panels and the associated converters and batteries. The motor is connected to a carbon vane pump with a constant flow device attached to the inlet. Flow rates will be maintained at 3 ± 0.5 cfm as measured by the rotameter attached to the venturi tube just upstream from the constant flow device. A vacuum gauge will be installed to measure the vacuum between the filter and the pump. During normal operation a vacuum of two inches of mercury or less is typical. If the vacuum is five inches or greater, the rotameter does not accurately measure the flow rate and the constant flow device does not maintain the flow rate at 3 cfm. Therefore, if the vacuum is five inches of mercury or greater when a sample is collected, this will be documented and the calculated volume flagged as estimated (E data qualifier). The timer will be connected to the motor such that the timer runs only when the motor runs. Reset buttons for the timers, if present, will be protected or positioned to prevent inadvertent resetting and to minimize the potential for resetting by unauthorized personnel. Tygon tubing used to connect the various components will have a wall thick enough so it does not collapse when the pump has drawn

the maximum vacuum it can draw. The diameters of the tubing and the nipples to which the tubing connects will be properly sized to provide air-tight seals. The above equipment will be in a protective container such as a “dog house.” For ease of operation, the timer and rotameter may be mounted on the dog house wall so they are visible without opening the dog house.

6.1.3.2 TRITIUM-IN-AIR

Tritium-in-air sampling locations are listed in Table A-3 and shown on Figures A-1 and A-2. Tritium-in-air samples will be collected biweekly in accordance with WI L-E10.603.WEV, “Tritiated Water Vapor Sampling,” and this QAASP. Sampling equipment includes a small air pump, typically a pump designed for home aquariums, which has been modified to draw air instead of blowing air. In most locations, electricity is provided from a nearby building, substation, or transformer. In a few of the locations, electricity is provided by solar panels and the associated converters and batteries. The air inlet is a 1/8-inch inside diameter copper tubing with the opening facing the ground between 60 and 65 inches above the ground. Downstream from the air inlet are two plastic cylinders about 2.5 inches in diameter and 12 inches high, marketed by Drierite, which have screw caps on top with a spring under the cap to put pressure on a metal plate with holes, which put pressure on felt pads. Nipples to which tubing can be connected are attached through a hole in the cylinder wall about 1 inch from each end. The dessicant fills the space between the felt pads in each column. The two columns are connected in series with tubing, with air going through Column 1 first. Just downstream from Column 2 is the rotameter which is used to control the flow rate to approximately 0.8 ft³/hour by adjusting the needle valve at the inlet to the rotameter. Downstream from the rotameter is a Kimmon model PK III dry gas meter or equivalent, which measures the volume drawn through the columns, followed by the pump. The equipment is to be in a protective container such as a “dog house.” Most tritium-in-air samplers are in the same dog house as a particulate-in-air sampler.

6.1.3.3 EQUIPMENT DECONTAMINATION

Operational experience has shown that air sampling equipment used for environmental surveillance does not become sufficiently contaminated during routine operations to cause detectable cross-contamination; therefore, routine decontamination of the equipment which will not improve the representativeness of the samples will not be performed. However, if sampling is performed in locations with contamination levels higher than levels routinely encountered, sample holders or columns will be decontaminated by washing with a solution of warm water and mild soap, rinsing, and thoroughly drying prior to installing the filter or molecular sieves. Tubing that is known or suspected to be contaminated will be replaced. Other equipment which is known or suspected of being contaminated will be decontaminated or replaced in accordance with a work plan which will be developed on a case-by-case basis to deal with the contamination. Radiological controls will be implemented if required by 10 Code of Federal Regulations (CFR) 835 (CFR, 1993), the *NV/YMP Radiological Control Manual* (DOE, 1996c), or other regulations in effect.

7.0 SAMPLE DOCUMENTATION AND CUSTODY

7.1 SAMPLE CUSTODY

Sample custody will be in compliance with WIs L-E10.601.WEV, L-E10.603.WEV, and L-E10.603.PS (BN, 1998c). Reasonable precautions will be used to assure that materials to be used for sampling (e.g., filters, filter holders, columns, molecular sieves, Drierite, etc.) are kept in areas free from radioactive contamination and are not accessible to unauthorized personnel. Once a sample has been collected and prior to submission to the ASL, it will be in a locked container, vehicle, or room when not physically in the immediate custody of EM personnel.

7.2 SAMPLE DOCUMENTATION

Sample documentation will be in compliance with WIs L-E10.601.WEV, L-E10.603.WEV, and L-E10.603.PS. Any abnormalities, problems, and investigations are to be appropriately documented.

7.2.1 PARTICULATE-IN-AIR SAMPLES

At the time of collection, each particulate-in-air sample will be placed in a separate plastic bag with a label identifying the LDAS analyses numbers (02, 03, 10), the sampling location by name, and the EM number used in the sample description field of the ASL LDAS. The format of the EM number is

AAHHH_WW□DDDDDD

where AA is the NTS area number, HHH is a unique number for the location assigned by EM called the HPD number, WW is the week number for the calendar year, □ is a blank space, and DDDDD is the description of the location, up to 12 characters. An example follows:
10893_14 SEDAN CRATER.

7.2.2 TRITIUM-IN-AIR SAMPLES

Each plastic cylinder will be labeled with the sampling location number or description and tare weight prior to installation. Except when weighing and during sampling, the air inlet and outlet nipples on the cylinders are to be sealed to prevent moisture from entering the cylinders. After exchange, the gross weight of the cylinders will be measured and the contents of cylinder 1 for each location placed in a plastic bag, the bag sealed, and a label attached identifying the LDAS analysis number (01), the sampling location by name, and the EM number used in the sample description field of the ASL LDAS. The format of the EM number is

AAHHH_WW□DDDDDD

where AA is the NTS area number, HHH is a unique number for the location assigned by EM called the HPD number, WW is the week number for the calendar year, ☐ is a blank space, and DDDDD is the description of the location (up to 12 characters). An example follows: 10122_14 SEDAN CRATER. If the contents of cylinder 2 are to be analyzed, the contents are to be placed in a plastic bag which is labeled with the same information as the contents of cylinder 1.

7.3 SHIPPING

Care will be taken during handling and transport to protect the samples from damage and cross-contamination, and to prevent dust on the particulate-in-air samples from coming off the filter paper. All samples will be delivered to Building 650 in Mercury. Particulate-in-air samples that are collected at the Tonopah Test Range (TTR) are removed from the sample holder at the TTR, placed in a plastic bag and mailed to EM at the NTS with a copy of the field log for the sample.

8.0 ANALYTICAL DESIGN, ANALYTES, AND METHODS

8.1 RADIOLOGICAL ANALYSIS

8.1.1 PARTICULATE-IN-AIR

Each weekly filter will be analyzed for gross alpha and gross beta. A monthly composite of all of the filters collected during the month for each sampling location will be analyzed for ^{238}Pu , $^{239+240}\text{Pu}$, and by gamma spectroscopy. The MDCs will be 3×10^{-15} $\mu\text{Ci/mL}$ or less for gross alpha, and 5×10^{-15} $\mu\text{Ci/mL}$ or less for gross beta for volumes of 7×10^8 mL or greater; and 6×10^{-16} $\mu\text{Ci/mL}$ or less for ^{137}Cs by gamma spectroscopy, 1×10^{-18} $\mu\text{Ci/mL}$ or less for ^{238}Pu , and 2×10^{-18} $\mu\text{Ci/mL}$ for $^{239+240}\text{Pu}$ for composited sample volumes of 4.5×10^8 mL or larger.

8.1.2 TRITIUM-IN-AIR

Two and one-half mL of distillate from each sample will be analyzed using liquid scintillation counting. The MDC for tritium for these samples will be 6×10^{-12} $\mu\text{Ci/mL}$ of air, assuming an air sample volume of 5×10^6 mL or greater. If less than 2.5 mL of distillate can be extracted for analysis, ASL is to contact EM personnel who will make a determination whether or not to analyze the distillate available.

8.2 PHYSICOCHEMICAL/GEOCHEMICAL ANALYSIS

No physicochemical or geochemical analyses are needed of the air samples addressed in this QAASP. However, if resources are provided, application of correction factors for air temperature, barometric pressure, elevation, and humidity may be used.

9.0 INTERNAL QUALITY CONTROL CHECKS

9.1 FIELD SAMPLING QUALITY CONTROL

9.1.1 ADMINISTRATIVE QUALITY CONTROLS

Compliance with WIs L-E10.601.WEV and L-E10.603.WEV, and surveillance and audits by supervisors and management will help assure field sampling quality control. A supervisor or manager will accompany each sampler at least once per year, through all the steps (e.g., preparation, collection, documentation, submittal to the ASL) of the weekly particulate-in-air sample collection, the biweekly tritium-in-air sample collection, and the quarterly calibration checks. All field logs and Laboratory Service Requests (LSRs) will be reviewed and initialed by a supervisor or scientist prior to submitting the samples to the ASL. The review will include evaluation of completeness, dates, times, flow rates, meter readings, etc., for accuracy and consistency with expected values. Any abnormalities will be investigated, corrected if possible, and documented. Data will be maintained to monitor trends that may affect the quality of the results. Trends that will be monitored include number and frequency of equipment failures or malfunctions, number and frequency of power outages, number and frequency of lost or unusable samples, and number and frequency of personnel errors.

9.1.2 CALIBRATION, CALIBRATION CHECKS, AND EQUIPMENT OPERATIONAL CHECKS

Rotameters

- **Particulate in Air.** The rotameters and the venturi tubes to which they are connected are calibrated together. Therefore, the rotameter/venturi tube pair must be used together for the calibration to be valid. The calibration of rotameters is to be checked and documented at least once each month using a calibrated Magnehelic gauge in accordance with the procedure in WI L-E10.601.WEV. If the ball on the rotameter is not entirely within the 2.5- and 3.5-cfm lines on the rotameter scale when the Magnehelic gauge needle is centered on the 3.0-cfm line, the rotameter will be replaced and recalibrated in accordance with WI L-E10.601.WEV. The calibration of a rotameter will be checked any time there is reason to question the rotameter calibration.
- **Tritium in Air.** Rotameters used with tritium-in-air samplers are used to control the flow rate to approximately 0.8 ft³/hour and do not need calibration. However, these rotameters deteriorate with use and will be replaced or repaired when they no longer function satisfactorily. The rotameters are also used to check for system leaks each time the columns are replaced by plugging the air inlet preceding Column 1 and determining if the flow rate drops to 0 or near to 0. The most frequent cause of leaks is improper seating of the O-rings between the caps and the cylinder wall. Normally, proper seating can be accomplished by loosening and retightening the caps.

Timers

The accuracy of the timers is critical to obtaining accurate volumes and radioactivity concentrations. Operational experience has shown that electronic timers with liquid crystal diode (LCD) displays do not keep accurate time when powered by some photovoltaic cell systems; therefore, mechanical timers must be used at locations powered by photovoltaic cell systems. Except for this problem with electronic timers, operational experience has demonstrated that timers keep accurate time except when they fail completely. Therefore, calibration of timers is not required. Observation of timers during weekly sample exchanges, comparison of the projected timer reading printed on the field log and the actual timer reading, and review of the data by scientists and supervisors provide quality control for the timers. Faulty timers will be repaired or replaced.

Vacuum Gauges

Vacuum gauges provide an indication of filter loading, pump failure, or air flow path blockage or leakage. Accuracy requirements for the vacuum gauges do not justify calibration of vacuum gauges. However, at least once a month, a second vacuum gauge will be attached to the air sampler inlet and the readings on the two gauges compared when the pump has drawn its maximum vacuum. The two gauges will agree within 2 inches of mercury. If the discrepancy is greater, the cause will be determined and corrected. If during this test the maximum vacuum is less than 22 inches of mercury, the system will be inspected for leaks and the leaks repaired if present. If there is a leak, this will be documented and an evaluation performed to determine if sample results were affected by the leak. If there is no leak, a low vacuum indicates the pump and/or motor are failing and will be replaced. If the vacuum gauge reads 2 inches of mercury or higher with nothing over the inlet, an air flow path blockage is indicated, such as a collapsed tube. Replace the tube or remove the cause of the blockage.

Magnehelic Gauge

Magnehelic gauges will be calibrated at least annually to read within 5 percent of the correct flow rate, traceable to the NIST. When using Magnehelic gauges, care will be taken to assure the gauge is level so accurate readings can be obtained. Magnehelic gauges will be calibrated any time the calibration is questionable due to damage, performance, or other valid reason.

Dry Gas Meters

Dry gas meters used with tritium-in-air samplers will be calibrated at least annually by an NTS calibration laboratory or BN-authorized calibration laboratory. At least one of the flow rates used to calibrate the meters will be within 25 percent of the typical flow rate used during sampling. Calibration accuracy will be within 10 percent of the correct flow rate, traceable to the NIST. Dry gas meters will be calibrated any time the calibration is questionable due to damage, performance, or other valid reason.

9.2 LABORATORY QUALITY CONTROL

Laboratory QA/QC samples will be processed as required by ASL procedures and the following. Analytical results for QA/QC samples will be included in reports.

9.2.1 LABORATORY BLANKS

At least one of every 20 samples (5 percent of samples) will be a laboratory blank. Laboratory blank results are assessed to determine an appropriate sample background, as well as the existence and magnitude of contamination problems. The criteria for evaluation of blanks applies to any blank associated with EM samples. The EM Statement of Work (SOW) with ASL provides for requirements addressing laboratory blanks. If problems with a blank exist (e.g., results are greater than MDC), all the results from samples in the same chemistry batch or counting batch are to have a comment entered by the ASL into the result record indicating that the blank was greater than MDC or other problems, and the blank result is to be assigned a “B” data qualifier by the ASL. Laboratory blank results are to be recorded and plotted by the ASL on a QC chart according to sample type and radionuclide, and be available for review during audits and surveillances.

9.2.2 LABORATORY CONTROL SAMPLES (LCSs)

Laboratory control samples serve as monitors of the overall performance of all steps in the analysis, including the sample preparation. The EM SOW with the ASL provides requirements addressing LCSs. At least one of every 20 $^{239+240}\text{Pu}$ and ^3H samples (5 percent of samples) will be an LCS. The ASL will use laboratory control samples with a matrix as similar as possible to that of the samples being analyzed.

The LCS percent recovery (LCS%R) is calculated using the following equation:

$$LCS \%R = \frac{LCS_{Found}}{LCS_{True}} * 100$$

where:

LCS_{Found} = concentration, in $\mu\text{Ci/mL}$, for each analyte measured in the LCS;
and
 LCS_{True} = actual concentration, in $\mu\text{Ci/mL}$, for each analyte in the LCS.

The LCS will contain greater than ten times the minimum detectable concentration and the LCS%R will be between 80 and 120 percent. If the LCS%R is outside of these ranges, all the results from samples in the same chemistry batch will be assigned a data qualifier by the ASL as follows:

<u>LCS % Recovery</u>	<u>Data Qualifier</u>
< 50	R
50 - 79	L
80 - 120	(none)
> 120	H

LCS results are to be recorded and plotted by the ASL on a QC chart according to sample type and radionuclide, and be available for review during audits and surveillance.

9.2.3 DUPLICATE SAMPLES

Analysis of duplicate samples provides indicators of laboratory precision, assuming the particulate and tritium activity in the air sampled by both the permanent sampler and portable duplicate sampler are homogeneous. The sampling schedule specifies two duplicate particulate-in-air samples each week and two duplicate tritium-in-air samples every two weeks.

Duplicate Rationale and Analysis

Results from duplicate sample data will be used to determine the precision of field measurements as follows:

The total statistical error in an environmental air result is composed of a series of contributing factors that can be identified by considering the sample collection and analysis process. These sources of error can be classified into three types: sampling errors, sample preparation errors, and counting errors. Sampling errors are such things as imprecise reading of flow rates and variability in flow over the duration of sample collection. Sample preparation errors occur during the preparation of the sample for analysis within the laboratory, for example weighing and extracting. Counting errors are due to the statistical nature of the radioisotope decay process. The standard deviations given in the data reports are only estimates of the counting errors. Differences between the results of duplicate samples contain contributions from all the above sources of errors.

In addition, the duplicate sampling protocol specified in Sections 5.3.1 and 5.3.2 allows for the evaluation of two additional sources of error. Collecting duplicates at stations that are historically high and low allows one to determine if the magnitude of the errors can be correlated with environmental concentrations of the measured radionuclide. Collecting duplicates at the same location for a period of time, such as the three months specified in this QAASP, allows an investigation of trends in errors.

These sources of errors can be examined for statistical significance using Analysis of Variance procedures on the duplicate results. Data values that are below minimum detectable concentrations can be used only if appropriate qualifiers are included in the interpretation of the results.

Duplicate Evaluation Criteria

If the activity in both the duplicate and original sample is below the instrument detection limit provided by the laboratory, no further evaluation of the results is to be performed.

If the activity in the original or duplicate sample is above the instrument detection limit, the sample results will be within the 3 sigma (standard deviation) range of the value around the original sample result. If duplicate analysis results for a particular radionuclide fall outside of the control window, the results for that radionuclide in all associated samples of the same matrix will be assigned a data qualifier of E or X based on the professional judgement of EM personnel.

9.2.4 YIELD

Laboratory performance on $^{239+240}\text{Pu}$ samples is established by means of spiking with the tracer ^{242}Pu during sample preparation. The laboratory control spike activity will be at least ten times MDA.

Yields for these samples will be within 50 and 105 percent. The evaluation of the yield is not necessarily straightforward. The sample itself may produce effects due to such factors as interferences. Because the effects of the sample matrix may be outside the control of the ASL, and may present relatively unique problems, the review and validation of data based on specific sample results is frequently subjective and demands analytical experience and professional judgement. Accordingly, this section consists primarily of guidelines, in some cases with several optional approaches suggested. Each yield will be recorded and plotted on a QC chart and be available during audits and surveillance.

The yield (Y) is calculated using the following equation:

$$Y = \frac{CT_{\text{Found}}}{CT_{\text{True}}} * 100$$

where:

CT_{Found} = measured concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample;
 CT_{True} = actual concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample;

Reported results will be qualified as follows:

<u>Yield</u>	<u>Data Qualifier</u>
< 20	R
20 - 50	L
50 - 105	(none)
> 105	H

If the yield for a sample is less than 20 percent, the ASL must investigate to determine the cause. The ASL may, at its discretion, reprocess the sample in an attempt to improve the yield. In any case, the ASL must meet the required MDC for the analysis and may compensate for low yield by increasing the count time.

9.3 DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

9.3.1 LABORATORY DATA QUALITY QUALIFIERS

The Laboratory will verify the quality of all results in accordance with WI L-E10.601.PS, “Analytical Data Package Review,” and the following guidelines. Reported results will include all appropriate data qualifiers as provided below:

B	=	The result of this laboratory blank was greater than MDC.
H	=	An LCS associated with this sample had a high recovery or this sample had a high tracer yield.
L	=	An LCS associated with this sample had a low recovery or this sample had a low tracer yield.
R	=	The data are unusable.
U	=	The result is less than the MDC.

Because only one of these data qualifiers per record is allowed in the file, data qualifiers H, L, and R have precedence over data qualifier U. Data qualifier R has precedence over all of the other data qualifiers.

9.3.2 EM DATA QUALITY QUALIFIERS

EM will validate and evaluate the quality of the data in accordance with the following guidelines. Reported results will include all appropriate data qualifiers listed below. Documentation for each result with data qualifiers E or X will explain the reason for the data qualifier.

- A = The associated sample result has been reviewed and accepted by EM.
- C = There is a comment associated with results for this sample (includes abnormal and potentially invalid results for which the cause has not been determined).
- E = The associated sample result is an estimated quantity because an input value (e.g., sample volume) was estimated.
- X = The results of the associated sample is not valid. Sample results are flagged as invalid only for the following reasons.
 - 1) Both columns for a tritium-in-air sample were saturated.
 - 2) The ASL flagged the data as unusable.
 - 3) An uncorrectable error was found in data collection or analysis.
 - 4) The sample was damaged or contaminated.

10.0 PREVENTATIVE MAINTENANCE

In general, all equipment will be maintained in good working condition. Maintaining equipment in good working order includes, but is not limited to, the following. Cracked filter heads will not be used for air sampling. The pipe onto which the filter heads are fitted will be kept smooth to prevent air leaks. Timers with LCDs will be protected from the sun. The O-rings on the tritium-in-air columns will be inspected periodically to verify they will maintain an air-tight seal. Tubing will be replaced at least every two years.

11.0 DATA REDUCTION, VERIFICATION, VALIDATION, AND REPORTING

11.1 DATA REDUCTION

Data reduction is performed by the LDAS. Following data reduction, the results are available to EM personnel using the standard display and report-generating options available on LDAS. In addition, LDAS has a report-generating option which creates files containing data in the format specified by EM. The files created can be electronically transferred from VAX node PLUCKY to a PC. Once in the PC, the records are formatted by EM personnel prior to data verification, validation, and reporting functions.

11.2 DATA VERIFICATION

Computer programs will be used to assist with the data verification process. The checks to be performed by these programs for each analysis are summarized below. In addition to the checks done by software, verify that all requested analysis for each sample has been performed.

11.2.1 PARTICULATE-IN-AIR SAMPLES

Gross Alpha Analysis

This program reads an input file sorted by location and date, normally created by the LDAS, containing weekly gross alpha in air data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file, then it performs the data checks listed below on each record in the file. Records in the file containing results for other than gross alpha in air results are ignored. The criteria for the data checks are listed in Table A-5.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 12, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 13 is "No," a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location. Take the following action(s) for each record in the output file. Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the concentration is greater than that listed in criterion 3, promptly inform management and investigate to determine the cause.

Gross Beta Analysis

This program reads an input file sorted by location and date, normally created by the LDAS, containing weekly gross beta-in-air data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file, then it performs the data checks listed below on each record in the file. Records in the file containing results for other than gross beta-in-air results are ignored. The criteria for the data checks are listed in Table A-5.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 12, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 13 is "No," a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

EM personnel are to take the following action(s) for each record in the output file. Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the concentration is greater than that listed in criterion 3, promptly inform management and investigate to determine the cause.

Gamma Analysis

This program reads an input file sorted by location and date, normally created by the LDAS, containing weekly gamma spectrum analysis of air sample data. Prior to reading the file, request the user to enter the number of sampling periods included in the file, then perform the

data checks listed below on each record in the file. Records in the file containing results for other than gamma in air results are ignored. The criteria for the data checks are listed in Table A-7.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 10 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

EM personnel are to take the following action(s) for each record in the output file. Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the results for radionuclides other than those listed in criterion 3 are greater than MDC, inform management and evaluate to determine if additional action is needed.

Plutonium Analysis

This program is to read an input file sorted by location and date, normally created by the LDAS, containing plutonium-in-air results from composited filters. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file, then it performs the data checks listed below on each record in the file. Records in the file containing results for other than plutonium-in-air results are ignored. The criteria for the data checks are listed in Table A-8.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 14, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 15 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

EM personnel are to take the following action(s) for each record in the output file. Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the concentration is greater than that listed in criteria 2 or 5, promptly inform management and investigate to determine the cause. If the flow rates are correct and not within anticipated values, inspect the sampling equipment for malfunctions and/or improper operation.

11.2.2 TRITIUM-IN-AIR SAMPLES

This program reads an input file sorted by location and date, normally created by the LDAS, containing biweekly tritium-in-air data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file, then it performs the data checks listed below on each record in the file. Records in the file containing results for other than tritium-in-air results are ignored. The checks divide the sampling locations into two groups: (1) locations that have historically had relatively higher tritium concentrations, and (2) all remaining locations. The group for each location is listed in Table A-3. The criteria for the data checks are listed in Table A-9.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 13, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 14 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Take the following action(s) for each record in the output file. Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the concentration is greater than that listed in criterion 3, promptly inform management and investigate to determine the cause.

11.3 DATA VALIDATION

Data validation for the samples collected under this QAASP is to assure compliance with National Emission Standards for Hazardous Air Pollutants (NESHAP) and to assure that data reported in the Annual Site Environmental Monitoring Report and other reports are technically defensible. Therefore, the data validation process is to consist of several statistical analyses of the data to identify trends, outliers, and consistency. The results of the statistical analysis and the significance of data qualifiers are to be evaluated by well-qualified and experienced professionals to determine NESHAP compliance and technical defensibility of the data. The following data qualifiers are to be reported with data that do not meet all of the acceptance criteria.

- J = The validity of the data is questionable.
- R = The data are not useable.

11.4 REPORTING

The air sampling results are used in generating three reports: the Annual Site Environmental Report (ASER), the annual NESHAP report, and the Environmental Data Report. These are described below.

11.4.1 ASER

This report is mandated by DOE Order O 231.1, “Environment, Safety, and Health Reporting,” and implemented in accordance with DOE M 231.1, “Environment, Safety, and Health Reporting Manual.” This requires an annual summary of environmental data to characterize site environmental management performance. A complete review draft for each calendar year is due by March 31 of the following year, with a published copy due to DOE Headquarters by October 1 of each year. The report includes radiological and nonradiological assessment of the NTS environment in all media, as well as efforts to comply with National Environmental Policy Act (NEPA) and various executive orders and legislative acts.

11.4.2 NESHAP REPORT

This report is mandated by the EPA through Title 40 CFR 61, Subpart H, “National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities” (CFR, 1989), which states that no DOE facility will emit radionuclides in such

quantity that any off-site person will receive an effective dose equivalent of 10 mrem per year. This requires the measurement of radionuclide concentration in air, surface water, and emissions so that no such source contributes a measurable portion of the 10 mrem to any off-site person. Usually, the data are assembled in early March of each year to prepare the report. The NESHAP report for each calendar year is due to DOE Headquarters and to Region 9 of the EPA.

11.4.3 ENVIRONMENTAL DATA REPORT

This report is a supplement to the ASER. It contains tables of all the data collected in a calendar year, statistical reviews of the data, graphical summaries of the data, some summary tables not found in the ASER, and analyses of historical trends in the data.

12.0 NONCONFORMANCES, CORRECTIVE ACTIONS, AND CHANGES

12.1 NONCONFORMANCES

Nonconformances include, but are not limited to: data missing from field logs, data recorded incorrectly in field logs and/or in databases, malfunctioning equipment, loss of power to a sampler which results in a sample of insufficient size to be able to attain the desired MDC using routine procedures, loss of a sample, use of out-of-calibration meters, small sample volumes, and failure to meet field and/or ASL QC/QA criteria. All nonconformances will be documented in the applicable log and/or report.

12.2 CORRECTIVE ACTIONS

The corrective action taken varies with the nonconformance. At a minimum, an investigation will be performed to recover lost data, compensate for lost data, or make a good estimate of the lost data. Significant problems will be identified as deficiencies and entered into the company's deficiency tracking system. Poor personnel performance will be addressed in accordance with good management practices and company policy. Sufficient resources will be made available and used to resolve equipment problems. Appropriate administrative actions will be taken for QA/QC problems. Investigations and corrective actions will be documented in the applicable log and/or report. Appropriate data qualifiers will be used for data that are affected by nonconformances.

12.3 CHANGES

All changes to this QAASP, sampling locations, types of equipment, calibration procedures, filter media material, operational procedures, and data reduction, validation, verification, or reporting procedures which may affect data quality or cost must be approved in writing by the Environmental Monitoring Project Manager (EMPM), or higher management, prior to implementation. The manager approving any change will evaluate the significance of the change with respect to the need for DOE involvement and/or concurrence with the change and request involvement/concurrence, as appropriate.

13.0 ASSESSMENTS AND SURVEILLANCE

In addition to a supervisor/scientist accompanying each sampler at least annually, a scientist selected by the EMPM will review all other portions of the sampling and analysis performed under this Sampling and Analysis Plan at least annually and document this in a report to the EMPM. The EMPM will assure these internal surveillances are adequate and request additional audits and surveillances as needed to address areas of concern. It is anticipated that outside organizations such as BN Performance Assurance and DOE will conduct audits periodically.

14.0 REFERENCES

Bechtel Nevada, 1998a. Air Sampling for Particulates and Radioiodines, Environmental Work Instruction L-E10-601WEV.

———, 1998b. Tritiated Water Vapor Sampling, Environmental Monitoring Work Instruction L-E10.603WEV.

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———, 1998d. Data Validation and Evaluation, Environmental Monitoring Work Instruction L-E10.606WEV.

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———, 1996c. *NV/YMP Radiological Control Manual*, Rev. 2. U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

Table A-1 Particulate-in-Air Sampling Station Network

Area	EM Number	Description	Program Code	Type*	Latitude °N Min	Longitude °W Min	Elevation (ft)
1	917	BJY	110	E	37 3.7933	116 3.2017	4265
2	950	2-1 SUBSTA	110	E	37 8.575	116 4.4833	4379
3	964	WELL ER 3-1	110	E	37 1.1055	115 56.3282	4703
3	918	BUNKER 3-300	110	E	37 2.829	116 1.957	4300
3	823	U3AH/AT N	101	O	37 3.0833	116 1.6083	4010
3	821	U3AH/AT S	101	O	37 2.94	116 1.575	4020
3	822	U-3bh N	101	O	37 2.7000	116 1.2980	3995
3	824	U-3bh S	101	O	37 2.5340	116 1.3230	4025
4	603	BUNKER T-4	110	E	37 5.7032	116 6.2397	4400
5	700	RWMS NE (4)	101	O	36 51.4667	115 57.1067	3200
5	709	RWMS W (7)	101	O	36 51.3117	115 57.5167	3200
5	716	RWMS S (9)	101	O	36 51.1383	115 57.3440	3200
5	961	RWMSTPBLGN	102	O	36 51.1625	115 57.2355	3210
5	608	WEF NE	101	O	36 51.12	115 57.09	3229
5	607	WEF SW	101	O	36 51.06	115 57.19	3240
5	847	DOD	110	E	36 52.1367	115 57.0033	3548
6	712	YUCCA	110	E	36 56.4267	116 2.4367	4020
7	705	UE7NS	110	E	37 5.9683	115 59.9333	4200
9	897	AREA 9-300	110	E	37 7.4183	116 2.5317	4220
10	893	SEDAN CRATER	110	E	37 11.0595	116 2.7152	4410
15	706	EPA FARM	110	E	37 12.53	116 2.5817	4500
18	610	LTTL FLLR2 N	110	A	37 7.713	116 17.673	5200
20	969	CABRIOLET	110	E	37 17.073	116 30.857	5800
20	601	SCHOONER	110	E	37 20.68	116 34.16	5660
25	889	E-MAD N	110	B	36 48.035	116 18.5517	3772
30	611	BUGGY N	110	A	37 0.55	116 22.31	5210
13	604	PROJECT 57	110	O	37 20	115 54.32	4206
52	614	CLEAN SLT II	110	O	37 45.7850	116 36.9110	5552
52	967	CLEAN SLT III	110	O	37 46.17	116 42.33	5494
52	966	DBLE TRACKS	110	O	37 42.49	116 59.31	5042

*E = Environmental Station B = Background Station O = Operational Station A = Assessment Station

Table A-2 Offsite Air Sampling Networks, TLD With Each High-Volume Sampler

<u>Station No.</u>	<u>Location</u>	<u>Sampling Frequency</u>	<u>Types of Analyses</u>
<u>High-Volume Samplers</u>			
001	Alamo, NV	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
030	Beatty	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
119	Rachel, NV	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
—	Amargosa Valley, NV	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
—	Indian Springs, NV	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
—	Goldfield, NV	Monthly	γ , ^{238}Pu , $^{239+240}\text{Pu}$
<u>Low-Volume HTO Samplers</u>			
119	Amargosa Valley, NV	Biweekly	Tritium
—	Indian Springs, NV	Biweekly	Tritium

Table A-3 Tritium-in-Air Sampling Station Network

Area	EM Number	Description	Program Code	Group	Type*	Latitude °N Min.	Longitude °W Min.	Elevation (ft)
1	113	BJY	110	2	E	37 3.795	116 3.2033	4265
5	137	WEF NE	101	2	O	36 51.12	115 57.09	3240
5	107	RWMS NE (4)	101	2	O	36 51.4667	115 57.1067	3200
5	110	RWMS W (7)	101	2	O	36 51.3117	115 57.5167	3200
5	112	RWMS S (9)	101	2	O	36 51.1383	115 57.3440	3200
5	130	WELL 5B	110	2	B	36 48.065	115 58.2067	3200
10	122	SEDAN CRATER	110	1	E	37 11.0595	116 2.7152	4410
12	131	STAKE T-18	110	1	A	37 11.734	116 12.902	7649
12	126	ETUNNEL PD1	110	1	E	37 11.28	116 11.37	5780
15	115	EPA FARM	110	1	E	37 12.53	116 2.58	4500
20	132	SCHOONER	110	1	A	37 20.68	116 34.16	5660

*E = Environmental Station B = Background Station O = Operational Station A = Assessment Station

Table A-4 Rotameter Gauge Readings to Record

If the ball is between:	If the ball is:	record:
1.5 & 2.0 cfm		1.8 cfm
	2.0 cfm	2.0
2.0 & 2.5		2.2
	2.5	2.5
2.5 & 3.0		2.8
	3.0	3.0
3.0 & 3.5		3.2
	3.5	3.5
3.5 & 4.0		3.8
	4.0	4.0
4.0 & 4.5		4.3

Table A-5 Data Check Criteria for Gross Alpha-in-Air Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration between 4.0 E-15 and 4.0 E-14 $\mu\text{Ci/mL}$?
No	3) Is the concentration $\geq 4.0 \text{ E-}14 \text{ } \mu\text{Ci/mL}$?
No	4) Is the concentration less than 1.0 E-16 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration above 3.0 E-15 $\mu\text{Ci/mL}$?
No	6) Is the minimum detectable concentration below 4.0 E-16 $\mu\text{Ci/mL}$?
No	7) Is the flow rate greater than 1.32 E+8 mL/day?
No	8) Is the flow rate less than 1.12 E+8 mL/day?
Yes	9) Are the numbers in the LDAS “weight,” “special volume,” and “special weight” fields zero?
No	10) Is the EM data qualifier other than A?
No	11) Is the ASL data qualifier other than U or blank?
Yes	12) Is the stop date for each sampling period equal to the start date for the next sampling period?
Yes	13) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Table A-6 Data Check Criteria for Gross Beta-in-Air Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration between 3.0 E-14 and 3.0 E-13 $\mu\text{Ci/mL}$?
No	3) Is the concentration $\geq 3.0 \text{ E-}13 \text{ } \mu\text{Ci/mL}$?
No	4) Is the concentration less than 1.0 E-15 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration above 5.0 E-15 $\mu\text{Ci/mL}$?
No	6) Is the minimum detectable concentration below 1.0 E-15 $\mu\text{Ci/mL}$?
No	7) Is the flow rate greater than 1.32 E+8 mL/day?
No	8) Is the flow rate less than 1.12 E+8 mL/day?
Yes	9) Are the numbers in the LDAS “weight,” “special volume,” and “special weight” fields zero?
No	10) Is the EM data qualifier other than A?
No	11) Is the ASL data qualifier other than U or blank?
Yes	12) Is the stop date for each sampling period equal to the start date for the next sampling period?
Yes	13) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Table A-7 Data Check Criteria for Gamma Analysis of Air Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the Cs-137 minimum detectable concentration less than 6 E-16 $\mu\text{Ci/mL}$?
No	3) Is the result identification other than ^7Be , ^{208}Tl , ^{212}Bi , ^{214}Bi , ^{137}Cs , ^{40}K , ^{212}Pb , ^{214}Pb , No Nuclide, or No Peak?
No	4) Is the flow rate greater than 1.3 E+8 mL/day (3.25 cu. ft./min)?
No	5) Is the flow rate less than 1.1 E+8 mL/day (2.75 cu. ft./min)?
Yes	6) Are the numbers in the LDAS “weight,” “special volume,” and “special weight” fields zero?
No	7) Is the EM data qualifier other than A?
No	8) Is the ASL data qualifier other than U if the result identification is other than ^7Be , ^{208}Tl , ^{212}Bi , ^{214}Bi , ^{40}K , ^{212}Pb , ^{214}Pb , No Nuclide, or No Peak?
Yes	9) Is the stop date for each sampling period equal to the start date for the next sampling period?
Yes	10) Is the number of records reporting ^{137}Cs concentration for each sampling location the same as the number of sampling periods entered by the user?

Table A-8 Data Check Criteria for Plutonium-in-Air Analysis

Anticipated Answer	Criterion
	^{238}Pu Criteria
No	1) Is the concentration greater than the highest typical concentration of 1.0 E-17 $\mu\text{Ci/mL}$?
No	2) Is the concentration ≥ 3.0 E-17 $\mu\text{Ci/mL}$?
No	3) Is the minimum detectable concentration above 6.0 E-18 $\mu\text{Ci/mL}$?
No	4) Is the minimum detectable concentration below 2.0 E-18 $\mu\text{Ci/mL}$?
	$^{239+240}\text{Pu}$ criteria
No	5) Is the concentration ≥ 2.0 E-17 $\mu\text{Ci/mL}$?
No	6) Is the minimum detectable concentration above 6.0 E-18 $\mu\text{Ci/mL}$?
No	7) Is the minimum detectable concentration below 2.0 E-18 $\mu\text{Ci/mL}$?
	Criteria which apply to ^{238}Pu and $^{239+240}\text{Pu}$
Yes	8) Is the sampling location ID number valid?
No	9) Is the flow rate greater than 1.32 E+8 mL/day (3.25 ft ³ /min)?
No	10) Is the flow rate less than 1.12 E+8 mL/day (2.75 ft ³ /min)?
Yes	11) Are the numbers in the LDAS “weight,” “special volume,” and “special weight” fields zero?
No	12) Is the EM data qualifier other than A?
No	13) Is the ASL data qualifier other than U or blank?
Yes	14) Is the stop date for each sampling period equal to the start date for the next sampling period?
Yes	15) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Table A-9 Data Check Criteria for Tritium-in-Air

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration between 3.0 E-11 and 1.0 E-10 $\mu\text{Ci/mL}$?
No	3) Is the concentration $\geq 1.0 \text{ E-}10 \mu\text{Ci/mL}$?
No	4) For Group 1, is the concentration less than 1.0 E-12 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration less than 1.0 E-12 $\mu\text{Ci/mL}$?
No	6) Is the minimum detectable concentration greater than 6.0 E-12 $\mu\text{Ci/mL}$?
No	7) Is the flow rate greater than 6.8 E+5 mL/day (1 cfm/hr)?
No	8) Is the flow rate less than 4.0 E+5 mL/day (0.6 cfm/hr)?
Yes	9) Is the weight of the water collected between 15 and 75 grams?
Yes	10) Are the numbers in the LDAS “special volume” and “special weight” fields zero?
No	11) Is the EM data qualifier other than A?
No	12) Is the ASL data qualifier other than U or blank?
Yes	13) Is the stop date for each sampling period equal to the start date for the next sampling period?
Yes	14) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

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Figure A-1
NTS Onsite Surface Air
Radiological Monitoring Sites

Air Sampling Sites
HTO (Tritium) Sampling Sites
Air Particulate Sites
Both HTO and Air Particulate Sites	Nuclear Tests
Surface and Above Ground
Man Made Isotopes (Preliminary Results from 1994 RSL Aerial Gamma Survey)
>27 microrems/hour
Plutonium Contamination (Approximate Area from McArthur, 1991)
>10 PicoCuries/Gram
Tunnel Portals and Vents
3
Nevada Test Site Boundaries
NTS Boundary
Operational Area	Radioactive Waste Management Sites
Area 3 and Area 5 RWMS

Bechtel Nevada

Location Map - NTS Region

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Air Sampling Sites

S High Volume Air Sampler and HTO Samplers, TLD

S High Volume Air Sampler, TLD

Part of Onsite Monitoring Network

[S] Air Particulate Site

Administrative Boundaries & Transportation

NTS Nevada Test Site (NTS)

N Nevada County

State

US Highway

Figure A-2

NTS Offsite Surface Air Radiological Monitoring Sites

10 0 10 20 30 40 50 60 70 80

Kilometers

10 0 10 20 30 40 50

Miles

Western US Location Map

N

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APPENDIX B

QUALITY ASSURANCE, ANALYSIS, AND SAMPLING PLAN FOR WATER ON AND OFF THE NEVADA TEST SITE

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ACRONYMS and ABBREVIATIONS

AA	Alluvial Aquifer
ASER	Annual Site Environmental Report
ASL	Analytical Services Laboratory - Bechtel Nevada Mercury radiological laboratory
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
BN	Bechtel Nevada
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
CoC	Chain of Custody
DOE	U.S. Department of Energy
DOE/ERD	DOE Environmental Restoration Division
DOE/NV	Department of Energy/Nevada Operations Office
DOT	U.S. Department of Transportation
DQO	Data Quality Objective
DRI	Desert Research Institute
EM	Environmental Monitoring Project
EPA	U.S. Environmental Protection Agency
EPD	DOE Environmental Protection Division
ES&H	Environment, Safety, and Health
FFACO	Federal Facility Agreement and Consent Order
ft	Feet/foot
FY	Fiscal Year
GPS	Global Positioning System
HASP	Health and Safety Plan
HRMP	Hydrology and Radiological Monitoring Program
IT	International Technology Corporation
L	Liter(s)
LANL	Los Alamos National Laboratory
LCS	Laboratory Control Samples
LID	Local Implementing Document
LLNL	Lawrence Livermore National Laboratory
LLW	Low-Level Radioactive Waste
LSR	Laboratory Services Request
LTHMP	Long-Term Hydrological Monitoring Program
m	Meter(s)
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration

ACRONYMS and ABBREVIATIONS

MDL	Method Detection Limits
NAFR	Nellis Air Force Range
NAD	North American Datum
NDEP	Nevada Department of Environmental Protection
NIST	National Institute for Standards and Technology
NTS	Nevada Test Site
pCi/L	Picocuries per liter
pH	Hydrogen Ion Concentration
QA	Quality Assurance
QAASP	Quality Assurance, Analysis, and Sampling Plan
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radiological Waste Management Site
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
SOW	Statement of Work
TD	Total Depth
UGTA	Underground Test Area (subproject)
USGS	U.S. Geological Survey
WP	Working Point
YMP	Yucca Mountain Project

CONVERSION TABLE

Multiply metric unit	by	To obtain English unit
Millimeter (mm)	0.03937	inch
Meter (m)	3.281	foot
Kilometer (km)	0.6214	mile
Liter (L)	0.2642	gallon
Liter per second (L/s)	15.85	gallon per minute
Centimeter (cm)	0.3937	inch
Degree Celsius ($^{\circ}\text{C}$)	$1.8\text{ C} + 32$	degree Fahrenheit
Milligram per liter ($\mu\text{g/L}$)	1.0	part per million
Microgram per liter (g/L)	1.0	part per billion
Microsiemen per centimeter (u S/cm)	1.0	micromho per centimeter
Cubic meter (m^3)	35.3	cubic foot
Meter cubed per second (m^3/s)	35.3	cubic foot per second

1.0 INTRODUCTION

Testing of nuclear weapons aboveground and underground at the Nevada Test Site (NTS) resulted in the contamination of the ground surface and some groundwater at and near the NTS. Contamination of the shallow vadose zone was primarily due to atmospheric testing prior to 1962, and subsequent disposal and cleanup operations. Radionuclides in the deep vadose zone and in the groundwater (at or below the water table) came primarily from underground nuclear tests. This contamination is a local phenomenon, but could pose a threat to human health and/or the environment at the NTS and its vicinity.

Environmental monitoring has been conducted on and near the NTS by the U.S. Department of Energy (DOE), through various agencies, for nearly 40 years. Environmental measurements were made at first to determine the extent of contamination for the protection of operations and workers. Later, monitoring was expanded (as needed) to comply with state and federal regulations and permit requirements, and to address stakeholder issues regarding radiation contamination as a result of DOE activities. The DOE recently conducted a review of environmental monitoring at the NTS, taking into consideration all the media being monitored (air, vadose zone, water, and biota) by several different organizations, and as a result redesigned the entire program. The resulting NTS Routine Radiological Environmental Monitoring Program (RREMP) is a single integrated and comprehensive monitoring program.

This document is a quality assurance, analysis, and sampling plan (QAASP) developed to guide groundwater and surface water sampling activities necessary to support the RREMP (three companion QAASPs address the other media). In addition to defining in detail the sampling and data-gathering methods, this plan also addresses data quality objectives (DQOs), sampling strategy, necessary equipment, sample handling and transport, analysis requirements, reporting, and quality control (QC). An overview of the RREMP water sampling and analysis activities is presented in flowchart form in Figure B-1. Background and technical justification for all four QAASPs are presented in a parent document, the RREMP (Bechtel Nevada [BN], 1998).

1.1 PROJECT DESCRIPTION

Bechtel Nevada was tasked by the DOE Nevada Operations Office (DOE/NV) to establish and manage the NTS RREMP. Among the existing environmental monitoring programs incorporated into the RREMP are the Long-Term Hydrologic Monitoring Program (LTHMP), and environmental monitoring operations by single programs or agencies, including the U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (EPA), Desert Research Institute (DRI), Joint Testing Organization, the DOE/NV Underground Test Area (UGTA) project, and others. The RREMP remains a multi-organizational program; however, the RREMP provides for centralized management and reporting. Goals of the RREMP initiative include optimizing efficiency and reducing duplication, thereby minimizing costs while continuing to meet all regulatory, health and safety, and environmental obligations.

1.2 MEDIA TYPES

The two media addressed in this QAASP are groundwater and surface water. Groundwater is the primary focus here for the following reasons: (1) very few surface water sites are present in the region of the NTS; (2) contaminated groundwater has the greater likelihood of migrating away from the NTS; and (3) sampling of groundwater is inherently more complex and requires consideration of the diverse equipment, procedures, and types of wells necessary for monitoring. Sampling of surface water is included to address sampling conducted at the several onsite sewage lagoons and containment ponds and the natural springs in the offsite portion of this monitoring program.

1.3 SAMPLING OBJECTIVES

Sampling objectives have been defined for the two media covered by this QAASP and are summarized below.

1.3.1 SAMPLING OBJECTIVES FOR SURFACE WATER

The objectives of the RREMP for surface water are listed below:

Objective 1: Determine if concentrations of radionuclides in surface water bodies at the NTS and its vicinity are a threat to the public health and the environment.

Objective 2: Determine if facilities at the NTS are in compliance with permit discharge limits.

1.3.2 SAMPLING OBJECTIVES FOR GROUNDWATER

The objectives of the RREMP for groundwater are listed below:

Objective 1: Determine if radionuclides originating from DOE operations on the NTS affect the quality of water in onsite and offsite supply wells (Supply Well Monitoring).

Objective 2: Determine if groundwater at the NTS and its vicinity is further degraded as a result of expansion of the radionuclide plumes associated with the underground test areas (Aquifer Monitoring).

Objective 3: Determine if surface and shallow vadose zone sources of radionuclides have an impact on groundwater at the NTS (Permitted Facilities Monitoring) .

An additional objective specific to water-level monitoring is to provide water-level information to determine if wellbore and aquifer conditions may have changed, thus potentially altering sample representativeness.

To support these objectives, the monitoring program was designed on the basis of professional judgment and a set of criteria established for the selection of monitoring wells, monitoring parameters, and action levels. These criteria are described in more detail in the RREMP.

2.0 DATA QUALITY OBJECTIVES

Data Quality objectives (DQOs) for the water sampling and analysis portion of the RREMP are summarized in this section. The DQOs are discussed in greater depth in the RREMP document. DQOs have been established to ensure that the data collected are sufficient and of adequate quality for their intended uses. The data must be scientifically valid, defensible, and of known precision and accuracy to satisfy the DOE, peer reviewers, and regulatory agencies.

During the DQO process, it was decided that due to uncertainties in potential contaminant release and transport scenarios, as well as data gaps in hydrogeologic details, the typical statistical approach would not be feasible in establishing the RREMP water sampling network. (Statistical analysis would be applied in data reduction and analysis.) However, a credible sampling program has been developed which is based on professional judgment and uses a subset of the available wells on and around the NTS. A set of criteria was established to address the number and location of wells to be sampled, the desired well configuration, sample frequency, and contaminants of concern to support overall program objectives as well as the three objectives specific to the water media (Section 1.3).

Note that a formal DQO process was not conducted for the water-level management component of this program. Such a process is being considered for fiscal year (FY) 1999.

For the RREMP, tritium (^3H) is the primary contaminant of interest in surface and groundwater. A two-tiered approach for tritium monitoring will be applied. To ensure detection of radiological contamination as soon as possible, the tritium-enrichment method will be used for samples from wells within, or immediately downgradient of, the Corrective Action Units (CAUs) on the NTS and from wells in Oasis Valley that are thought to be downgradient from sources of groundwater contamination at the NTS. This highly sensitive method (tritium levels as low as 10 picocuries per liter [pCi/L] [near background level] can be detected) provides the ability to establish a baseline for new sample locations and to trend very small changes for flow modeling where needed. For most other locations, the standard tritium analysis method, along with gross alpha and gross beta, and/or gamma scans, will provide a cost-effective means for satisfying program objectives. Scanning of samples for the presence of other specific radionuclides will provide data that will be used to characterize the source term and to reduce uncertainties in contaminant transport scenarios. Standard detection limits will suffice for these parameters.

The program DQOs were used to establish requirements for precision, accuracy, representativeness, comparability, and completeness. Each of these quality parameters is summarized below.

Precision

Precision will be monitored through the use of field and laboratory duplicate samples and Laboratory Control Samples (LCSs). Precision objectives for the RREMP are generally ± 30 percent and are discussed in Section 7.0.

Accuracy

Accuracy will be evaluated by the use of laboratory matrix spikes, laboratory control samples, blind samples, and by participation in interlaboratory performance evaluation programs. Analytical accuracy is determined by comparing spike recovery with spike value, and is reported in percent recovery (%R). Objectives for analytical accuracy are generally ± 20 percent and are also discussed in Section 7.0.

Representativeness

Program goals for data representativeness are addressed by the choice of sampling locations, specification of well construction (e.g., wells completed in aquifers having hydraulic continuity with testing horizons, using appropriate materials, and adequately developed, etc.), sampling frequency, and sample collection techniques. These requirements are integral components of the sampling strategy (presented in Section 3.0) and will help assure that the data are representative of the groundwater at their respective sampling locations.

Comparability

Comparability is achieved by using Local Implementation Documents (LIDs) and/or Standard Operating Procedures (SOPs) for sample collection, handling, analysis, and data reporting. This standardization is intended to ensure comparability of data among sites, field sampling teams, and analytical laboratories over time.

Completeness

Data may be lost or unattainable for various reasons, including sample destruction or loss during handling and shipping, or analytical difficulties (e.g., unacceptable with respect to precision, accuracy, or detection limits, etc.). Also, water supply wells may be shut down for operational purposes, precluding sample collection. Other monitoring programs at the NTS (e.g., UGTA and LTHMP) have specified completeness objectives of 80 percent. Through the implementation of approved sampling practices, standard analytical techniques, and comprehensive documentation, a similar completeness objective of 80 percent is expected for the RREMP.

3.0 SAMPLING STRATEGY

The sampling strategy for surface water and groundwater on and off the NTS is presented in this section. The various components which form the RREMP water sampling network are shown in Figure B-2. More details regarding the sampling strategy, including selection of parameters and locations, are provided in the RREMP document.

3.1 SURFACE WATER SAMPLING SITES

The surface water sample locations on the NTS include the E Tunnel containment ponds and nine sewage lagoons (Figure B-3). Offsite locations include nine natural springs (included in Table B-1 and shown in Figure B-3). The criteria for selection were based on the monitoring

Figure B-2 RREMP Water Monitoring Network Relationship Diagram

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Surface Water Monitoring Locations

- Containment pond
- Sewage Pond
- Surface/spring

Boundaries and Transportation

- Corrective Action Unit (CAU)
- Nevada Test Site (NTS)
- NTS Operational Area
- Nellis Air Force Range
- Nevada County
- State
- Interstate Highway
- Primary Road

Figure B-3

NTS Region Surface Water Radiological Monitoring Sites

50 0 5 10 15 20

Kilometers

5 0 5 10

Miles

Location Map - NTS Region

NTS GIS 98182.2

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Table B-1 Surface Water Sampling Sites

Location		Location	General	Coordinates ²			New	Sampling
Name	Objective ¹	Type	Location	Lat	Long	Analysis	Loc	Frequency
Big Springs	2	Surface/spring	Ash Meadows	362230	1161625	le	no	3 years
Colson's Pond	2	Surface/spring	Oasis Valley	370438	1164132	le	yes	Semiannual
Crystal Pool	2	Surface/spring	Ash Meadows	362513	1161923	le	no	3 years
Fairbanks Spring	2	Surface/spring	Ash Meadows	362926	1162030	le	no	3 years
Goss Springs	2	Surface/spring	Oasis Valley	365945	1164251	le	no	Annual
Longstreet Spring	2	Surface/spring	Ash Meadows	362803	1161932	le	no	3 years
Peacock Ranch	2	Surface/spring	Springdale	370148	1164518	le	yes	Annual
Revert Spring	2	Surface/spring	Oasis Valley	365504	1164437	le	no	Annual
Spicer Ranch	2	Surface/spring	Beatty	365916	1164209	le	yes	Annual
E-Tunnel Pond 1	3	Containment pond	NTS Area 12	371116	1161123	P	no	Quarterly
E-Tunnel Effluent	3	Containment pond	NTS Area 12	371110	1161112	P	no	Quarterly
A12 Sewage Pond	3	Sewage Pond	NTS Area 12	371147	1160829	P	no	Quarterly
A22 Sewage Pond	3	Sewage Pond	NTS Area 22	363844	1160019	P	no	Quarterly
A23 Final EPD	3	Sewage Pond	NTS Area 23	363918	1160040	P	no	Quarterly
Central Sewage Pond	3	Sewage Pond	NTS Area 25	364631	1161741	P	no	Quarterly
DAF Sewage Pond	3	Sewage Pond	NTS Area 6	365345	1160232	P	no	Quarterly
LANL Sewage Pond	3	Sewage Pond	NTS Area 6	365838	1160159	P	no	Quarterly
Reactor Control Swg Pond	3	Sewage Pond	NTS Area 25	364634	1161743	P	no	Quarterly
RWMS Sewage Pond	3	Sewage Pond	NTS Arrea 5	365051	1155708	P	no	Quarterly
Yucca Sewage Pond	3	Sewage Pond	NTS Area 6	365629	1160227	P	no	Quarterly
¹ Objectives:			² Coordinates-Degrees/min/sec; NAD 27, as provided by the USGS					
2 - Aquifer monitoring								
3 - Permit compliance								
Analysis le - Tritium (Enriched method)								
Analysis P - Permit driven constituents								
For new locations, the first sampling event shall include full chemistry (Type IV analysis, see Table 4-8), including gross alpha and beta, Sr, Pu, and gamma spectroscopy in additon to enriched tritium analysis.								

objectives described in Section 1.3.1. Water sources were selected for monitoring if they had the potential for exposing the public, onsite biota, or the environment to significant levels of radionuclides, or if they required monitoring under an existing state discharge permit.

3.1.1 CONTAMINANTS AND ACTION LEVELS

All surface water samples will be analyzed for tritium and gamma emitters. The conventional tritium analysis method will be used unless specified otherwise. At selected locations, and at all new locations where a hydrochemical baseline does not exist, the analysis will be expanded to include gross beta and gross alpha emissions, tritium (by the enrichment method), plutonium-238 (^{238}Pu), $^{239+240}\text{Pu}$, and strontium-90 (^{90}Sr).

Minimum contaminant levels at which action is required (action levels) for the onsite containment ponds and sewage lagoons are established in the facility permits. For offsite springs, an action level only for tritium was established as 10 percent of the primary drinking water standard.

3.1.2 SAMPLING AND ANALYSIS DESIGN

Surface water from onsite containment ponds and sewage lagoons will be sampled and analyzed quarterly for all contaminants listed in Section 3.1.1 except ^{90}Sr , which will be checked only once a year. Offsite spring water will be sampled and analyzed for tritium and gamma emitters semiannually, annually, or every three years, depending upon the proximity to the NTS and relation to groundwater flow paths. The initial samples at new locations will be analyzed for a wider suite of radioactive contaminants, including tritium (by the enrichment method), as well as standard water properties such as pH, and conductivity, and hydro-chemistry (alkalinity, bicarbonate, and principle anions/cations) to establish a baseline. This sampling plan is summarized in Table B-2. Sampling will not occur as scheduled if there is insufficient water at a site (e.g., the springs) to obtain a sample.

3.1.3 ACTIONS DEPENDENT ON RESULTS OF MONITORING

If radionuclide activities in surface water samples do not exceed the defined action levels, routine monitoring will continue and the concentrations will be documented in the Annual Site Environmental Report (ASER) (BN, 1997b).

If radionuclide activities exceed the prescribed action levels, DOE will be advised of the elevated levels and additional evaluations or studies will be performed. These may include additional validation of laboratory analysis results, taking more water samples, or sampling of other related media (such as pond sediment) to confirm source levels. All study results will be documented in the ASER. If further analyses confirm that an action level has been exceeded, corrective actions will be taken.

Table B-2 Sampling and Analysis Design for Groundwater Radiological Monitoring Wells

Well Type	Sample Analysis	Sample Frequency	Regulatory Driver
Onsite locations	Potable water supply well within CAU	Quarterly	Title 40 CFR 141, DOE Order 5400, and Safe Drinking Water Act (SDWA)
		Annually	
	Other potable water supply well	Quarterly	DOE Order 5400 Series and SDWA
		Annually	
	CAU nonpotable water supply well	Semiannually	DOE Order 5400 Series
		Biennially	
	Monitoring well (non-water supply)	Annually	DOE Order 5400 Series
		Biennially	
	Source characterization well ¹	3 years ²	DOE Order 5400 Series
	New wells	Semiannually ³	DOE Order 5400 Series
Offsite locations ⁴	Surface waters (sewage lagoons and containment ponds)	Permit-driven	State Permits
	Group A locations (Oasis Valley and vicinity)	Semiannually	Title 40 CFR 141 and DOE Order 5400
		Annually	
	Group B locations (more distant)	Annually	DOE Order 5400 Series
	Group C locations (most distant)	3 years	DOE Order 5400 Series
	New locations	First sample ³	Title 40 CFR 141 and DOE Order 5400

Note: All parameters and frequencies of analysis are subject to revision after data are acquired and reviewed, if justified. Some sampling events at water supply wells may be skipped, with program management approval, if the well is not being used. Corrective Action Units (CAUs) are as defined by the Underground Testing Area (UGTA) Project (International Technology Corporation [IT], 1996d).

1) Source characterization wells are currently known as the Hot Well Network. Additional sampling parameters may be specified for each hot well.

2) Three-year frequency can be modified for well-specific sampling program.

3) After four semiannual samples are acquired (for the initial characterization sample for new offsite wells), sampling parameters and frequency will be based on the well type.

4) Offsite locations include both drilled wells and natural springs.

Type I Analysis include standard tritium; at select wells enriched tritium analysis (Type Ie) will be performed

Type II Analysis include gross alpha and gross beta.

Type III Analysis include gamma spectroscopy and plutonium. Type III+ analysis includes Type III plus ⁹⁰Sr.

Type IV Analysis include pH, specific conductivity, temperature, principle cations/anions, total dissolved solids, alkalinity, and bicarbonate.

Type V Analysis includes ²²⁶Ra and ²²⁸Ra

Miscellaneous studies/analyses may also be conducted as deemed appropriate or useful to the overall program (e.g., studies of colloidal particles and their mineralogy).

3.2 GROUNDWATER SAMPLING STRATEGY

The characteristics of regional and local groundwater regimes at the NTS, and the sources of radionuclides with potential impacts on groundwater are presented in Chapter 2 of the RREMP document. The release and transport of radionuclides from the underground test areas, and the human exposure pathways are also discussed in Chapter 2. Chapter 3 of the RREMP document discusses the regulatory drivers with which the monitoring must comply. The groundwater sampling strategy presented below incorporates these hydrogeologic and regulatory factors.

3.2.1 CRITERIA FOR SELECTION OF WELLS FOR ROUTINE RADIOLOGICAL MONITORING PROGRAM

Virtually all existing wells that penetrate the water table at the NTS and vicinity were considered for this radiological monitoring program (Drellack *et al.*, 1996; Gillespie *et al.*, 1996a,b; Rose *et al.*, 1997; Reiner *et al.*, 1995; Mihevc, 1992; GeoTrans, 1994; Kilroy, 1991; and IT, 1996b,g). A set of location and construction criteria was applied to yield a short list of potential monitoring wells. Many of these candidate wells were already being sampled to measure water chemistry, quality, elevation, and use, and were also considered for inclusion during the development of this radiological monitoring program (Hershey and Gillespie, 1993; BN, 1997b; Chapman and Lyles, 1993; GeoTrans, 1994; and Rose *et al.*, 1997). They include several groups of wells drilled and sampled to support various programs and objectives (also refer to Figure B-2). The wells selected for inclusion in the radiological monitoring program are described below, and are listed in Table B-3. The wells selected include all onsite water supply wells, many of the onsite UGTA wells, available source-term wells ("hot wells"), permitted facility monitoring wells, and some wells selected from among the existing boreholes that can be retrofitted cost effectively to become monitoring wells. The offsite wells were selected from the drinking water supply wells in nearby communities, and existing UGTA/DOE monitoring wells in Oasis Valley. Separate criteria were established for the selection of monitoring wells to support each objective, as briefly summarized in this section.

Wells Selected to Support Objective 1 (Water Supply Monitoring)

The onsite water supply wells will continue to be used to support the proposed program. No new wells are expected to be added to the NTS water supply system because water usage at the NTS is not forecast to exceed current usage in the foreseeable future. In addition to the water supply wells onsite, the network will include offsite wells selected on the basis of the following criteria:

- Select point-of-use water supply wells that are down-gradient of the NTS (in the general direction of regional groundwater flow). Current site knowledge eliminates the possibility of transport of radionuclides from source areas to wells upgradient of the NTS, or opposite to the general direction of regional groundwater flow (Blankenagel and Weir, 1973; IT Corp., 1996b,d,f,g,h; Laczniak *et al.*, 1996; O'Hagen and Laczniak, 1996; Waddell *et al.*, 1984; DOE, 1997; Ervin *et al.*, 1992; and Winograd and Thordarsen, 1975).

- Select wells close to the NTS boundary and in close proximity to the underground testing areas.
- Give preference to community wells.
- Give preference to high-yield, high-volume wells.
- Select wells where access is possible.
- Consult with Community Technical Liaison Program/Stakeholder programs to ensure that the concerns of local communities are addressed.

The offsite and onsite wells selected for monitoring to address the first program objective are shown in Figure B-4, and listed in Table B-3.

Wells Selected to Support Objective 2 (Aquifer Monitoring)

From among existing onsite wells and boreholes that are designated as point-of-opportunity wells, those that are located downgradient of the CAUs and/or are located within the regional aquifer are selected to become part of the proposed network of wells supporting the second program objective. Point-of-opportunity wells located within or immediately downgradient of CAUs have been screened based on the following criteria for their inclusion in the proposed network.

- Select point-of-opportunity wells down-gradient of source areas.
- Give preference to wells within 1,000 meters (m) (3,280 feet [ft]) of underground testing areas which are located below or within 100 m (328 ft) of the water table.
- Select wells that access relevant hydrostratigraphic units within structural blocks having an upgradient source or sources.
- Give priority to wells in the most transmissive units that also contain most of the underground test locations.

Wells thus screened have been further scrutinized to select those that would be most cost-effective to monitor, and those that meet the following construction criteria (Aller *et al.*, 1989; American Society for Testing and Materials [ASTM], 1994; EPA, 1994; Cullen *et al.*, 1991; and Barcelona *et al.*, 1995, 1983):

- Give priority to wells with immediate access to the aquifer.
- Give priority to wells with diameters already appropriate for sampling.
- Give priority to wells which are already completed (developed, casing exists, etc.).

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Offsite Monitoring Locations

- UGTA Monitoring Well
- Monitoring Well
- Community Well
- Domestic Well
- Water Supply
- Yucca Mountain Project Well

Onsite Monitoring Locations

- Area 5 RWMS - RCRA
- Monitoring Well
- Nonpotable Water Supply Well
- Potable Water Supply Well
- Sewage Lagoon Monitoring Well
- Source Characterization Well
- UGTA Characterization
- Yucca Mountain Project Well

Boundaries and Transportation

- Corrective Action Unit (CAU)
- Nevada Test Site (NTS)
- NTS Operational Area
- Nellis Air Force Range
- Nevada County
- State
- Interstate Highway
- Primary Road

Figure B-4

NTS Region Groundwater

Radiological Monitoring Sites

50 Kilometers

50 Miles

50 Kilometers

50 Miles

NTS

Bechtel Nevada

NTS

Bechtel Nevada

Location Map - NTS Region

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Table B-3 Groundwater Monitoring Network

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
ONSITE WELLS								
UE-1q	2	Monitoring Well (UGTA recompletion well)	Central Yucca Flat	N841500	E677500	Ie	Annual	TCU & LCA
						II, III, & IV	Biennially	Along Topgallant fault
WW-2	2	Monitoring Well (Decommissioned water well)	N Yucca Flat	N880,000	E668224	Ie	Biannually	
						II, III & IV	Biennially	
UE-2ce WW	2	Nonpotable Water Supply Well within an UGTA CAU	W Central Yucca Flat	N871,100	E654,900	Ie	Biannually	
						II, III, & IV	Biennially	
ER-3-2	2	UGTA Characterization	S Central Yucca Flat	N833,112	E684,015	Ie	Annual	Near Well A;
						II, III, & IV	Biennially	three comp. strings
UE-3e #4	2	Monitoring Well	S Central Yucca Flat	N844,888	E680,001	Ie	Annual	HRMP hole near ALEMAN
						II, III, & IV	Biennially	(U-3kz); 3 comp. strings
U-3cn #5	2	Monitoring Well (UGTA recompletion well)	S Central Yucca Flat	N841255	E687,998	Ie	Annual	BILBY Hydro test hole
						II, III, & IV	Biennially	Pz completion
U-3cn PS#2	2	Source Characterization Well (UGTA recompletion well)	S Central Yucca Flat	N841,600	E688,169	I, II, III, & IV	3 years	BILBY post-shot hole
WW A	2	Monitoring Well (plume monitoring well)	Central Yucca Flat	N833,000	E684,000	Ie	Annual	Inactive water supply well
						II, III, & IV	Biennially	
TW-D	2	Monitoring Well	W Central Yucca Flat	N846,600	E672,600	Ie	Annual	
						II, III, & IV	Biennially	
U-4u PS#2A	2	Source Characterization Well	Central Yucca Flat	N851,215	E680,078	I, II, III, & IV	3 years	DALHART test

Table B-3 (continued)

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
ONSITE WELLS (cont.)								
UE-4t	2	Monitoring Well	Central Yucca Flat	N855,565	E680,350	Ie	Annual	Two comp. strings
						II, III, & IV	Biennially	
U-4t PS3A	2	Source Characterization Well	Central Yucca Flat	N856,640	E680,539	I, II, III, & IV	3 years	GASCON test (completed 5/93)
WW 5B	1 & 2	Potable Water Supply Well	Frenchman	N747,359	E704,263	Ie, II & V	Quarterly	
		at S edge of UGTA CAU	S edge of CAU			III, & IV	Annual	
WW 5C	1 & 2	Potable Water Supply Well	Frenchman	N742,860	E705,888	Ie, II & V	Quarterly	
		S of the UGTA CAU	Flat			III, & IV	Annual	
UE-5c WW	2	Nonpotable Water Supply	Frenchman Flat	N760,133	E700,997	Ie	Biannually	
		west edge of CAU	Flat			II, III, & IV	Biennially	
UE-5n	2	Monitoring Well (plume monitoring well)	Frenchman Flat	N754,460	E706,415	I, II, III, & IV	Biennially	CAMBRIC related 10 pCi/L ³ H noted
RNM #1	2	Source Characterization Well	Frenchman Flat	N755,823	E704,831	I, II, III, & IV	3 years	CAMBRIC related (21 degree post-shot hole)
RNM #2S	2	Monitoring Well (plume monitoring well)	Frenchman Flat	N755,200	E704,809	I, II, III, & IV	Biennially	CAMBRIC related (pumping well)
UE5 PW-1	2 & 3	Area 5 RWMS - RCRA	Frenchman Flat	N765,702	E706,832	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
UE5 PW-2	2 & 3	Area 5 RWMS - RCRA	Frenchman Flat	N770,396	E709,894	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
UE5 PW-3	2 & 3	Area 5 RWMS - RCRA	Frenchman Flat	N771,291	E703,460	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
ER-6-1	2	UGTA Characterization	SE Yucca Flat	N814,004	E696,800	Ie	Annual	Comp planned for, but not scheduled.
						II, III, & IV	Biennially	
UE-6e	2	Monitoring Well	S Yucca Flat	N814,000	E688,200	Ie	Annual	Completed in Tpt WTA
		(UGTA recompletion well)				II, III, & IV	Biennially	
WW C	1 & 2	Potable Water Supply Well	S Yucca Flat	N790,082	E692,061	Ie, II & V	Quarterly	LCA completion
		outside an UGTA CAU				III, & IV	Annual	Sample one, C or C-1

Table B-3 (continued)

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
ONSITE WELLS (cont.)								
WW C1	1 & 2	Potable Water Supply Well	S Yucca Flat	N790,011	E692,132	Ie, II & V	Quarterly	LCA completion
		outside an UGTA CAU	(next to WW C)			III, & IV	Annual	Sample one, C or C-1
WW 4	1 & 2	Potable Water Supply Well	CP Basin	N784,999	E687,900	Ie, II & V	Quarterly	WTA completion
		outside an UGTA CAU				III, & IV	Annual	Sample one, 4 or 4A
WW 4A	1 & 2	Potable Water Supply Well	CP Basin	N784,350	E686,900	Ie, II & V	Quarterly	WTA completion
		outside an UGTA CAU				III, & IV	Annual	Sample one, 4 or 4A
UE-7nS	2	Monitoring Well (plume monitoring well)	E Yucca Flat	N855,600	E693,700	Ie	Annual	BOURBON test related
						II, III, & IV	Biennially	Pz completion; 3H noted
UE-11a	2	Monitoring Well	N Frenchman Flat	N777,130	E708,280	Ie	Annual	Recompleted 1982
						II, III, & IV	Biennially	poss bridge @ SWL
ER-12-1	2 & 3	UGTA Characterization	S. Rainier Mesa	N886,642	E640,539	Ie	Annual	Downgrad from E-Tunnel
						II, III, & IV	Biennially	Crossed thrust faults
UE-16d	1 & 2	Potable Water Supply Well	W Yucca Flat	N844,878	E646,567	Ie, II & V	Quarterly	
		outside an UGTA CAU				III, & IV	Annual	
HTH#1	2	Monitoring Well	W of Yucca Flat/	N876,855	E629,310	Ie	Annual	low water yield
			S of Rainier Mesa			II, III, & IV	Biennially	140 pCi/L of ³ H noted
WW 8	1 & 2	Potable Water Supply Well outside UGTA CAU	S Pahute Mesa	N879,468	E609,999	Ie, II & V	Quarterly	
						III, & IV	Annual	
UE-18r	2	Monitoring Well	Timber Mt. Moat	N868,100	E564,700	Ie	Annual	Bridge plug at 763m
						II, III, & IV	Biennially	(2504 ft)
ER-19-1	2	UGTA Characterization	W Rainier Mesa	N884,237	E624,548	Ie	Annual	Crossed thrust fault to Mc;
						II, III, & IV	Biennially	3 completion intervals

Table B-3 (continued)

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
ONSITE WELLS (cont.)								
UE-19c WW	1 & 2	Nonpotable Water Supply	Pahute Mesa	N917,000	E601,027	Ie & II	Biannually	inactive
		Well within an UGTA CAU				III, & IV	Biennially	
U-19v PS#1	2	Source Characterization Well	Pahute Mesa	N909,396	E592,425	I, II, III, & IV	3 years	USGS Instruments ALEMANDRO Test
U-19bh	2	Monitoring Well	Pahute Mesa	N902,900	E585,700	Ie	Annual	96" dia. Emplacement hole
						II, III, & IV	Biennially	
ER-20-1	2	UGTA Characterization	SW Area 20	N900,001	E551,000	Ie	Annual	Comp. plans proposed
						II, III, & IV	Biennially	Requires deepening
ER-20-2#1	2	UGTA Characterization	SW Area 20	N896,556	E577,562	Ie	Annual	Satellite hole
						II, III, & IV	Biennially	
ER-20-5 #1	2	UGTA Characterization-Near field drilling	S Central Area 20	N899,134	E555,174	I, II, III, & IV	Annual	TYBO nearfield completed in Tpt WTA
ER-20-5 #3	2	UGTA Characterization-Near Field Drilling	S Central Area 20	N899,031	E555,170	I, II, III, & IV	Annual	TYBO nearfield Deeper, Tacp LFA)
ER-20-6 #1	2	UGTA Characterization-Near Field Drilling	S Central Area 20	N913,791	E571,559	I, II, III, & IV	Annual	BULLION near-field (closest to Bullion)
ER-20-6 #2	2	UGTA Characterization-Near Field Drilling	S Central Area 20	N913,692	E571,444	I, II, III, & IV	Annual	BULLION near-field
ER-20-6 #3	2	UGTA Characterization-Near Field Drilling	S Central Area 20	N913,420	E571,337	I, II, III, & IV	Biennially	BULLION near-field (FGE pumping well)
U-20 WW	2	Nonpotable Water Supply	Pahute Mesa	N910,582	E569,090	Ie, II	Biannually	
		Well within an UGTA CU				III, & IV	Biennially	
PM-1	2	Monitoring Well	Pahute Mesa	N921,104	E575,868	Ie	Annual	Deep HSU
						II, III, & IV	Biennially	
UE-20n #1	2	Source Characterization Well	Pahute Mesa	N906,545	E571,239	I, II, III, & IV	3 years	HRMP hole CHESHIRE test
U-20n PS1DDh	2	Source Characterization Well	Pahute Mesa	N906,531	E570,834	I, II, III, & IV	3 years	Recompleted 5/85 CHESHIRE test

Table B-3 (continued)

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
ONSITE WELLS (cont.)								
Army #1 WW	1 & 2	Potable Water Supply Well outside UGTA CAU	Mercury Valley	N670,902	E684,774	Ie, II & V III, & IV	Quarterly Annual	
SM 23-1	2 & 3	Sewage Lagoon Monitoring Well	Near the Mercury Sewage Lagoon	N692,662	E690,904	Ie II, III, & IV	Annual Biennially	
UE25p #1	2	Yucca Mountain Project Well	Yucca Mt	N756,171	E571,485	Ie	3 years	Volcanics and LCA 1805 (5923 ft TD)
UE25 WT #6	2	Yucca Mountain Project Well	Yucca Mt	N780,576	E564,524	Ie	3 years	Volcanics
J-12 WW	1 & 2	Potable Water Supply Well outside UGTA CAU	Jackass Flats	N733,508	E581,012	Ie, II & V III, & IV	Quarterly Annual	State Water Rights Permit
J-13 WW	1 & 2	Potable Water Supply Well outside UGTA CAU	Jackass Flats	N749,209	E579,651	Ie, II & V III, & IV	Quarterly Annual	State Water Rights Permit
OFFSITE WELLS								
PM-3			Offsite, just west of Area 20	371412	1163337	Ie II, III, & IV	Semi-annual Biennially	HRMP hole, Two comp. strings
USW H-1	2	Yucca Mountain Project Well	Offsite, just west of Area 25	365158	1162700	Ie	3 years	1829m (6000 ft) TD
American Resources Well	2	Monitoring Well	Ash Meadows	362148	1161757	Ie	3 years	New well
Amargosa Valley RV Park	2	Community Well	Amargosa Valley	363830	1162352	Ie	3 years	New well
ASH-B (both piezometers)	2	Monitoring Well	Amargosa Valley	364329	1164029	Ie	3 years	
Barn Well #2, Pond. Dairy	2	Water Supply	Amargosa Valley	362941	1162658	Ie	3 years	New well
Beatty Water and Sewer	2	Community Well	Beattv	365412	1164518	Ie	Annual	

Table B-3 (continued)

Well	Objective ¹	Well	General	Coordinates ²		Analysis ³	Sample ³	Comments
Name		Type	Location				Frequency	
OFFSITE WELLS (cont.)								
Cherry Patch Well	2	Domestic Well	Amargosa Valley	362929	1160857	Ie	3 years	New well
Cind-R-Lite Mine	2	Water Supply	Amargosa Valley	364105	1163026	Ie	3 years	
Coffer's Ranch Windmill	2	Water Supply	Oasis Valley	370014	1163325	Ie	Semi-annual	
						II, III, & IV	Annual	
Cook's Ranch Well #2	2	Domestic Well	Amargosa Valley	363430	1162351	Ie	3 years	New well
De Lee Ranch	2	Domestic Well	Amargosa Valley	363248	1163031	Ie	3 years	New well
Fire Hall #2 Well	2	Water Supply	Amargosa Valley	362442	1162511	Ie	3 years	New well
Last Trail Ranch	2	Domestic Well	Amargosa Valley	363406	1163606	Ie	3 years	New well
Longstreet Casino Well#1	2	Water Supply	Amargosa Valley	362451	1162533	Ie	3 years	New well
Low Level Waste Site	2	Water Supply	Beatty	364610	1164130	Ie	Annual	New well
Road D Well, Spicers	2	Water Supply	Beatty	370255	1165034	Ie	Annual	
Roger Bright Ranch	2	Domestic Well	Amargosa Valley	362914	1163043	Ie	Annual	New well
School Well	2	Community Well	Amargosa Valley	363411	1162740	Ie	Annual	New well
TW-5	2	Monitoring Well	Amargosa Valley	363815	1161759	Ie	Annual	
Tolicha Peak	2	Water Supply	Tolicha Peak	371732	1164725	Ie	Annual	
Younghan's Ranch	2	Domestic Well	W. Oasis Valley	370141	1164309	Ie	Annual	
ER-OV-01	2	UGTA Monitoring Well	N. Oasis Valley	370504	1164049	Ie	Semi-annual	New well
						II, III, & IV	Annual	
ER-OV-02	2	UGTA Monitoring Well	C. Oasis Valley	370210	1164215	Ie	Semi-annual	New well
						II, III, & IV	Annual	
ER-OV-03a	2	UGTA Monitoring Well	C. Oasis Valley	365956	1164216	Ie	Annual	New well
ER-OV-03a3	2	UGTA Monitoring Well	C. Oasis Valley	365956	1164216	Ie	Annual	New well
ER-OV-03c	2	UGTA Monitoring Well	E. Oasis Valley	365948	1163604	Ie	Semi-annual	New well
						II, III, & IV	Annual	

Table B-3 (continued)

Well Name	Objective ¹	Well Type	General Location	Coordinates ²		Analysis ³	Sample ³ Frequency	Comments
OFFSITE WELLS (cont.)								
ER-OV-03c2	2	UGTA Monitoring Well	E. Oasis Valley	365948	1163604	Ie	Semi-annual	New well
						II, III, & IV	Annual	
ER-OV-04a	2	UGTA Monitoring Well	S. Oasis Valley	365705	1164242	Ie	Annual	New well
ER-OV-05	2	UGTA Monitoring Well	N.W. Springdale	370246	1164619	Ie	Annual	New well
ER-OV-06a	2	UGTA Monitoring Well	N. Oasis Valley	370504	1164049	Ie	Semi-annual	New well
						II, III, & IV	Annual	
¹ Objectives:	1 - Supply well monitoring		Abbreviations:	C - Central	W - West		WTA - Welded Tuff Aquifer	
	2 - Aquifer monitoring			E - East	S - South		TCU - Tuff Confining Unit	
	3 - Permitted facilities monitoring			SW - Southwest			LCA - Lower Carbonate Aquifer	
				UGTA - Underground Test Area			CAU - Corrective Action Unit	
² Coordinates:	for onsite locations are Central Nevada State Planar, in feet; NAD 27, from the NTS Drilling and Mining Summary (RSN, 1990).							
	for offsite locations are given in latitude and longitude, degrees/min/sec; NAD 27, as provided by the USGS.							
³ See Section 4								
Sampling Frequency may vary based upon well and attendant equipment availability (e.g. pumps).								
<u>Underline = Regulatory Mandates</u>			Bold = Water Supply Wells					
Regular font = Conventional monitoring wells			<i>Italic =Source term wells</i>					

The network of onsite and offsite wells selected to address Objective 2 are listed in Table B-3 and shown in Figure B-4. Other onsite wells which may be incorporated into the program in the future are listed in Attachment B3. Potential onsite reserve monitoring wells are listed in Attachment B3-1 and wells in locations suitable to the RREMP, but requiring remedial work, are listed in Attachment B3-2.

Water-level measurements will be made during each sampling event at all wells. (Pumping wells without access tubes/piezometers are excluded from this requirement.) Onsite wells proposed for water-level measurements are shown in Attachment B2-1. The 1998 USGS water-level network for the NTS region is shown in Figure B-5.

Wells Selected to Support Objective 3 (Permitted Facilities Monitoring)

The three permitted wells (UE-5PW-1, -2, and -3) are included to monitor the groundwater in the vicinity of the Area 5 Radioactive Waste Management Site (RWMS) (Shott *et al.*, 1995). Well ER-12-1, downgradient of the E Tunnel ponds in Area 12 (Russell *et al.*, 1993), and well SM-23-1 near the Area 23 sewage lagoon are also included in the RREMP. These wells will be sampled in accordance with existing permits and the data integrated with the RREMP.

3.2.2 CONTAMINANTS AND ACTION LEVELS

Unless regulatory changes in permit conditions occur, the parameters and the action levels for the monitoring of the water supply wells and the permitted facilities on the NTS will remain the same. The parameter of interest for the routine radiological monitoring of groundwater is tritium. The action level for tritium will be 10 percent of the drinking water standard. The standard method for tritium analysis can detect tritium at concentrations between 300 and 700 pCi/L and higher, and therefore may be used to satisfy program objectives. However, in practice, the RREMP may choose to use the enriched method which can detect tritium levels as low as 10 pCi/L. All wells will be sampled for tritium and additional parameters as shown in Table B-2.

Other water properties (e.g., pH, specific conductivity, principle anions and cations, etc.) will be measured at selected wells at the same that time water samples for radiological analysis are collected. For example, at new monitoring wells that do not have previously established baseline data for water chemistry, water chemistry data will be collected during the first year of sampling. Also, at selected wells, it may be necessary to measure other water quality characteristics to confirm certain assumptions of radionuclide migration models for groundwater (e.g., the existence of colloidal transport). These other properties are shown in Table B-2 (see Type IV Analysis).

3.2.3 SAMPLING FREQUENCY

Sampling frequency for the wells in the proposed network will differ: water supply wells and wells near source areas will be sampled more frequently, and wells without established background data will be sampled more frequently for one year. Some sampling events at water supply wells maybe skipped, with program management approval, if the well is not

Wells

- N Water Level Wells - Onsite
- T Water Level Wells - Offsite
- U Monitoring Wells - Onsite
- S Monitoring Wells - Offsite

Administrative Boundaries

- Corrective Action Unit (CAU)
- Nevada Test Site (NTS) Boundary
- NTS Operational Area
- Yucca Mountain Site Characterization Project
- Core Right of Way and Ranch Areas
- Nellis Air Force Range
- Nevada County
- State

Transportation and Populated Areas

- # City / Town
- Primary - Limited Access Roads
- Primary Roads

Figure B-5
NTS Region Network for Onsite and Offsite Water Level Measurements

Location Map - NTS Region

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being used. Sampling frequencies of the wells are summarized in Table B-2. Table B-3 shows, for each well, the proposed type of analysis, sample frequency, and the preferred method of sampling. Some sampling events at water supply wells may be skipped, with program management approval, if the well is not being used.

3.2.4 ACTIONS DEPENDENT ON RESULTS OF MONITORING

If radionuclide activities in groundwater samples do not exceed the prescribed action levels, routine monitoring will continue and the concentrations will be documented in the ASER.

If radionuclide concentrations in groundwater samples exceed the action levels, DOE will be advised of the elevated levels and additional evaluations or studies will be performed. These may include additional validation of laboratory analysis results and taking more water samples. Analyses for selected radionuclides may be expanded to include ^{99}Tc , ^{129}I , ^{36}Cl , and others as appropriate (Smith *et al.*, 1997; Nimz and Thompson, 1992; Fraser, 1986; Hoffman *et al.*, 1977; Borg *et al.*, 1976; Bryant and Fabrika-Martin, 1991; and Daniels *et al.*, 1992). All study results will be documented in the ASER. If further analyses confirm that the action level has been exceeded, corrective actions will be taken.

3.3 DRINKING WATER CONSUMPTION ENDPOINTS

The drinking water network at the NTS consists of five separate systems, with seven consumption endpoints (BN, 1997b). Ten potable supply wells feed the five drinking water systems (Table B-4). As a check on any effect the water distribution system might have on water quality, the seven water system endpoints (tap water) are sampled on a monthly (pre-FY 1997) or quarterly (FY 1997) basis. No test-related radionuclides have been detected to date.

To support RREMP objectives and to demonstrate compliance with relevant regulations (e.g., SDWA, DOE Order 5400.5, and Nevada Revised Statutes [NRS] 445A.361), the seven drinking water consumption endpoints will continue to be sampled according to the schedule presented in Table B-4. Distribution systems located within, or traversing, the historical testing areas will be sampled more frequently (quarterly), while the other systems will be sampled on an annual basis. The tap water samples will be analyzed annually for gamma emitters, gross alpha, gross beta, tritium (enriched method), ^{238}Pu , $^{239+240}\text{Pu}$, and ^{90}Sr .

4.0 FIELD OPERATIONS

4.1 PLANNING

This section is divided into four parts: Training; Initial Planning, which includes establishing well location and elevation datums, equipment procurement, etc.; Routing Preactivity Planning, which includes review of well-specific data, assembling supplies, anticipating well purging etc.; and Access and Security Requirements.

Table B-4 Sampling and Analysis Schedule for NTS Drinking Water System Consumption Endpoints

Endpoint	System	Supply Wells	Sampling Frequency	Analysis
Area 6, Cafeteria	No. 1	Wells C-1, 4, and 4A	Quarterly	Ie, II, III
Area 6, Building 6-400			Quarterly	Ie, II, III
Area 2, Restroom	No. 2	Well 8	Quarterly	Ie, II, III
Area 12, Building 12-23			Annually	Ie, II, III
Area 1, Building 101	No. 3	Well UE-16d	Annually	Ie, II, III
Area 23, Cafeteria	No. 4	Wells 5B and Army No. 1	Quarterly	Ie, II, III
Area 25, Building 4221	No. 5	Wells J-12 and J-13	Annually	Ie, II, III

¹Analysis:

Type Ie: Includes tritium (enriched method).

Type II: Includes gross alpha and gross beta.

Type III: Includes gamma spectroscopy, ²³⁸Pu, ²³⁹⁺²⁴⁰Pu, and ⁹⁰Sr (annually).

4.1.1 PERSONNEL TRAINING

This section describes the minimum training requirements for personnel involved in the water sampling and analysis portion of the RREMP, with emphasis on the requirements for the field sampling team.

General

Each employee assigned to the RREMP must meet minimum requirements for technical training, experience, and personal skills. Because of the interdisciplinary nature of this project and the diversity of technical tasks to be conducted, a training matrix should be developed to assure that personnel training is complete and relevant. The matrix should include all project positions including technical leads and management, and list each procedure they would be expected to be familiar with to do their job. Training can be divided into three categories:

- Company-mandated training. This may include such required classes as General Employee Radiological Training (GERT), ethics, security briefings, computer usage, etc.
- Job-specific procedures. Many of these procedures are listed in the technical sections of this QAASP and are listed in the References section of this appendix.
- Field orientation and on-the-job training. On-the-job training is important to maintain continuity from year to year and among personnel.

Training Records

- Groundwater sampling and processing activities at the NTS involve potential exposure to ionizing radiation. All personnel performing such work shall be trained in all applicable facility and operation safety procedures including the project Health and Safety Plan (HASP). All field sampling team members and selected Analytical Services Laboratory (ASL) personnel shall receive Radworker II training.
- The sampling and analysis process also involves potential exposure to hazardous chemicals. Although most water monitoring locations are not Occupational Safety and Health Administration (OSHA) 1920.120 sites, it is recommended that the field sampling team and selected personnel receive the 40-hour OSHA Hazardous Waste Site Worker initial training and the 8-hour refresher course, as necessary. The source-characterization wells ("hot wells") are designated as 1910.120 sites and will require special training and procedures.

All training shall be documented using the appropriate forms. Training records shall be maintained.

Refresher Training

Most orientation and training described here is meant to be a one-time activity at the startup of this new project or for the new employee unfamiliar with the project or the NTS. However, if operating procedures are revised, implementation training, either by reading or classroom instruction, may be necessary.

Refresher training is required for certain training such as:

- 40-hour OSHA Hazardous Waste Site Worker
- Radworker II
- NTS/DOE Security

4.1.2 INITIAL PLANNING

Well Database

A database of relevant information for each well in the monitoring program should be compiled. Important information to assemble includes:

- Well location and elevation (elevation should include both ground and wellhead data, if available)
- Map of the well location showing access roads, security barricades, etc.
- Well construction data
- Hole diameter(s)
- Casing type and sizes
- Screened/slotted and gravel-packed intervals
- Static water level
- Hole total depth (TD)
- Downhole equipment (e.g., dedicated pump)
- Hydraulic information (formation permeability, etc.)
- Hydrogeologic information (what aquifers are accessed)
- Water chemistry records
- Radiological analyses

Most of this information is readily available for existing wells (Drellack *et al.*, 1996; Drellack, 1997; RSN, 1991a; Wagoner and Richardson, 1986; and Russell, 1990); the emphasis here is to acquire information for “new” wells in the monitoring network. Well construction information for the onsite wells is provided in Attachment B1. The Reference section of this QAASP lists additional sources for these data.

Location and Elevation Datum

The RREMP requires that all selected wells be accurately located (surveyed) in three-dimensional space. Accuracy requirements for such surveys was determined for the UGTA Project and is hereby adopted for the RREMP. Vertical accuracy should be within

15 centimeters (cm) (0.5 foot [ft]). Horizontal accuracy can be less (within 30.5 cm [1 ft]), although greater horizontal accuracy is relatively easy to obtain (3 cm [0.1 ft]). Accuracy can be obtained by survey-grade geographic positioning systems [GPSs]). Location data should be referenced to NAD 83. Additionally, downhole gyroscopic surveys may be needed in some wells to correct for borehole deviation.

Equipment Procurement

Sampling equipment, supplies, and instruments should be procured well in advance of scheduled sampling activities. Certain items such as downhole pumps or special analytical instruments may require additional time over the typical procurement cycle because of their higher costs and the need to involve quality assurance (QA) or engineering personnel in developing specifications.

Miscellaneous Advanced Planning

Personnel must be assigned and trained (Section 4.1.1). Vendors must be identified and certified, and contracts for analytical services, maintenance programs, etc., may need to be established.

Pre-Sampling Reconnaissance Trip

It may be prudent for the field sampling team to make a reconnaissance trip to some of the newly included sites and wells not previously included in other NTS sampling programs. The purpose of such a trip might simply be to find the well: Is it located where the database shows it to be? Other objectives would include identification of physical access requirements (uncooperative owners or locked barricades may need to be addressed) and verification of the wellhead condition, labeling, and access (are the well elevation datum and measuring point marked? Does the key fit the wellhead lock?).

4.1.3 ROUTINE PRACTIVITY PLANNING

A readiness review should be conducted prior to each field operation. The sampling team leader should ensure that the team has the information and materials needed for the sampling activity. Site-specific information that must be reviewed includes, but is not limited to, the following:

- Site location and access.
- Hole design and construction, including tubing sizes and depth to water.
- Sampling materials and equipment requirements.
- Sampling criteria.
- Wellbore purging requirements:

Calculate purge volumes. Purging may take several days, and may involve running temporary pumps down-hole or turning on installed pumps several days in advance of the scheduled sampling.

- Previous water chemistry and radiological data.
- Coordination with others:

LLNL and Radiological Control for hot-well sampling.

EPA and others for QC sampling, as needed.

BN Utilities for water supply well sampling.

Notify ASL of impending sample delivery.

Notify offsite well owners of planned sampling activities.

Appropriate sampling materials, equipment, and instruments must be assembled, cleaned, and checked as necessary. Relevant plans and procedures should be reviewed including:

- SOPs
- HASPs
- Equipment/instrument manuals

Some of these preparations must begin well in advance of the scheduled sampling activity. Coordination with and/or notification of other participants should also be anticipated.

4.1.4 SITE ACCESS AND SECURITY REQUIREMENTS

Routine access to the NTS requires a standard DOE Security Badge and a minimum Level 1 clearance. If a camera is used for photo documentation of equipment, samples, or procedures, a Level 2 clearance and a photographic permit are required. Personnel working on the NTS must be aware of and abide by all NTS security rules and regulations. A security orientation training class is mandatory for all personnel new to the NTS.

Currently, there are no additional access restrictions to any of the RREMP wells. However, the addition of wells in certain areas or future site operations might result in limited access to a particular location. If such a situation occurs, or should a security barricade be encountered, proper access authorization must be obtained. Additional information regarding these matters can be obtained from BN Security or the DOE Safeguards and Security branch office in Mercury, Nevada.

Information regarding road closures (e.g., Buckboard Mesa and Pahute Mesa roads often are closed during the winter months) may be obtained from the DOE Operations and Coordination Center at Control Point (CP)-1 (295-4015), where keys to barricades can also be obtained.

In the near future, monitoring wells on the Nellis Air Force Range (NAFR) will be added to the RREMP network. For these offsite wells, access authorization will need to be obtained from the U.S. Air Force through the DOE/ERD office.

4.2 WELL PURGING

As a general rule, all monitoring wells should be pumped or bailed prior to sampling (EPA, 1991b). Under certain conditions, some chemical properties of the water standing in a well may change with time, and therefore may not be representative of the groundwater within the aquifer. Potentially stagnant water should be purged from the well casing/tubing and the gravel pack prior to sampling. The preferred well purging method is by using a pump. Bailing of deep wells is time consuming and often ineffective. However, the use of bailers may be an acceptable alternative if pumps are unavailable or not practical.

4.2.1 WATER SUPPLY WELLS

It is not necessary to purge on-line pumping water supply wells prior to sampling. However, if the well has been shut down for more than several days, purging is recommended. If purging is required, the procedures outlined for monitoring wells in Subsection 4.2.2 below should be followed.

4.2.2 MONITORING WELLS

The actions specified in the following general purging procedure should ensure that any samples collected after purging are representative of the aquifer(s) open to the well bore. For specific information, ERD-05-304, "Groundwater Monitoring Well Purging and Sampling" (DOE, 1995a) may be consulted.

Purge Volume

The volume of water to evacuate from a well is a debatable but important determination. It is recommended that approximately three well volumes of water be pumped from the well prior to sampling. For wells completed in very transmissive aquifers and that have relatively large screened intervals (e.g., minimal stagnant water column above the screened interval), the purge volume may be reduced to approximately one well volume. Alternatively, purging should continue until water quality indicator parameters (pH, specific conductance, temperature) have stabilized within approximately 10 percent over at least two measurements (EPA, 1991).

If, however, the well can be pumped or bailed dry (e.g., for very low transmissivity units), sampling may begin after purging one well volume and as soon as sufficient volume of groundwater has reentered the well bore. Micro-purging is also being explored.

Well construction information (e.g., well bore and casing diameters) is provided in Attachment B1. Pump or bailer dimensions, as well as purge volumes, can be determined for each well using the information in Attachment B1. It is recommended that such site-specific details be compiled for this repetitive sampling program.

Purge Rate

A low flow rate should be used for purging a well (EPA, 1995). This rate should be less than that originally used to develop the well.

Purge Water Disposal

All fluids generated during the purging process should be containerized until it is determined (either through analytical testing or historical records and process knowledge) whether or not they may be disposed to the onsite sump or must be transported for treatment as hazardous waste. If no sump(s) exist, purge water should be disposed in accordance with criteria specified in the site-specific work plans.

Equipment Decontamination

All purging equipment which is not dedicated and in place (e.g., a fixed downhole pump) will be decontaminated, or certified to have been decontaminated, prior to use. The recommended cleaning procedure for such equipment is as follows:

- Wash equipment with a nonphosphate detergent.
- Rinse equipment with tap water.
- Rinse equipment with deionized water.

Note that for some pieces of equipment, this could involve disassembly, cleaning, and reassembling according to owners/operating manuals.

All fluids generated during the decontamination process should be containerized until it is determined (through analytical testing or process knowledge) whether they may be disposed to the onsite sump or transported for treatment as hazardous waste.

If the equipment will not be used immediately, it should be allowed to dry thoroughly in a dust-free environment. The equipment should then be adequately packaged and stored to protect it from dust and possible contaminants. Stored equipment should be tagged clearly stating when and how the equipment was decontaminated. Additional information on decontamination is presented in Section 4.5.

4.2.3 SOURCE-TERM CHARACTERIZATION WELLS (“HOT WELLS”)

Workers must always consult the site-specific work plan (to be provided by LLNL and/or LANL) prior to sampling source-term characterization wells. The field sampling team must be cognizant of the relevant HASPs and properly trained for such sampling operations. Because fluids produced from these wells are likely to be contaminated with tritium and possibly other radionuclides, excessive purging of the well is strongly discouraged.

Fluids produced during purging and sampling must be containerized, handled, and disposed in accordance with all applicable waste management criteria.

4.3 FIELD MEASUREMENTS

All field activities shall be conducted in accordance with DOE/NV orders and policies, industry practices and standards, and the requirements established in this QAASP.

4.3.1 WATER-QUALITY MEASUREMENTS

Certain water-quality measurements may be made at the well site, to accomplish two purposes:

- Help ascertain the representativeness of a water sample. For example, a well might be judged sufficiently purged after certain indicator properties have stabilized to within predetermined values, indicating that a reasonably representative water sample may be collected.
- Capture data on unstable elements, compounds, or characteristics. For wells lacking water chemistry characterization data, it must be determined if physically or chemically unstable species are present that would not be properly measured in the laboratory after handling and transport.

Water-quality measurements will be made in the field prior to sampling events at surface sites, monitoring wells, source-term characterization wells and temporarily inactive (nonpumping) water-supply wells. Field measurement of water-quality characteristics is not required from active water-supply wells because historical data records will show that the water chemistry has stabilized, and representative samples can be obtained. Water-quality data must be measured in the field for wells without adequate water chemistry records (e.g., new wells and many offsite wells). After a minimum of four data sets (quarterly or semiannual, etc.) for newly drilled wells and one data set for newly added offsite wells have been established, the data will be evaluated by the project technical leads and a decision made whether to continue or discontinue such measurements.

These water properties may be measured in the field either by installing an in-line flow cell, or by using field test kits or meters on separate discrete samples collected for such measurements. In either case, field analyses will not be performed directly on samples that will be submitted for laboratory analysis. In most cases, the field water quality parameters should be run on unfiltered samples. Water-quality properties selected for the RREMP include:

- pH
- Specific conductance
- Temperature

Each of these properties is briefly addressed in Sections 4.3.1.1 through 4.3.1.3. It is beyond the scope of this QAASP to provide detailed instrument-specific instructions; however, general guidelines for each measurement procedure are presented. The appropriate SOPs or LIDs should be consulted for each field test and for operation of equipment.

4.3.1.1 FIELD MEASUREMENT pH

The pH is one of three indicator properties that will be used by the RREMP field team to evaluate water quality and determine when a representative water sample may be collected. An approved procedure, such as ERD-05-902, “Field Measurement of pH of Water and Oxidation Reduction (REDOX) Potential in Water” (DOE, 1998g), must be followed by the field sampling team. The following summary guidelines are presented only to highlight the more important features of the procedure:

- Equipment and Materials
 - pH meter (battery-operated, rugged construction, foam-lined carrying case)
 - Buffers (pH 4.0, 7.0 and 9.0)
 - Low-lint paper or material for blotting
 - Combination pH electrodes
 - Electrode holder
 - Thermometer
 - Distilled water and wash bottle
 - Disposable beakers
- The pH meter shall be calibrated daily in accordance with the manufacturer’s instructions prior to first use. Commercially prepared buffer solutions are used for calibration of the meter (pH of 4.0, 7.0, and 10.0). Temperature may affect pH measurements, so the three calibration buffers and the samples must be measured at the same temperature (within 2°C [35°F]).
- The temperature and specific conductance of the sample must also be measured and recorded so that the pH measurement can be properly interpreted later.
- The electrode must be rinsed thoroughly with deionized water after each sample measurement.

4.3.1.2 FIELD MEASUREMENT OF SPECIFIC CONDUCTANCE

Specific conductance is another of the three indicator properties that will be measured by the field sampling team prior to each sampling event. It is recommended that ERD-05-901, “Field Measurement of Dissolved Oxygen, Temperature, Conductivity, and Turbidity in Water” (DOE, 1998f), or another approved procedure, be followed during this process. The following summary guidelines are presented only to highlight the more important features of the procedure.

- The field-specific conductance meter must be battery operated and of rugged construction. A foam-lined carrying case is considered essential. The instrument should be capable of measuring temperature, and ideally be equipped with a temperature compensator.

- Other Equipment and Materials
 - Deionized or distilled water and wash bottle
 - Disposable beakers
- The instrument shall be calibrated on a daily basis. A standard solution of 0.01 M concentration of potassium chloride (KCl) is generally used for calibration.
- To ensure uniformity of readings, the data should be corrected to 25°C (77°F), and reported in micromhos/cm.
- The conductivity cell must be thoroughly rinsed with deionized water after each sample measurement.
- Field personnel must know the cell constant and check it prior to use on a daily basis. A large change in the cell constant may indicate that the probe requires cleaning.

4.3.1.3 FIELD MEASUREMENT OF WATER TEMPERATURE

Water temperature will be measured by the field sampling team at each sampling event. It is recommended that ERD-05-901 (DOE, 1998f), or another approved procedure, be followed for this procedure. The following summary guidelines are presented only to highlight the more important features of the procedure.

- The accuracy of the field thermometer, or other appropriate measurement device, shall be checked periodically against a certified, calibrated mercury-filled thermometer. The temperature reading of the field thermometer must be within 0.5°C (33°F) of the reading of the certified thermometer.
- The water temperature should be taken as soon as possible after sample collection.
- The measuring device must be thoroughly rinsed with deionized water after each use.

4.3.2 WATER LEVEL MEASUREMENTS

The depth to water will be measured during each sampling event at each of the listed wells (Table B-3). (This requirement is waived for pumping water supply wells where an access tube may not be available). Water-level tags are also required from a larger array of wells, on- and offsite, to support this monitoring program (see Attachment B2). Depth to water data will: (1) provide input to regional modeling for the purposes of groundwater resource management, (2) detect impacts from onsite and offsite water withdrawal, (3) monitor trends to assure no reversal of groundwater flow directions upon which the groundwater monitoring was designed, and (4) provide information useful operationally for acquiring bailed or pumped water samples. The USGS has generally been responsible for performing these depth-to-water measurements (Arteaga *et al.*, 1987; Doty and Thordarson, 1983; Reiner *et al.*, 1995; and Wood, 1992). For continuity purposes, it is recommended that the USGS

continue this task. However, there could be circumstances under which the other field sampling teams (staffed by BN, IT, or the EPA, for example) might also take water-level measurements. BN Environmental Monitoring Division (EMD) will, therefore, coordinate with all participants to assure uniformity and avoid unnecessary redundancy. Currently, the following procedures are approved for water-level measurements:

- Depth-to-Water Measurements in Monitoring Wells and Piezometers, ERD-05-302.
- Depth-to-Water Measurements, IT DOP No. ITLV-UGTA-308 (IT,1995a)
- Depth-to-Water Measurements, USGS
- Water-Level Measurement, EPA SOP 2151 (EPA, 1991b)

The following summary guidelines are presented only to highlight the more important features of the procedure:

Method

Depth-to-water measurements may be obtained by one of several methods, including:

- Steel tape coated with carpenter's chalk (wetted-tape method)
- Float-type devices
- Pressure transducers
- Electric sensors

If possible, water levels should be measured and recorded to the nearest .003 m (0.01 ft). It is recommended that water-level measurements be obtained before purging; however, water levels may be taken later if the well is allowed to recover for a minimum of 24 hours after development or purging operations. During the readiness review, well histories should be consulted for necessary information such as previous water levels, reference/measuring point location and elevation, casing constrictions, etc. The reference/measuring point, typically the top of the riser pipe or casing (may be different than the official elevation datum) must be identified and noted in the logbook. The type of measuring device must also be recorded in the logbook. Care must be taken when lowering the wireline into the well not to exceed the recommended rate (e.g., 40 m/min).

Equipment/Materials

The list of equipment and materials needed to perform water-level measurements at wells and piezometers is dependant upon the specific type of measurement device. This list can be quite extensive when spare parts for wireline winches and decontamination setups are included. Therefore, the field sampling team must refer to the appropriate procedure and device-specific checklists for a complete list of necessary equipment and materials.

Calibration

Measuring tapes and wirelines shall be calibrated annually. Three onsite wells are presently used for the calibration process: WW 5A, TW B, and U-2gh (Otto, 1998). These holes are convenient, have appropriate depths and stable water levels, and are not contaminated.

Pressure transducers and electric sensors shall be calibrated according to the manufacturers' recommendations.

Decontamination

All downhole equipment used for water-level measurements shall be decontaminated according to approved procedures (Section 4.5) prior to use at each well.

4.4 SAMPLE COLLECTION

This section discusses methods for collecting representative water samples from various types of wells and surface locations, and is organized into three parts: sampling materials and equipment (Section 4.4.1), groundwater sampling (Section 4.4.2), and surface water sampling (Section 4.4.3). The groundwater and surface water sections are further subdivided by location.

4.4.1 FIELD SAMPLING MATERIALS AND EQUIPMENT

Table B-5 provides a generalized list of the materials and equipment that will be needed to perform the field sampling activities. This list includes sampling equipment, field test equipment, documentation forms and office supplies, health and safety equipment, and other items that will be used in the field. Well-specific needs (e.g., well purging equipment) and field parameter SOPs (e.g., pH, specific conductance, etc.) should also be consulted for any specific material/equipment prior to any field activities.

Groundwater sampling methods included in this QAASP involve the use of several different kinds of downhole pumps and wireline bailers. Workers must receive on-the-job training from experienced personnel prior to using such equipment. Operating manuals and specific procedures should also be studied by the field sampling team.

In general, the sampling materials and equipment are expected to be constructed of relatively inert material (e.g., stainless steel, glass), easy to clean, economical to use, and capable of being operated at remote sites. The choice of sampling materials or equipment may vary from site to site. For example, the choice of well-purging equipment will depend upon the diameters of well-access strings, depth to water, and equipment availability. Types of sample containers and preservatives are specified in Table B-6.

Table B-5 Field Materials and Equipment Required: Water Sampling/Field Parameter Measurements

Operation	Equipment Required
Sample Collection	Appropriate keys for wellhead locks Waterproof pen/marker Watch or clock Buckets Sample collection containers - 500-mil plastic sample containers, one-quart glass jars (see Table B-6) Surface water sampling apparatus Well purging equipment (pumps, bailers, etc)
Field Analysis	pH meter and standard solutions Specific conductance meter Thermometer
Packaging/Shipping	Sample jar boxes Cooler/ice chest Blue Ice® or equivalent Vermiculite or equivalent packing material Ziplock® plastic bags Tape
Equipment Decontamination	Tap water Deionized water Buckets Decontamination solutions Several brushes Plastic sheeting
Documentation	Request for Analytical Services/chain of custody Sample labels Shipping forms (as needed) Chain of custody seals / tape Field logbook Sample collection log
Health and Safety	Hard hat Safety boots Earplugs, as required Safety glasses with side shields First-aid kit Respiratory protection, as required Water-impervious gloves Plastic sleeve covers, if forearms might be splashed Water-impervious safety boots or boot covers, if feet might be splashed Safety belt and man-rated safety line, if working within five feet of edge of sumps Soap and water for decontamination Paper towels and/or wipe rags Receptacles for trash, used PPE, paper towels, etc.

Table B-6 Groundwater Monitoring Parameters

Parameter	Analysis Type	Analytical Equipment	Container Type ^a	Preservative ^a	Maximum Holding Time	Number of Containers ^a	Primary Laboratory	QC/Back-Up Laboratory
Tritium	I (conventional)	Liquid scintillation counting	1 quart glass (or 1 liter)	none	6 months	1	ASL ^b	EPA ^c
Tritium	Ic (enriched)	Liquid scintillation counting	1 quart glass (or 1 liter)	none	6 months	1	ASL	DRJ ^d
Gross Alpha	II	Gas flow proportional counter	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	EPA
Gross Beta	II	Gas flow proportional counter	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	EPA
Gamma-Ray Spectroscopy	III IIg	Germanium gamma spectrometer	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	EPA LLNL ^e
^{226,228} Radium	II	Low background Ge-gamma spectrometer	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	LLNL
⁹⁰ Strontium	III	Gas flow proportional counter	1 quart glass (or 1 liter)	HNO ₃ to pH <2	6 months	1	ASL	EPA LLNL
^{238,239,240} Plutonium	III	Alpha spectrometry	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	EPA LLNL
⁹⁹ Technetium	III	Alpha spectrometry	1 quart glass (or 1 liter)	HCl or HNO ₃ to pH <2	6 months	1	ASL	EPA LLNL
Anions Cations	IV	Standard lab methods	1 liter poly	HCl or HNO ₃ to pH <2	6 months	1	Contract Lab	Contract Lab
Alkalinity pH Total Dissolved Solids Electrical Conductivity	IV	Standard lab methods	1 liter poly	none	6 months	1	Contract Lab	Contract Lab

^aTypical

^bBechtel Nevada - Analytical Services Laboratory

^cU.S. Environmental Protection Agency

^dDesert Research Institute

^eLawrence Livermore National Laboratory

4.4.1.1 BAILERS AND PUMPS

The two general types of equipment used for well pumping and sampling are bailers and pumps.

Bailers

Bailers are simple rigid tubes that fill with water when lowered into a well (typically on a motorized wireline apparatus). A single check-valve-type bailer collects the first water encountered. A valve-actuated pressure tube can be used as a bailing system to collect a water sample from a discrete depth interval. Advantages of bailers include their low cost, ease of use, portability, and ease of cleaning. Two of the disadvantages of bailers are that they are more labor intensive than dedicated pumps and thus usually require more field time for sample collection, and they may alter the chemistry of the water sample (by degassing, aeration, or by mobilizing particulates). Ambient flow logging may be necessary to determine any flow pattern within the well bore and identify any “self-purging zones.” Bailers will commonly be used when any of the following situations are encountered:

- Wells with small-diameter completion string and deep water level
- Wells completed in very low-transmissivity formation
- Wells requiring very little volume to purge (e.g., less than 100L)
- Wells with high total dissolved solids
- Pumps are not available

Pumps

The deep water table at the NTS limits the type of pump that can be used successfully at the NTS. The ideal situation is a well with a dedicated downhole pump. This is not always practical, so it will be common practice to transport the pump, tubing, and required accessories to the well specifically for the purging and sampling operation. Dedicated pumps are almost always run downhole on rigid tubing (a “pump string”). Temporary pumps are more often run downhole on flexible hose. The flexible hose, sampling tube, safety cable, and sometimes a bundle of air lines will be run downhole and retrieved from a motorized spool. Pumps may be powered by a variety of sources, including:

- Electrical (either a permanent land line or portable generator)
- Mechanical (e.g., pump rods)
- Compressed air

It will be common for the field sampling team to require the assistance of pump experts, electricians, mechanics, extra laborers, or drill rig and crew to run a pump with tubing. The need for such assistance should be identified in the readiness review.

4.4.2 GROUNDWATER SAMPLING

Sampling operations will vary with well type. Groundwater sampling for a generic monitoring well is described below in Subsection 4.4.2.1. Departures from this general methodology are addressed by well type in separate subsections.

4.4.2.1 ONSITE WATER SUPPLY WELLS

RREMP sampling activities at water supply wells on the NTS shall be coordinated with others as appropriate, including:

- BN Environment, Safety & Health – Responsible for monitoring for compliance with the national drinking water standards (excluding the radiological component).
- BN EM Project – Responsible for sampling for radiological constituents.
- BN Utilities – Operates and maintains the water supply wells.
- EPA – Performs QC sampling as necessary.
- State of Nevada – Performs QC sampling, as necessary, and regulatory oversight.

Water samples for the RREMP shall be collected from the same discharge point or spigot on the well head assembly as used for the national drinking water standards sampling. If the well is on line, no purging is necessary. All other activities are to be conducted as outlined elsewhere in this QAASP.

4.4.2.2 MONITORING WELLS

It is preferable that the well be purged prior to collecting groundwater samples (see Section 4.2, Well Purging), and groundwater sampling should begin as soon as possible after the well is purged. The same downhole equipment (pumps or bailers) used for the well purging may be used for sampling. The choice of sampling techniques will vary depending upon the equipment.

Bailers

Although bailers are the simplest of groundwater sampling devices, they do require some expertise to operate safely and to acquire quality samples. Check valves must be inspected to ensure that they will open and close properly. Care must be taken when lowering or retrieving the bailer so as not to knock particles from the casing, or mobilize particulate from the gravel pack or formation (via a “plunger affect”). The bailer should be lowered to a depth adjacent to the screen/slots and allowed to fill. Care must be taken when transferring the sample from the bailer to the sample container to prevent spillage or sample contamination.

Pumps

When pumps are used for sampling, it is best to keep the pumping rate relatively low. This will help ensure that normally immobile particulates are not mobilized and entrained in the flow. Pumps should be operated in a continuous, constant rate to minimize aeration and facilitate flow-rate measurements.

Samples

Two general categories of water samples are collected from monitoring wells:

- Field-measured water-quality samples
- Laboratory analysis samples.

Samples for the field measurement of water quality will always be collected first. If the water-quality indicators have not stabilized, it may be necessary to continue pumping/bailing the well for a period of time, then a second (or a third, etc.) volume of water collected for water quality measurements. Section 4.3.1 of this QAASP addresses the field measurement of water-quality indicators.

Only after the indicator properties have stabilized should water samples for laboratory analyses be collected. Sample volumes, container type, intended analyses, etc., are presented in Table B-6. Quality-control samples will also be prepared at this time (see Table B-10). Samples will be preserved according to the methods prescribed in Table B-6. Sample labeling, documentation packaging, and transport tasks are to be performed in accordance with procedures presented elsewhere in this QAASP.

Post-Operation

After the samples have been collected and completely processed, several important steps remain:

- Nondedicated pumps and attendant equipment must be removed from the well (or labor scheduled for its removal).
- The well cap must be replaced and locked.
- The sampling equipment and reusable materials must be decontaminated (Section 4.5).
- The site must be cleaned.
- The samples from certain wells must be radiologically surveyed (Section 5.6) before transport and delivery to the laboratory.

4.4.2.3 SOURCE-TERM CHARACTERIZATION WELLS

RREMP sampling at source-term characterization wells shall be coordinated with others, as appropriate, including:

- LLNL – Provides additional sampling criteria. Assists in field sample collection.
- LANL – Provides additional sampling criteria.
- USGS – Assists in field sampling activities.
- Radiological Control Technician – Monitors downhole sampling equipment and samples for radioactivity.

Sampling activities at source-term characterization wells will be conducted in accordance with this QAASP, the appropriate HASP, and the following two LLNL procedures:

- OSP-HRMP-001, “Low-Pressure Sampling Procedure (Bailers)”
- OSP-HRMP-002, “Operational Safety Plan for Water Sampling in Holes with Potentially Low-Level Radioactivity”

For most source-term characterization wells, sample collection will employ a modified stainless steel bailer on a wireline. Two-liter capacity pressure tubes will be used to collect water samples from discrete depths. Multiple runs into the well may be done to acquire additional sample volume or to sample different depth intervals.

Several of the source-term characterization wells are completed with a downhole pump. On these wells, the pump will be used for well purging, as specified, and sampling. Purging of the well prior to sample collection to some extent is desirable. However, all effluent must be containerized and characterized prior to disposal. Rinseate from the decontamination of equipment must also be containerized. No effluent from the well(s) shall be discharged onto the ground. All waste streams generated from the sampling process shall be disposed in accordance with all applicable federal, state, DOE, and NTS regulations and/or procedures.

Source-term characterization samples are usually sent to LLNL and LANL. Typical sample volumes, container type, and the analytical laboratory are specified in Table B-6. However, changes may be made to satisfy specific studies or program needs. If the samples exceed radioactivity levels for general offsite release, they will be handled and transported according to:

- LLNL-NTOD Procedure, “Onsite Handling, Transportation, and Storage of Radioactive Material”

All other aspects of this sampling operation, including sample labeling, documentation, etc., should be conducted as outlined in this QAASP.

4.4.2.4 PERMITTED FACILITY WELLS

Sampling of wells at permitted facilities at the NTS will continue in accordance with their respective groundwater monitoring programs. The following monitoring wells are in this category:

- The three wells around the Area 5 RWMS (UE-5PW-1, -2, and -3)
- Well ER-12-1, immediately downgradient from the E Tunnel ponds in Area 12
- Well SM-23-1, near the Area 23 Sewage Lagoon

Groundwater sampling at these wells will continue to be performed by the current support personnel. RREMP will interface with each of these groups to integrate the appropriate data into the EM database. RREMP management will periodically assess the Sampling and Analysis Plans (SAPs) for each permitted facility to confirm that RREMP needs are met.

4.4.2.5 MONITORING WELLS UNDER THE PURVIEW OF OTHER PROGRAMS

In addition to wells at the permitted facilities mentioned above, several monitoring wells established by other NTS programs are included in the RREMP network. The UGTA and YMP wells are the main focus of this subsection. Typically, field sampling of these wells will continue to be performed by the controlling program or in a cooperative manner between that entity and the RREMP. RREMP management will take the initiative to ensure that the appropriate data are integrated into the EM database.

A complicating factor for the UGTA and YMP wells is that these programs are still in a characterization phase (as of July 1998). Routine sampling may not yet be in place for all the wells (including the several selected for the RREMP). In the interim, these holes may be sampled by the RREMP. The DOE will provide guidance and concurrence in this matter.

4.4.3 SURFACE WATER SAMPLING

For the purpose of this QAASP, surface-water sampling is divided into offsite and onsite categories. The offsite surface-water-sampling locations are comprised of nine natural springs. Onsite locations consist of one containment pond and nine sewage lagoons. Sampling methods for each category are addressed separately below.

4.4.3.1 OFFSITE LOCATIONS

Representative water samples will be collected from the designated locations at the specified frequency according to the sampling methods described in this QAASP, and supplemented by other approved methods. The location, sampling frequency, and analysis type for the nine offsite springs are included in Table B-1 (see “surface/spring”).

4.4.3.2 SAMPLE TYPE

A grab sample will be taken in small ponds associated with the springs in a manner that minimizes the volume of sediments in the samples. In larger ponds, three grab samples will be taken and composited for analysis. Surface water sample duplicates, field preservation blanks, equipment blanks, and trip blanks will be prepared, as specified in the Field QC Procedures presented in Section 7.0 and as shown in Table B-10. Spring water may be sampled using a hand-held container, or by a low-volume pump-and-tubing arrangement (e.g., a peristaltic pump).

The preferred methods for analyzing the chemical and radiological constituents are shown in Table B-3.

Sampling Frequency

Surface-water quality and spring-flow rates are naturally variable, and may also be affected by man-made conditions. For example, heavy or prolonged rains or snowmelt may dilute contaminants or may flush contaminants into surface waters from sediments. If possible, sampling will be performed during dry and nonwindy days. Sampling will not occur as scheduled if there is insufficient water at a site (e.g., the springs) to obtain a sample.

Table B-6 summarizes sample volume, container type, etc.

Sampling Methods

Surface water samples from the static water bodies can be taken using either manual samplers or a peristaltic pump. The most commonly used manual surface samplers include beakers, sealable bottles and jars, pond samplers, and weighted-bottle samplers. Beakers, bottles, and jars are hand-dipped into the water and allowed to fill. Pond samplers are sample containers to which a fixed or telescoping pole has been attached by means of a clamp. The weighted-bottle samplers are devices that can be lowered to some depth below the water surface before the sample bottle is opened. Once opened, the bottle is allowed to fill and then brought to the surface. When retrieved, the bottle is tightly capped and removed from the sampler assembly. The Kemmerer or Van Down water samplers are specific types of weighted-bottle samplers. Other acceptable devices are described in EPA and ASTM procedures and ERD-05-409, "Surface Water Sampling" (DOE, 1995c).

Hand-held sample bottles are limited to use in shallow water. Pond samplers are useful for extending the reach of sample technicians, but large bodies of water require access by boat for accurate sampling. Peristaltic pump water-sampling systems are typically used to decrease the likelihood of exposure of the user to the fluid being sampled. These systems can be used to obtain samples from depths to about 6.1 m (20 ft), or in situations where technician exposure is too hazardous or decontamination procedures too involved for practical purposes.

Sample Handling and Preservation

Samples collected for radionuclide scans should not be filtered or preserved in the field. However, 1-L samples to be analyzed for anions/cations will be filtered in the field through a 0.45-micron filter, and then acidified to pH<2. Samples may be cooled to 4°C (39°F) after collection and during transport to the laboratory, if required. Sample containers should be polyethylene or glass. The maximum holding time is six months. Table B-8 summarizes the field processing requirements.

Equipment Decontamination

Care must be taken so that the sampling equipment is properly cleaned or decontaminated to avoid cross-contaminating subsequent samples. If samples are to be transferred from the sampler to a second container, the entire sampling assembly must be decontaminated between each sampling location. Alternatively, clean, disposable glass containers can be used. Transfer of water samples from the sampler to a second container should be done carefully to avoid aeration and spillage.

Water-Quality Indicators

Field measurement of pH, temperature, and conductivity will also be performed on sample splits in accordance with procedures listed in Sections 4.3.1.1 through 4.3.1.3 of this QAASP. Sample labeling, documentation, equipment decontamination, etc., will be conducted as described elsewhere in this QAASP.

Flow-Rate Measurement

It may be necessary to acquire flow-rate data for the springs at or near the time of sampling. This information is usually available from other agencies (USGS Water Resources Division, U.S. Fish and Wildlife, etc.) Therefore, spring flow-rate measurements will not be measured routinely by RREMP field samplers.

There are several different methods to obtain flow-rate data for a spring. However, certain physical attributes of the spring may render only one method appropriate. The flow rate can be established by the bucket-and-stop-watch method, if spring water issues as a single streamline, or the spring flows through a well-defined cross-sectional area. Weirs, flumes, submerged orifices, or similar devices can be used to restrict flow to a well-defined cross-sectional area. Springs equipped with such man-made flow controls will require procedures compatible with the type of control device available at the sampling site.

Reporting, sample handling, packaging, and shipping requirements are spelled out in Section 9.0 of this QAASP.

4.4.3.3 ONSITE CONTAINMENT PONDS AND SEWAGE LAGOONS

Surface water from onsite containment ponds and sewage lagoons will be sampled and analyzed in accordance with existing permits. This sampling will continue to be performed by

the appropriate support group. RREMP management will interface with these regulatory monitoring efforts to ensure that environmental data are integrated into the EM database.

4.5 EQUIPMENT DECONTAMINATION

All field-sampling equipment shall be decontaminated prior to use. Logical exceptions to this rule are items certified to be “clean” (e.g., new/unused sample jars) or items known to have been decontaminated after last usage. In practice, the decontamination process should be performed as soon as possible after the equipment has been used. Following the decontamination process, the clean items shall be stored in a clean, controlled manner that protects them from possible exposure to contaminants. The cleaned items shall be tagged or otherwise labeled as having been decontaminated, the process used, the name of the person who cleaned the item, and the date on which it was cleaned. Decontamination of RREMP equipment shall be conducted in accordance with ERD-05-701, “Sampling Equipment Decontamination” (DOE, 1998e), or comparable approved procedures. For the purposes of this QAASP, “small sampling equipment” includes all reusable sampling materials, instruments, and nondedicated downhole equipment such as pumps and tubing. Decontamination of wireline equipment is addressed in specific SOPs.

In general, decontamination to remove traces of tritium (the likely or, perhaps only contaminant expected) involves a multi-rinse process using tap water and deionized water. However, if organic contaminants are encountered, an approved solvent may be used. If the presence of inorganic contaminants (e.g., metals) is suspected, an approved acid solution may be used in the rinse cycles. Fluids generated during the decontamination process shall be collected in plastic buckets or tubs. When cleaning larger equipment, a decontamination area with a liner and sump may be established and a sump pump used to transfer fluids to holding tanks. The waste fluids must be contained until they are determined to be nonhazardous/nonradioactive. Disposal of such fluid will be conducted in accordance with regulatory requirements and DOE and NTS Waste Management protocols.

Following decontamination, an equipment rinse sample (“Rinsate Sample”) will be collected and submitted for analysis for QC purposes (see Section 7.2).

4.6 HEALTH AND SAFETY

Because of the multifaceted aspect of the groundwater monitoring program, there may be several HASPs in affect that cover:

- Certain field sampling activities (e.g., downhole pump emplacement, well maintenance)
- “Hot well,” or source-term characterization sampling activities

In addition, all appropriate OSHA, DOE, and company-/agency-specific health and safety procedures will apply. It is the responsibility of each participant to become familiar with the HASP and appropriate procedures and to review these documents as necessary for each specific task for which they are assigned (also see Personnel Training, Section 4.1.1). Copies of the HASP and procedures are to be maintained by the Project Manager, Technical Leads, and the Field Sampling Team Leader.

Standard safe operating practices should be followed at all times, including minimizing contact with potential contaminants (particularly in regards to the hot-well sampling activities); vigilance of slip, trip, and fall conditions; and cognizance of heat/cold stress due to extreme and variable weather conditions at the NTS. The vast areal expanse of the study area will require the sampling team to cover many miles, dictating that safe driving habits be practiced.

Level D PPE may be required for some routine field sampling activities. Level D protection includes:

- Steel-toed boots
- Hard hat (when overhead hazards exist)
- Safety glasses (and splash shield, as necessary)
- Appropriate protective clothing

The specific level of PPE or other safety requirements should be obtained from the appropriate safety documents and postings. General health and safety equipment is included in Table B-5. Refer to the appropriate HASPs for health and safety equipment specific to hot-well sampling.

5.0 SAMPLE DOCUMENTATION AND CUSTODY

The validity of environmental monitoring data is dependent upon the ability to demonstrate that samples have been obtained from the specified locations, were processed in accordance with established QA/QC procedures, and were transported and delivered to the analytical laboratory without alteration. Custody, documentation, and handling procedures to be used for the RREMP water samples are presented in this section.

5.1 SAMPLE CUSTODY PROCEDURES

Continuous custody of the groundwater samples will be maintained and documented from origin to disposal in accordance with BN LID L-E10.603.PS, “Sample Receiving Criteria”; a sample is in custody if it meets one of the following criteria:

- Held in a person’s physical possession or within view
- Stored within a locked container, vehicle, or room
- Stored in a secured area restricted to authorized personnel.

Sample custody is initiated by the field sampling team. When the sample(s) are transferred to another person or entity (e.g., for shipping, or to an analytical laboratory), the transfer will be documented on the Laboratory Services Request and Chain of Custody form (LSR/CoC) or equivalent, as outlined in Section 5.2.3. During changes in custody, the LSR/CoC form shall be signed by both parties, the one relinquishing the samples and the responsible person receiving the samples. The date and time of transfer must also be recorded.

5.2 SAMPLE DOCUMENTATION

Proper and thorough documentation for each sample and the field activities is imperative. This documentation includes:

- Sample labels
- Sample collection log
- LSR/CoC forms
- Custody seals/tape
- Field logbooks
- Waybills
- Analytical laboratory logs.

5.2.1 SAMPLE IDENTIFICATION NUMBER

Samples collected in support of the RREMP water media will be assigned a unique identification number according to the BN EM numbering scheme. The format of the EM Sample Identification Number is:

AAHHH_WW▯DDDDDD

where AA is the NTS Area; HHH is a unique number for each sampling location, assigned by EM, called the HPD number; WW is the week number for the calendar year; ▯ is a blank space; and DDDDDD is an alphabetic field used to indicate if the sample is a duplicate or one of the several types of blanks (up to 12 characters) (see Section 7.2.1).

Use of this system will allow the field-sampling team to assign sample numbers that are unique and which will not be duplicated for samples collected elsewhere or by other environmental sampling programs. This system will be used by all organizations participating in the RREMP. Note that there may be more than one container with the same sample number, but with different preservatives (see Table B-6).

The sample identification number will be recorded on the individual sample label, the sample collection log, and on the LSR/CoC form. All analytical information, sample collection information, and other relevant data, either in paper or electronic databases, will be referenced to the primary sample number.

5.2.2 SAMPLE LABELS

Sample containers shall be labeled in the field with black waterproof markers/pens. Standardized adhesive labels may be used, but must be sufficiently durable to remain intact when wet. Each sample label should contain, at a minimum, the following information:

- Unique sample identification number.
- Project name or project code number.

- Sample location/origin.
- Sampling date and time (military time).
- Collector's name (or, alternatively, their initials if space is a problem).
- Analysis requested (e.g., tritium, plutonium, gross alpha/beta).
- Preservative used (if any).

5.2.3 LABORATORY SERVICES REQUEST/CHAIN OF CUSTODY FORM

The LSR/CoC form shall be completed prior to transfer of custody of the samples from the sampler. The LSR/CoC form shall accompany the samples during handling, shipment, and delivery to the laboratory. It is also the form used to record custody transfers. The LSR/CoC form presently used by the NTS ASL is provided in Figure B-6 and includes the following information:

- Job reference number
- The name and phone number of the project contact/manager
- The unique identification number assigned to each sample
- Sample type and, if a surface sample, whether it was a grab or composite sample
- Sample depth
- The date and time (military) of the sample collection
- Container type (e.g., glass or polyethylene)
- Sample volume and number of containers (e.g., 2 by 40 mL, 3 by 1 L)
- Sample preservative (e.g., HNO₃, H₂SO₄, 4 °C [39 °F])
- Requested analyses (analysis codes)
- Special instructions to the laboratory, including handling requirements, QC, health and safety, hazard warnings, and sample disposition
- The project name and number
- Date due
- Name and address where to send analyses results
- The names of the relinquishing party and the receiving party
- Conditions of shipping container, custody seals, and samples (including sample temperature) upon receipt (completed by laboratory).

5.2.4 CUSTODY SEALS/TAPE

All water monitoring samples shall be sealed with custody seals or tape. The custody seals/tape shall be placed over and/or around the cap of each sample container. Additionally, two or more custody seals shall be affixed to each shipping container in a manner that would indicate if the container was opened in transit. It might be necessary to place transparent strapping tape over the delicate seals to ensure that they are not accidentally broken during shipment. Each custody seal must be signed and dated by the sample custodian.

SDG No. _____
Packet No. _____
Charge No. _____
Supervisor _____

This LSR completed by _____

Project Code

Program/Event Code

Sample Type

Analyses

Supervisor

Collection Start Date	Mon-Day-Year
1970-01-01	1970-01-01
1970-01-02	1970-01-02
1970-01-03	1970-01-03
1970-01-04	1970-01-04
1970-01-05	1970-01-05
1970-01-06	1970-01-06
1970-01-07	1970-01-07
1970-01-08	1970-01-08
1970-01-09	1970-01-09
1970-01-10	1970-01-10
1970-01-11	1970-01-11
1970-01-12	1970-01-12
1970-01-13	1970-01-13
1970-01-14	1970-01-14
1970-01-15	1970-01-15
1970-01-16	1970-01-16
1970-01-17	1970-01-17
1970-01-18	1970-01-18
1970-01-19	1970-01-19
1970-01-20	1970-01-20
1970-01-21	1970-01-21
1970-01-22	1970-01-22
1970-01-23	1970-01-23
1970-01-24	1970-01-24
1970-01-25	1970-01-25
1970-01-26	1970-01-26
1970-01-27	1970-01-27
1970-01-28	1970-01-28
1970-01-29	1970-01-29
1970-01-30	1970-01-30
1970-01-31	1970-01-31
1970-02-01	1970-02-01
1970-02-02	1970-02-02
1970-02-03	1970-02-03
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1970-02-15	1970-02-15
1970-02-16	1970-02-16
1970-02-17	1970-02-17
1970-02-18	1970-02-18
1970-02-19	1970-02-19
1970-02-20	1970-02-20
1970-02-21	1970-02-21
1970-02-22	1970-02-22
1970-02-23	1970-02-23
1970-02-24	1970-02-24
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1970-03-08	1970-03-08
1970-03-09	1970-03-09
1970-03-10	1970-03-10
1970-03-11	1970-03-11
1970-03-12	1970-03-12
1970-03-13	1970-03-13
1970-03-14	1970-03-14
1970-03-15	1970-03-15
1970-03-16	1970-03-16
1970-03-17	1970-03-17
1970-03-18	1970-03-18
1970-03-19	1970-03-19
1970-03-20	1970-03-20
1970-03-21	1970-03-21
1970-03-22	1970-03-22
1970-03-23	1970-03-23
1970-03-24	1970-03-24
1970-03-25	1970-03-25
1970-03-26	1970-03-26
1970-03-27	1970-03-27
1970-03-28	1970-03-28
1970-03-29	1970-03-29
1970-03-30	1970-03-30
1970-03-31	1970-03-31
1970-04-01	1970-04-01
1970-04-02	1970-04-02
1970-04-03	1970-04-03
1970-04-04	1970-04-04
1970-04-05	1970-04-05
1970-04-06	1970-04-06
1970-04-07	1970-04-07
1970-04-08	1970-04-08
1970-04-09	1970-04-09
1970-04-10	1970-04-10
1970-04-11	1970-04-11
1970-04-12	1970-04-12
1970-04-13	1970-04-13
1970-04-14	1970-04-14

Collection Stop Date	Mon-Day-Year
11/11/2011	11-11-2011

Chain-of-Custody

[illegible]

Not for Computer Data Entry

[illegible]

Special Instructions

- Special instructions
1. For each location, acidify all but one sample to pH <2. Unacidified jar is for tritium analysis.
 2. Preserve samples in polyethylene bottles by placing filled bottles in ice.
 3. Perform gamma analysis on Poor Boy system; MDC must be less than 10 pCi/L.
 4. Sample only one of two wells at same location (Wells C and C-1; Wells 4 and 4

Figure B-6

**Laboratory Services Request/Chain of Custody Form – Analytical Services Laboratory
(1998)**

5.2.5 FIELD LOGBOOKS

Field-sampling activities shall be documented by the sampling team in a field logbook. The following information should be recorded in a timely fashion each time water-monitoring activities are conducted in the field:

- Well or surface site identification
- Date and time of arrival onsite
- Sampling team personnel
- Well-Purging Information
 - Equipment and procedure
 - Start/end times
 - Purge volume and pumping rate
- Static water level and measurement technique
- Water quality parameters
- Sampling Collection Information
 - Sample collection method
 - Types of sample containers/bottles
 - Preservatives used (if any)
- Weather conditions
- Time departed from location
- Shipping/Transport Information
 - Shipping container type(s)
 - Time delivered to laboratory

5.2.6 PHOTOGRAPHIC DOCUMENTATION

Photographs of equipment, samples, and/or procedures may be taken as requested. Photography must be conducted in accordance with NTS or NAFR security requirements (e.g., Level 2 clearance and photo permit for the NTS, etc.). If practical, photographs should include an information sign or cue card in the photo. This cue card should include:

- Date
- Project

- Location or subject
- Identification number or title

Photographs shall be documented in the field logbook and possibly a separate photograph log as required. The film must be processed and stored in accordance with DOE/NV security procedures.

5.3 SAMPLE HANDLING, PACKAGING, AND SHIPPING

The ASL is responsible for sample custody, packaging, and shipment of samples to offsite laboratories in accordance with LID L-E10.602.PS, “Packaging and Shipping Samples to Contract Laboratories” (BN, 1996c).

Packaging

Water samples, collected onsite and intended for the NTS ASL, may simply be packaged and transported in the original partitioned sample container boxes. However, samples to be shipped to offsite laboratories require the more rigorous packaging procedure described in the above-mentioned LID.

Radiological Clearance

Radiological clearances are not required for water samples from the following sources:

- Offsite wells
- Onsite water supply wells
- Onsite monitoring wells for which previous knowledge of analysis shows no elevated levels of man-made radionuclides and no upward trend of trace amounts of radionuclides.

Radiological clearances are required for the following water samples prior to shipment offsite or being transported from a forward NTS area to Mercury:

- Source-term characterization water samples.
- Water samples from wells known, or suspected, or for which there is a credible possibility to contain elevated levels of radionuclides.

Samples requiring radiological clearances may be checked on location by Radiological Control Personnel or will be transported to Site Monitoring Services, , Building 6-72 in Area 6 (as appropriate) and surveyed by a trained Radiological Technician.

The field sampling team leader shall apprise the ASL or other designated laboratory of any samples which show elevated levels of radioactivity.

Delivery to the Bechtel Nevada Analytical Services Laboratory

Unless otherwise directed, all water samples will be delivered to the ASL, Building 650, Mercury, with the exception of source-term characterization samples, which will be delivered to LLNL.

If schedules permit, samples should be delivered to Sample Management personnel during normal working hours (Monday through Thursday, 7 a.m. to 5:30 p.m.). However, samples may be delivered after hours by utilizing the lockers located on the loading dock at the northwest corner of Building 650. Samples delivered by this method must be relinquished to the specific locker number. Fill in the locker number on the LSR/CoC form, sign, and add the appropriate date and time.

Additional details regarding handling and transport of samples may be found in the following references and SOPs:

- DOE/NV, 1998a. "Chain of Custody," SOP ERD-05-201
- DOE/NV, 1998b. "Sample Handling, Packaging, and Shipping of Nonhazardous Environmental Samples," SOP ERD-05-202
- BN, 1997a. Analytical Services Laboratory Statement of Work with Environmental Monitoring Project

6.0 ANALYTICAL DESIGN, PARAMETERS, AND METHODS

Sample analyses must be conducted using standard methods (when possible) and shall meet the requirements specified in the BN ASL Statement of Work (SOW) (BN, 1997a). Analyses shall be conducted under a documented QA/QC program as discussed in Section 8.0.

6.1 RADIOLOGICAL ANALYSES

Whenever possible, industry standard methods, such as those promulgated by the EPA, the ASTM, or the DOE, should be used for radiochemical analysis. However, because of the unique requirements associated with the radiological analysis of NTS groundwater (especially for source-term characterization), internal procedures developed by BN, LLNL, or LANL may be used. All methods used must be documented or referenced to existing procedures.

The typical analyses requested for RREMP water samples are listed in Tables B-2 and B-3. Additional radiochemical parameters may be requested and may require specially developed methods. Some of these special radiochemical analyses may be conducted at other laboratories such as LANL and/or LLNL. The minimum detectable concentrations (MDCs) for radiological analyses are specified in Table B-7. Quality Control requirements (precision, accuracy, and completion) are addressed in Section 7.0

Table B-7 Minimum Detectable Concentrations (MDC) for Water Sample Radiological Analysis

Analysis	Count Method	Nominal Sample volume (mL ^a)	MDC (pCi/mL ^b)
Tritium - conventional	Liquid scintillation counting	50	0.8
Tritium - enrichment	Liquid scintillation counting	500	0.02
Gross Alpha	Gas Proportional counting	900	0.002
Gross Beta	Gas Proportional counting	900	0.002
Gamma Scan (for ¹³⁷ Cs)	Gamma-ray spectrometry	500	10
²³⁸ , ²³⁹ + ²⁴⁰ Pu	Alpha spectrometry	900	0.00003
⁹⁰ Strontium	Gas proportional counting	900	0.0004
²²⁶ & ²²⁸ Radium	Gamma-ray spectrometry	900	0.002

^a Milliliters

^b Picocuries per milliliter

6.2 STANDARD WATER CHEMISTRY ANALYSIS

Several parameters will be analyzed by standard wet chemistry procedures or ion chromatography. These parameters include:

- Alkalinity
- Bicarbonate
- Principle Anions (carbonate, sulphate, chloride, and fluoride)
- Principle Cations (calcium, magnesium, sodium, and potassium)
- Total Dissolved Solids.

Specific conductivity, temperature, and pH will be measured in the field; however, laboratory measurements of conductivity and pH may be requested for comparison. Quality Control requirements for these analyses are specified in Section 7.0.

6.3 POST-ANALYSIS STORAGE AND DISPOSAL

The NTS ASL routinely saves samples for 90 days after analysis for reference and/or reanalysis. If a longer retention period is required, it must be specified on the LSR/CoC form. Post-analysis storage and disposal is addressed in the BN ASL SOW.

7.0 INTERNAL QUALITY CONTROL CHECKS

Quality assurance and QC practices are implemented to ensure (1) the reliability and the validity of field and analytical laboratory data, and (2) that these data meet the DQOs of the overall program. The following three categories of QC practices are discussed in the section:

- Administration Quality Control
- Field Sampling Quality Control
- Laboratory Quality Control

7.1 ADMINISTRATION QUALITY CONTROL

Strict adherence to approved procedures is required through all phases of this monitoring program, including sample collection, processing, custody, documentation, laboratory analysis, and data reporting. Periodic surveillance and audits by supervisors and management will help assure that the proper QC requirements are followed. A supervisor or manager shall accompany each sampler at least once per year as he/she performs a routine sampling event. Additionally, all documentation (including logbooks, LSR/CoC forms, etc.) will be reviewed for completeness and accuracy by the supervisor, who will initial and date these records to indicate they are complete and are of acceptable quality. Specific administrative QA/QC practices are addressed in various sections of this QAASP as listed below:

- Personnel Training – Section 4.1.1
- Chain-of-Custody and Documentation Procedures – Section 5.0
- Assessments and Surveillances – Section 11.0

7.2 FIELD SAMPLING QUALITY CONTROL

Field QC practices include the adherence to approved procedures and the methods prescribed in this QAASP. Additionally, acceptable limits of precision and accuracy for field measurements are prescribed in Tables B-8 and B-9. Quality control samples are discussed in Subsection 7.2.1.

7.2.1 QUALITY CONTROL SAMPLES

Field-sampling activities shall include the introduction of QC samples into the overall collection, handling, and analytical process. QC samples help verify that the sample collection and handling processes have not affected the quality of the groundwater samples. Field QC samples should have the same volume, container type, and preservation as the regular groundwater samples. The field samples should be handled, documented, and processed exactly as the other environmental samples. Field QC sample types are described in the following paragraphs.

Field Blanks

A field blank is prepared by filling a sample container with deionized or distilled water at the sample collection location. The field blank shall be maintained handled, stored, packaged, and shipped along with the other environmental samples.

Table B-8 Water Chemistry Field Data Precision and Accuracy Requirements

Use	Type	Unit Parameter	Method	Precision	Accuracy
Well Sampling	Temperature ^a	°C	Mercury thermometer	±0.1 °C	±0.1 °C
			LCD ^b	±0.1 °C	±2 °C
			Combination meter (LCD)	±0.05 °C	±0.1 °C
	pH ^a	pH	pH meter	±0.01 pH unit	±0.1 pH unit
			Hand-held Instrument ^c	±0.1 pH unit	±1 pH unit
			pH paper	±1 pH unit	±1 pH unit
	Specific ^a conductance	Conductance and resistivity	Instrument	1% of range	5% of instrument range

Source: Adapted from UGTA SAP Quality Assurance Project Plan (QAPP).

^a Measurement is collected in line.

^b Liquid Crystal Diode display.

^c pH meter calibrated to 4, 7, and 10 pH units. Hand-held pH instruments are pH “pencils” that do not require periodic calibration.

Table B-9 Water-Level and Flow Rate Measurements Precision and Accuracy Requirements

Use	Type	Parameter	Method	Precision	Accuracy
Well Sampling and Monitoring	Water-Level Data	Depth, in feet, of water from ground surface	Steel tape	±0.01 feet (ft) ^a	±0.02% of depth
			Electric tape	±0.05 ft	± 1 ft per 1,000 ft depth
			Fluid density	± 1 ft	± 1 ft per 1,000 ft depth
			“Iron Horse” ^b	± 0.01 ft	± 1 ft per 1,000 ft depth
			USGS wireline	± 0.01 ft	± 1 ft per 1,000 ft depth
	Transducers: relative water level (pressure hydraulic head)	Pressure (pounds per square inch [psi])	Dependent on SOP and SOW	± 0.1% of pressure range for specific transducer ^c	±0.1% of pressure range for specific transducer

Table B-9 (continued)

Use	Type	Parameter	Method	Precision	Accuracy
Well Sampling and Purging	Flow rate, water volume	Flow rate ^d	Meter ^d	±5% of flow rate ^e	±5% of flow
		Flow totalizers ^d (turbine meters, mass flux, pressure flow)	Meter	±1% of total flow ^e	±1% of total flow

Source: Adapted from UGTA SAP QAPP.

^a Measurement will be taken twice and both values recorded on the appropriate field logs.

^b An “Iron Horse” is a steel-tape reel previously used at the NTS to measure depth to water.

^c Transducer data is typically recorded continuously or at short time intervals.

^d Type of meter used depends on established DQO.

^e Totalizer flow meters typically record continuously at short time intervals.

Trip Blanks

A trip blank is a QC sample of analyte-free media (typically deionized water) provided by the analytical laboratory, transported to the sampling site, and returned to the laboratory unopened. The purpose of trip blanks is to check for possible cross contamination of tritium and other volatile contaminants. Typically, trip blanks will not be required for the RREMP. The possibility of cross contamination will be minimized by segregating “hot well” sampling operations from other sampling activities.

Rinsate Blanks

A rinsate blank (sometimes referred to as an “equipment rinseate blank”) is a sample of the solution (typically deionized or distilled water) used to rinse a particular piece of sampling equipment after it has been decontaminated. It is used to demonstrate that there is no residual contamination remaining on the tool which could be carried over to the next sampling event. A rinsate blank shall be collected from all nondedicated sampling equipment (e.g., downhole pumps) used at “hot wells” and those several monitoring wells where radionuclides have been detected.

Field Duplicates

A field duplicate (or triplicates as requested) is a sample collected from the same location at approximately the same time as the primary sample. Field duplicates are to be handled in the same fashion as the primary samples, but may be analyzed by the same laboratory or by a secondary laboratory.

Table B-10 summarizes field QC sample types and lists the minimum frequency requirements.

Table B-10 Field Quality Control Sample Types and Frequency Requirements

Field QC Sample Type	Well Type (Groundwater)			Surface Water (Offsite Springs)
	Water Supply Well	Monitoring Well	Source-Term Characterization Wells	
Field Blank	Not required	One per day or one with each sample batch (or 1 in 20)	Not required	Not required
Trip Blank	Not required	One per day or one with each sample batch (or 1 in 20)	Not required	Not required
Rinsate Blank	Not required for wells with dedicated downhole pumps	One per well with history of contaminants above MDC	One per sample event; however, not required for wells with dedicated downhole pumps	Not required
Field Duplicate	One with each sample batch (or 1 in 20)	One with each sample batch (or 1 in 20)	One per sample ¹	One per day

¹One set per lab (LLNL and LANL).

The laboratory will not be aware of the field QC samples. Results of the field QC sample analyses will therefore initially be included with the corresponding sample batches. Quality control sample results will be evaluated during data validation and evaluation processes.

The EPA, state of Nevada, or another designated entity may accompany the BN field sampling team on sampling events to collect replicate samples for QC purposes. It is expected that a certain percentage (to be determined annually, but assumed to be on the order of 10 percent) of onsite wells will be sampled and analyzed independently by the EPA for QC purposes. Similarly, approximately 10 percent of the offsite wells may be sampled and analyzed independently by BN or another entity (e.g., state of Nevada, DRI) for QC purposes.

7.3 LABORATORY QUALITY CONTROL

Laboratory QA/QC samples will be processed as required by ASL procedures and the following. Analytical results for QA/QC samples will be included in the laboratory data reports.

7.3.1 DATA PRECISION AND ACCURACY OBJECTIVES

Data precision and accuracy objectives are presented in Table B-11.

Table B-11 Precision, Accuracy, and Completeness for Laboratory Activities

Parameters	Typical Precision RPD% ^a	Typical Accuracy or % Recovery
Radiochemical Parameters		
¹³⁷ Cesium	±20	80-120
³ Hydrogen (Tritium)	±20	80-120
^{226,228} Radium	±20	80-120
^{238,239+240} Plutonium	±25	75-125
⁹⁰ Strontium	±20	80-120
Gross α/β	±25	70-120
Stable Isotope Parameters		
Cations (Ca, Mg, Na, K)	±20	80-120
Anions (Cl, CO ₃ , SO ₄ , F)	±20	80-120
Total Dissolved Solids	±20	80-120
Alkalinity	±20	80-120
pH	±20	0.5 (pH Units)
Conductivity	±20	N/A ^b

^a Relative percent difference.

^b Not applicable.

7.3.2 LABORATORY BLANKS

At least one of every 20 samples (5 percent of samples) shall be a laboratory blank. Laboratory blank results are assessed to determine an appropriate sample background, as well as the existence and magnitude of contamination problems. The criteria for evaluation of blank results applies to any blank associated with EM samples. If problems with blank results exist (e.g., results are greater than MDC), all the results from samples in the same chemistry batch or counting batch must be carefully evaluated to determine if the sample results were affected, or if the problem is an isolated occurrence not affecting the sample results. If from the investigation, sample results are determined to be correct, the blank results shall be reported with the data qualifier B and result records in the affected chemistry batch have a comment stating that the blank was greater than the MDC. If the sample results are determined to be incorrect, the results shall be reported with the data qualifier R. Laboratory results are to be recorded and plotted on a QC chart according to sample type and radionuclide and be available for review during audits and surveillance.

7.3.3 LABORATORY CONTROL SAMPLES

Laboratory control samples serve as monitors of the overall performance of all steps in the analysis, including the sample preparation. Table B-12 summarizes the required laboratory QC sample types and frequency. At least one of every 20 $^{239+240}\text{Pu}$, ^3H , and ^{90}Sr samples (5 percent of samples) shall be an LCS. The ASL shall use laboratory control samples with a matrix as similar as possible to that of the samples be analyzed.

Table B-12 Laboratory Quality Control (QC) Sample Types and Frequency Requirements

Laboratory QC Sample Type	Requirements
Laboratory blank	One with each sample batch (or 1 in 20)
Laboratory control sample	One with each sample batch (or 1 in 20) of $^{239+240}\text{Pu}$, ^3H , and ^{90}Sr analysis
Duplicate samples	One per batch (or 1 in 20)

The LCS percent recovery (LCS%R) is calculated using the following equation:

$$LCS \%R = \frac{LCS_{Found}}{LCS_{True}} * 100$$

where:

LCS_{Found} = concentration, in $\mu\text{Ci/mL}$, for each analyte measured in the LCS; and
 LCS_{True} = actual concentration, in $\mu\text{Ci/mL}$, for each analyte in the LCS.

The LCS should contain greater than 10 times the minimum detectable concentration and the LCS%R should be between 80 to 120 percent. If the LCS%R is outside of these ranges, all the results from samples in the same chemistry batch shall be assigned a data qualifier as follows:

<u>LCS % Recovery</u>	<u>Data Qualifier</u>
< 50	R
50 - 79	L
80 - 120	(none)
> 120	H

LCS results are to be recorded and plotted on a QC chart according to sample type and radionuclide and must be available for review during audits and surveillance.

7.3.4 DUPLICATE SAMPLES

Analysis of laboratory duplicate samples provides indicators of laboratory precision, assuming the activity in the water samples is homogeneous. The sampling schedule specifies one duplicate sample per batch of water samples.

Evaluation criteria:

- If the activity in both the duplicate and original sample is below the instrument detection limit provided by the laboratory, no further evaluation of the results is to be performed.
- If the activity in the original or duplicate sample is above the instrument detection limit, the sample results should be within the 3-sigma (standard deviation) range of the value around the original sample result. If duplicate analysis results for a particular radionuclide fall outside of the control window, the results for that radionuclide in all associated samples of the same matrix may be qualified as estimated (E).

7.3.5 YIELD

Laboratory performance on $^{239+240}\text{Pu}$ and ^{90}Sr samples is established by means of spiking with a tracer during sample preparation. The spike levels should be at least 10 times Minimum Detectable Activity (MDA).

Yields for these samples should be within 50 to 105 percent. The evaluation of the yield is not necessarily straightforward. The sample itself may produce effects due to such factors as interferences. Because the effects of the sample matrix may be outside the control of the ASL and may present relatively unique problems, the review and validation of data based on specific sample results is frequently subjective and demands analytical experience and professional judgment. Accordingly, this section consists primarily of guidelines, in some cases with several optional approaches suggested. Each yield should be recorded and plotted on a QC chart and be available during audits and surveillance.

The yield (Y) is calculated using the following equation:

$$Y = \frac{CT_{\text{Found}}}{CT_{\text{True}}} * 100$$

where:

CT_{Found}	=	measured concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample; and
CT_{True}	=	actual concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample.

Reported results should be qualified as follows:

<u>Yield</u>	<u>Data Qualifier</u>
< 20	R
20 - 50	L
50 - 105	(none)
> 105	H

If the yield for a sample is less than 20 percent, the laboratory must investigate to determine the cause. The laboratory may, at its discretion, reprocess the sample in an attempt to improve the yield. In any case, the laboratory must meet the minimum MDA for the analysis and may compensate for low yield by increasing the count time.

7.4 DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

7.4.1 LABORATORY DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

The Laboratory should verify the quality of all results in accordance with LID L-E10.601.PS, “Analytical Data Package Review” (BN, 1996d), and the following guidelines. Reported results should include all appropriate data qualifiers as provided below:

- B = The result for this laboratory blank was greater than the MDC.
- H = An LCS associated with this sample had a high recovery or this sample had a high tracer yield.
- L = An LCS associated with this sample had a low recovery or this sample had a low tracer yield.
- R = The data are unusable.
- U = The result is less than the MDC.

7.4.2 ENVIRONMENTAL MONITORING DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

Environmental Monitoring should validate and evaluate the quality of the data in accordance with Work Instruction L-E10.606.WEV, “Data Validation and Evaluation,” and the following guidelines. Reported results should include all appropriate data qualifiers as provided below. Documentation for each result with data qualifiers E or X shall explain the reason for the data qualifier.

- A = The associated sample result has been reviewed and is accepted by EM.
- C = There is a comment associated with results for this sample. Includes abnormal and potentially invalid results for which the cause has not been determined.
- E = The associated sample result is an estimated quantity because an input value (e.g., sample volume) was estimated.
- X = The results of the associated sample are not valid. Sample results are flagged as invalid only for the following reasons: (1) the ASL flagged that data as unusable, (2) personnel error resulted in invalid data, or (3) the sample was damaged or contaminated.

8.0 CALIBRATION AND MAINTENANCE

8.1 EQUIPMENT CALIBRATION AND MAINTENANCE

A system of calibration and preventative maintenance shall be employed to ensure that all equipment and instruments used in the RREMP sampling and analysis process are in working order and capable of yielding credible, quality data consistent with the DQOs. The appropriate team leaders are responsible for implementing calibration and preventative maintenance programs (i.e., the Field Sampling Team lead for field equipment, and the ASL manager for all laboratory equipment).

8.1.1 CALIBRATION

Calibration of equipment and instruments must be performed in accordance with approved procedures or the manufacturer's recommendations. Calibrations shall be performed by trained and qualified personnel, the NTS Calibration Laboratory, other approved external agencies, or the equipment manufacturer. A list of field equipment/instruments requiring routine calibration is presented in Table B-13. Laboratory instrumentation requiring calibration is more extensive and test-specific. The laboratory analytical procedures should be consulted for lists of instruments requiring routine calibration.

Calibration Documentation

All equipment/instrument calibrations shall be documented. Calibration data shall be recorded on the data collection form(s), field logbook, and/or in the instrument-specific logbook, as applicable. Periodic calibration records shall include, at a minimum, the following information:

- Name/type and identification number of the equipment/instrument
- Calibration procedure used
- Date/time of calibration
- Required calibration frequency and acceptance criteria

Table B-13 Field Equipment and Instruments Requiring Periodic Calibration

Equipment / Instrument	Calibration type		
	Operational ¹	Periodic ²	Cal Check ³
Water-Quality Parameter Instruments			
pH meter	Yes	Yes	Yes
Specific conductance meter	Yes	Yes	Yes
Temperature-measuring device	Yes	Yes	No
Wireline and Depth Equipment			
Wireline depth recorder	No	Yes	No
Depth sonde / transducer	No	Yes	No

¹ Performed prior to the start of work.

² Performed at prescribed intervals; e.g., annually.

³ Quick calibration check performed during usage; e.g., during the day.

- Reference standards used
- Calibration data
- Statement concerning calibration acceptance, or failure
- Next calibration due date
- Name of individual performing calibration

8.1.2 PREVENTIVE MAINTENANCE

It is prudent that a system of preventive maintenance be established and implemented for both field and laboratory analytical equipment. The frequency of such maintenance is typically based on the manufacturer's recommendations and the professional knowledge and experience of the individual users. It is important to the RREMP that routine maintenance checks are performed and documented at prescribed intervals to minimize equipment failure, which leads to the potential for impacts upon operation, data quality, and cost effectiveness.

Equipment found to be out of calibration or otherwise inoperable shall be removed from service and tagged to prevent inadvertent use. As with calibrations, any repairs must be performed by competent, trained personnel, an approved contractor/service company, or the equipment manufacturer.

Preventive Maintenance Documentation

A control system shall be developed for routine maintenance of equipment and instruments used in the RREMP. Maintenance records shall be kept by the appropriate entity (field sampling team or ASL). The following preventative maintenance information shall be compiled:

- A list of equipment included in the maintenance program
- Equipment/instrument manuals
- For each piece of equipment/instrument in the program
 - Item to be checked and/or serviced and instructions for performing such maintenance
 - List of spare parts in inventory
 - External service contracts in place
 - Frequency of routine maintenance
- Preventative maintenance records

8.2 WELL MAINTENANCE

The groundwater monitoring wells in the RREMP program will require periodic maintenance to ensure continued operation of attendant equipment (e.g., downhole pumps) so that representative samples may be obtained. A program of routine inspection and maintenance should be established with a maintenance cycle of three to five years. Surface inspections should include verification of the presence of the well-identification label and survey points and an evaluation of the well head. The downhole inspection should include pulling the pump (if one is installed), and testing or servicing, as necessary. A downhole video camera survey might also be scheduled to identify corrosion or encrustation problems. Remedial procedures such as brushing or purging the well to remove deposits that may block the well screen/slots or potentially effect water quality should be performed, as necessary. Some resources should be reserved for nonroutine well maintenance when problems are identified during sampling activities.

9.0 DATA REDUCTION, VERIFICATION, VALIDATION, AND REPORTING

To ensure the quality of the data, and that these data meet the prescribed program DQOs, formal procedures for data reduction, verification, validation, and reporting will be followed. Although implemented at essentially all levels within the program, Project Management is ultimately responsible for the overall process.

9.1 DATA REDUCTION

Analytical Services Laboratory results from water samples are resident on the Laboratory Data Analysis System (LDAS) and are available to EM personnel using the standard display and report generating options available on LDAS. In addition, LDAS has a report-generating

option which creates files containing data selected by EM personnel in the format specified. The files created can be electronically transferred from VAX node PLUCKY to a personal computer (PC). Once transferred to the PC, EM personnel format the records as needed to perform required data verification, validation, and reporting functions.

To facilitate subsequent data verification processes, the data reduction step must be sufficiently documented to allow a reviewer to understand the calculations and verify the results.

9.2 DATA VERIFICATION

Verification is the process of checking and reviewing the field and laboratory data, accompanying documentation, and initial data reduction processes. Field and laboratory personnel will review their data sheets, forms, and logs for accuracy, completeness, and legibility. At this point, the originator will sign and date the data sheets/forms as specified in Section 5.0, "Sample Documentation and Custody." These signed records shall be submitted for review, typically to a project supervisor, on a regular basis (at least weekly). The reviewer will check the data for completeness, correctness, and accuracy. The reviewer is also responsible for verifying that the appropriate procedures were followed, QC samples collected, instruments calibrated, etc. If corrections or additions are required, the data sheets may be returned to their originator for the necessary changes. When the reviewer is satisfied with the records, he/she will sign and date them. This verification process also applies to calculations and other forms of data reduction. In addition to checking for obvious mathematical errors, the reviewer must verify that any assumptions are reasonable, equations are identified or referenced, and output (graphic or tabular) is complete and in the standard format specified for each analysis.

The EM personnel use several computer programs to assist with the laboratory data verification process. Those applicable to water sample analyses are discussed below.

Gross Alpha Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing gross alpha in water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks listed below on each record in the file. Records in the file containing results for other than gross alpha analysis of water samples are ignored. The criteria for the data checks are listed in Table B-14.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion that was not met and the total number of criteria the record did not meet. If the answer to criterion 2 is "Yes," additional analysis must be performed to determine which radionuclide(s) produce the alphas, per Title 40 CFR 141. If the answer to criterion 10 is "No," a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Table B-14 Data Check Criteria for Gross Alpha-in-Water Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration > 15 pCi/L?
No	3) Is the concentration less than 0?
No	4) Is the minimum detectable concentration above 2.0 E-9 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration below 0.5 E-9 $\mu\text{Ci/mL}$?
No	6) Is the sample size larger than the maximum anticipated volume of 1,000 mL?
No	7) Is the sample size less than the minimum anticipated volume of 700 mL?
No	8) Is the EM data qualifier other than A ?
No	9) Is the ASL data qualifier other than U or blank ?
Yes	10) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Gross Beta Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing gross beta-in-water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks listed below on each record in the file. Records in the file containing results for other than gross beta analysis of water samples are ignored. The criteria for the data checks are listed in Table B-15.

Table B-15 Data Check Criteria for Gross Beta-in-Water Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration > 2.0 E-7 $\mu\text{Ci/mL}$ at the E Tunnel Pond?
	3) Is the concentration > 5.0 E-8 $\mu\text{Ci/mL}$ at all other locations? (EPA limit)
No	4) Is the concentration less than 2.5 E-9 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration above 4.0 E-9 $\mu\text{Ci/mL}$ at the E Tunnel pond?
	6) Is the minimum detectable concentration above 2.0 E-9 $\mu\text{Ci/mL}$ at all other locations?
No	7) Is the minimum detectable concentration below 1.0 E-9 $\mu\text{Ci/mL}$?
No	8) Is the sample size larger than the maximum anticipated volume of 1,000 mL?
No	9) Is the sample size less than the minimum anticipated volume of 700 mL?
No	10) Is the EM data qualifier other than A ?
No	11) Is the ASL data qualifier other than U or blank ?
Yes	12) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

When the answer to a criterion is different than the anticipated answer for criteria 1 through 11, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 12 is "No," a comment is printed in the output file that identifies the sampling location and the number of records in the input file for that sampling location.

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Gamma Spectrum Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing gamma spectrum analysis of water samples. The program performs the data checks listed below on each record in the file. Records in the file containing results for other than gamma spectrum analysis of water samples are ignored. The criteria for the data checks are listed in Table B-16.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 7, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet.

Table B-16 Data Check Criteria for Gamma Spectrum Analysis of Water Samples

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the minimum detectable concentration above 10 E-6 $\mu\text{Ci/mL}$?
No	3) Is the minimum detectable concentration below 0.1 E-6 $\mu\text{Ci/mL}$?
No	4) Is the sample size larger than the maximum anticipated volume of 520 mL?
No	5) Is the sample size less than the minimum anticipated volume of 450 mL?
No	6) Is the EM data qualifier other than A ?
No	7) Is the ASL data qualifier other than U or blank?

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If any fission or activation products are detected, compare the concentrations with expected concentrations and notify management if the concentrations are of concern.

Tritium-in-Water Analysis (Conventional Method)

This program reads an input file sorted by location and date, normally created by LDAS, containing tritium in water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks

listed below on each record in the file. Records in the file containing results for other than tritium in water results are ignored. The criteria for the data checks are listed in Table B-17.

Table B-17 Data Check Criteria for Tritium-in-Water (Conventional Method)

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration > 3.0 E-7 $\mu\text{Ci/mL}$?
No	3) Is the concentration < -3.0 E-7 $\mu\text{Ci/mL}$?
No	4) Is the minimum detectable concentration above 7.7 E-7 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration below 7.0 E-7 $\mu\text{Ci/mL}$?
No	6) Is the sample size other than 2.5 mL?
No	7) Is the EM data qualifier other than A ?
No	8) Is the ASL data qualifier other than U or blank ?
Yes	9) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion that was not met and the total number of criteria the record did not meet. If the answer to criterion 10 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Tritium-in-Water Analysis (Enrichment Method)

This program reads an input file sorted by location and date, normally created by LDAS, containing tritium-in-water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks listed below on each record in the file. Records in the file containing results for other than tritium in water results are ignored. The criteria for the data checks are listed in Table B-18.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 10 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Table B-18 Data Check Criteria for Tritium-in-Water (Enrichment Method)

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration > 1.0 E-8 $\mu\text{Ci/mL}$?
No	3) Is the concentration < -1.0 E-8 $\mu\text{Ci/mL}$?
No	4) Is the minimum detectable concentration above 1.65 E-8 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration below 1.00 E-8 $\mu\text{Ci/mL}$?
No	6) Is the sample size other than 5.0 mL?
No	7) Is the EM data qualifier other than A ?
No	8) Is the ASL data qualifier other than U or blank ?
Yes	9) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Plutonium Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing plutonium-in-water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks listed below on each record in the file. Records in the file containing results for other than plutonium analysis of water samples are ignored. The criteria for the data checks are listed in Table B-19.

Table B-19 Data Check Criteria for Plutonium-in-Water Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the minimum detectable concentration above 50 E-11 $\mu\text{Ci/mL}$?
No	3) Is the minimum detectable concentration below 1 E-11 $\mu\text{Ci/mL}$?
No	4) Is the sample size larger than the maximum anticipated volume of 1,000 mL?
No	5) Is the sample size less than the minimum anticipated volume of 650 mL?
No	6) Is the EM data qualifier other than A ?
No	7) Is the ASL data qualifier other than U or blank?
Yes	8) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

When the answer to a criterion is different than the anticipated answer for criteria 1 through 7, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 2 is "Yes," additional analysis must be performed to determine which radionuclide(s) produce the alphas, per Title 40 CFR 141. If the answer to criterion 8 is "No," a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Strontium-90 Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing ^{90}Sr -in-water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data checks listed below on each record in the file. Records in the file containing results for other than ^{90}Sr are ignored. The criteria for the data checks are listed in Table B-20.

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 5 is “Yes,” reanalysis or resampling is required. If the answer to criterion 10 is “No,” a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Table B-20 Data Check Criteria for ^{90}Sr -in-Water Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the concentration > 15 pCi/L?
No	3) Is the minimum detectable concentration above 5 E-10 $\mu\text{Ci/mL}$?
No	4) Is the minimum detectable concentration below 2 E-10 $\mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration above the EPA limit of 4 E-9 $\mu\text{Ci/mL}$?
No	6) Is the sample size larger than the maximum anticipated volume of 1,000 mL?
No	7) Is the sample size less than the minimum anticipated volume of 700 mL?
No	8) Is the EM data qualifier other than A ?
No	9) Is the ASL data qualifier other than U or blank?
Yes	10) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected.

Radium Analysis

This program reads an input file sorted by location and date, normally created by LDAS, containing ^{226}Ra and ^{228}Ra -in-water data. Prior to reading the file, the program requests the user to enter the number of sampling periods included in the file; then it performs the data

checks listed below on each record in the file. Records in the file containing results for other than radium analysis of water samples are ignored. The criteria for the data checks are listed in Table B-21 and apply to both ^{226}Ra and ^{228}Ra .

Table B-21 Data Check Criteria for ^{226}Ra and ^{228}Ra -in-Water Analysis

Anticipated Answer	Criterion
Yes	1) Is the sampling location ID number valid?
No	2) Is the ^{226}Ra concentration $> 3.0 \text{ E-}9 \mu\text{Ci/mL}$?
No	3) Is the ^{228}Ra concentration $< 2.0 \text{ E-}9 \mu\text{Ci/mL}$?
No	4) Is the minimum detectable concentration for ^{226}Ra $> 3.0 \text{ E-}9 \mu\text{Ci/mL}$?
No	5) Is the minimum detectable concentration for ^{228}Ra $> 2.0 \text{ E-}9 \mu\text{Ci/mL}$?
No	6) Is the sample size larger than the maximum anticipated volume of 900 mL?
No	7) Is the sample size less than the minimum anticipated volume of 775 mL?
No	8) Is the EM data qualifier other than A ?
No	9) Is the ASL data qualifier other than U or blank ?
Yes	10) Is the number of records for each sampling location the same as the number of sampling periods entered by the user?

When the answer to a criterion is different than the anticipated answer for criteria 1 through 9, the record is copied to an output file with a comment identifying each criterion which was not met and the total number of criteria the record did not meet. If the answer to criterion 10 is "No," a comment is printed in the output file which identifies the sampling location and the number of records in the input file for that sampling location.

Data reviewers take the following action(s) for each record in the output file: Determine if there were any data input errors. If there were input errors, assure that all affected fields in the reported sample information and results are corrected. If the answer to criteria 2, 3, 4 and/or 5 is "Yes," contact management because the requirements of the SDWA may not have been met.

9.3 DATA VALIDATION

Data validation is accomplished through a systematic process of reviewing the data against a set of known criteria. This process consists of data editing, screening, checking, and review. The validation process will include a review of laboratory analytical methods, minimum detection limits, instrument calibration, preparation of standards, QC/duplicate samples, etc. Statistical assessments, including the use of control charts, will also be used to validate data sets. Personnel other than those who performed the original work shall perform data validation.

9.4 REPORTING

Analytical data for radiological parameters shall be reported in $\mu\text{Ci/l}$. Analytical data for nonradiological chemical parameters shall be reported in accordance with standardized formats for chemical data. Support documentation sufficient to conduct an independent data validation process must be provided with the data. The following information, as specified in the ASL SOW, shall be included in the laboratory result summaries:

- Field and laboratory sample number cross-references.
- Results for blanks, duplicates, replicates, and standards (reporting units shall be the same as for sample results).
- Observed value for laboratory control samples.
- Sample size: The size of the sample should be determined and reported in liters for liquid matrix samples.
- Radionuclide: The radionuclide specified for analysis on the LSR.
- Analysis Type: The type of analysis performed on the sample (gamma spectroscopy, liquid scintillation, etc.). This should be the same as that listed on the LSR.
- Sample result: Results of analyses shall be reported using the units specified above. The activity reported should be the “net” activity.
- Uncertainty: The uncertainty is reported as twice the coefficient of variation expressed as a percentage.
- Minimum Detectable Activity (units same as Sample Result).
- Chemical tracer percent recovery (CT%) (as appropriate).
- Associated laboratory control sample percent recovery (LCS%R) (as appropriate).

The laboratory analytical data summary reports shall be delivered to the RREMP Project Manager in both hard copy and electronic file formats. The deliverable turnaround time is specified in the ASL SOW. In addition to the laboratory analytical data reports discussed above, project activities will result in various other reports, including:

- Monthly status reports
- Technical reports
- Management reports
- QA reports.

RREMP data may also be published in reports generated outside the RREMP. An example of such a report is the NTS ASER. All records generated by this program shall be processed and maintained in accordance with BN management procedures.

9.4.1 ELECTRONIC DATABASES

RREMP laboratory data initially will reside on the LDAS. After the data have been verified and validated, they will be transferred to the BN EM Database, which will be considered the parent database. It is beyond the scope of this QAASP to list all possible databases where RREMP (water media) data might reside. The list includes all NTS programs, regulatory agencies, data generators, and users. Examples include:

- Laboratory Data Analysis System – The computer database system used by the NTS ASL to calculate and record sample results.
- BN EM Database – A comprehensive NTS-wide environmental database.
- IT Field Environmental Restoration Database – The database management system used by UGTA to manage and report sampling data and relevant information.
- USGS Water Level Database.
- EPA Database.
- LLNL ISD (water chemistry).
- LLNL (source-term data).
- LANL (source-term data).
- YMP.
- Area 5 RWMS.
- Defense Threat Reduction Agency

9.4.2 REPORTING OF PARTICIPANTS TO BECHTEL NEVADA PROJECT MANAGER

All RREMP participants will provide status reports to the BN project manager as requested.

9.4.3 MONTHLY PROGRESS REPORTS

The BN field-sampling team leader shall provide a monthly summary to the BN project manager. This monthly status report shall include, at a minimum, the following:

- Description of field activities completed and in progress
- Variances between accomplishments and planned schedules
- Problems and corresponding corrective actions
- Status of equipment and supplies

9.4.4 TECHNICAL REPORTS

Various technical reports may be generated by the RREMP. All such reports will be coordinated through the appropriate manager, and subjected to review processes prescribed in the management procedures. Copies of these reports will be maintained in the RREMP technical library.

9.4.5 ANNUAL REPORTS

RREMP activities and/or data may be presented in several types of annual reports, including:

Contractual Annual Reports

All participating agencies are responsible for compiling a contractual annual report that summarizes the activities of the previous fiscal year. RREMP activities shall be clearly identified in this annual report, including milestones completed or in progress.

DOE/NV Annual Site Environmental Report

Environmental monitoring data for the NTS and support facilities will be reported in the ASER. BN EM is responsible for compiling and integrating data from the various NTS environmental data collection groups.

9.4.6 CLASSIFICATION ISSUES

Current classification guidelines must be followed in reporting all data related to nuclear testing. Information about, or reference to, the ratio of certain radionuclides, plutonium isotopes for example, is classified SRD if obtained from drillback samples. To address this issue, data regarding certain isotopes may not be specifically requested or reported by the RREMP. In general, this program will generate no classified data or reports. Derivative source-term studies conducted at the LLNL or LANL potentially could generate classified information. This issue will be addressed internally by each laboratory.

10.0 NONCONFORMANCES, CORRECTIVE ACTIONS, AND CHANGES

This section establishes methods and responsibilities for identifying, reporting, and resolving nonconformances and other conditions adverse to the program.

10.1 NONCONFORMANCES

Nonconformances are unapproved deviations from the project's written plans or procedures. Nonconformances include, but are not limited to, data missing from field logs, data recorded incorrectly in field logs and/or in databases, malfunctioning equipment, loss of a sample, use of out-of-calibration meters, too-small sample volumes, and failure to meet field and/or ASL QA/QC criteria. Nonconformances may be detected by any project participant including the field team, laboratory personnel, QA personnel, technical staff, or outside auditors. Significant nonconformances shall be documented on a Nonconformances Report (NCR) form and reported to the project manager in accordance to the applicable BN SOP/LID. All nonconformances shall be documented in the applicable log and/or report. All deviations from the plan should be documented as to the extent of and reason for the deviation. Deviations from the plan may or may not affect data quality.

Stop Work Order

A Stop Work Order (SWO) may be initiated if a condition is identified that is dangerous or might adversely affect data quality. An SWO is appropriate for conditions that would result in personnel injury, damage to equipment or property, or that would adversely affect data quality, program budget, or schedule. An SWO may be specific to an activity or item, or may be broad in scope. Stop Work Orders may be verbally imposed for situations immediately dangerous to personnel health and safety, or presented as a written or verbal communication through the appropriate chain of command for less profound situations. All RREMP personnel are empowered with the authority to initiate an SWO (refer to BN Company Procedure C-A20.002, "Stop Work Order").

10.2 CORRECTIVE ACTIONS

The recognition of a nonconformance requires that action be taken to correct the problem and, if possible, prevent the problem from recurring. The corrective action taken varies with the nonconformance. At a minimum, action should be taken to recover lost data, compensate for lost data, or make a good estimate of the lost data. Significant problems should be identified as deficiencies and entered into BN's deficiency tracking system. Poor personnel performance should be addressed in accordance with good management practices and company policy. Sufficient resources should be made available and used to resolve equipment problems. Appropriate administrative actions should be taken for QA/QC problems. Investigations and corrective actions shall be documented in the applicable log and/or report. Appropriate data qualifiers shall be used for data that are affected by nonconformances. Errors, deficiencies, deviations from plan, certain field events, or data that fall outside established acceptance criteria should be investigated. Such investigations, and any subsequent corrective actions should be documented.

10.3 CHANGES

All changes to this QAASP, sampling locations, types of equipment, calibration procedures, and operational procedures; and data reduction, validation, verification, or reporting procedures which may affect data quality or cost must be approved in writing by the

Environmental Operations Project Manager or higher prior to implementation. To facilitate the work schedule, the Project Manager may authorize a change verbally. All verbal changes must be followed by written changes within three days.

11.0 ASSESSMENTS AND SURVEILLANCES

To verify compliance with specific project requirements, BN QA and Project Management shall perform assessments of all RREMP activities, including an evaluation of written procedures, work activities, and a review of data reports and attendant documentation. To meet this requirement, audits, surveillances, and management assessments will be conducted in accordance with BN QA procedures and as discussed in this section.

11.1 AUDITS AND SURVEILLANCES

Audits shall be performed to verify compliance with RREMP requirements and applicable DOE Orders. Both laboratory performance evaluation audits and field operations audits will be conducted. It is anticipated that outside organizations, such as BN Performance Assurance and the DOE, will also conduct audits periodically.

In addition to audits, surveillances shall be conducted. Surveillances are typically narrower in scope and are directed at specific activities. An example of a project-required surveillance is when a supervisor accompanies the field-sampling team as it performs its assigned tasks.

Audit and surveillance schedules will depend upon the frequency of the subject activities, their importance, results of previous audits and surveillances, nonconformance reports, etc. Scheduled audits may be supplemented by unscheduled audits. All audits and surveillances must be documented in a report. Such audit/surveillance reports will include, at a minimum:

- Date of surveillance
- Individuals performing the surveillance
- Group/individuals observed/audited
- Activities or tasks observed/audited
- Deficiencies or process improvements identified (if any)
- Whether corrective actions are required

Copies of the audit/surveillance reports will be issued to the RREMP Manager, the appropriate supervisor, and any other directly affected personnel.

11.2 MANAGEMENT ASSESSMENTS

A comprehensive assessment of the RREMP shall be conducted at least annually and include direct participation of BN EM and RREMP management. Management from the other RREMP participants should also be involved in such assessments. The results of such assessments shall be documented in a final report and disseminated to the appropriate managers.

12.0 DEFINITIONS

This section contains definitions for terms commonly used in hydrogeology, groundwater sampling, and underground nuclear testing. These definitions reflect the context of their application and historical usage within the underground testing community and related groundwater monitoring activities, which may or may not be the same as in other disciplines or at other sites. Numerous sources were consulted to compile this glossary, including the following:

Allen *et al.*, 1997
RSN, 1991b
DOE, 1988a, 1992b
EPA, 1994

Accuracy:	The closeness of agreement between an observed value and an accepted reference value. When applied to a set of observed values, accuracy will be a combination of a random component and a common systematic error (or bias) component.
Alluvium:	Sediment deposited by a stream in comparatively recent times.
Alteration:	Changes in the chemical or mineralogical composition of a rock, generally as a result of weathering or reaction with water.
Aquifer:	A water-bearing stratum of permeable rock, sand, or gravel located beneath the surface of the earth, which is capable of yielding water to a well or spring.
Ash-Fall Tuff:	A consolidated, usually bedded, deposit of volcanic ash, pumice, and other debris, resulting from the accumulation of material falling from an eruption cloud.
Ash-Flow Tuff:	A consolidated, non-sorted, and non-bedded deposit of volcanic materials produced when a hot, turbulent mixture of gases and ash is expelled along the ground surface. Physical properties vary widely with degree of welding, from soft (nonwelded) to very hard and brittle (densely welded). Also known as ignimbrite.

Batch:	A group of samples that behave similarly with respect to the sampling or the testing procedures being employed and which are processed as a unit. For QC purposes, if the number of samples in a group is greater than 20, each group of 20 samples or less will all be handled as a separate batch.
Bed:	The smallest division of a layered series of rocks. Marked by a well-defined divisional plane ("bedding plane") from its neighbors above and below. The bedding plane may or may not be a plane of weakness.
Blank:	A sample with none of the analyte of interest. See Rinseate Blank and Trip Blank.
Borehole:	A hole drilled into rock or other material; also "drillhole."
Casing:	Special pipe used either to hold back overburden or to line defective or cavernous drillholes. May be installed permanently or temporarily while the hole is being drilled or after the hole has reached total depth.
Cavity:	The approximately spherical void created by the vaporization, melting, and compaction of earth materials surrounding the point of detonation.
Chimney:	A roughly cylindrical region of disoriented rock and rubble formed after the collapse of the explosion cavity, when the overlying material (overburden) fails and falls into the void.
Collapse Sink:	Topographic depression caused by the sudden failure of surface materials above a chimney. Genetically distinct from a crater in that there is no throw-out or vaporization of surface materials.
Control Sample:	A QC sample introduced into a process to monitor the performance of the system.
Critical Pathways:	Those pathways that which result in the most significant amount of exposure to radiation.
Curie:	The common unit used for expressing the magnitude of radioactive decay in a sample containing radioactive material. Specifically, the curie is that amount of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second. This unit does not give any indication of the radiological hazard associated with the disintegration.

Data Quality Objectives (DQOs):	A statement of the overall level of uncertainty that a decision-maker is willing to accept in results derived from environmental data.
Data Validation:	The process of evaluating the available data against the project DQOs to ensure that the objectives are met.
Decontamination:	The removal of radioactive and hazardous constituents from facilities, equipment, or soils by washing, heating, chemical action, mechanical cleaning, or other techniques.
Depth of Burial (DOB):	The vertical distance below the ground surface at which an explosive device is detonated.
Dose:	A general term which denotes the quantity of radiation or energy absorbed; usually expressed in rems for doses to man.
Dose Commitment:	The total radiation dose accrued by an individual over a specified period of time due to the exposure to radiation over a given interval of time. This includes the total time the radioactive material would reside in the body, if ingested or inhaled (usually expressed in rems).
Dose Equivalent:	A quantity used to express all radiations on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose and certain modifying factors and is expressed in rems.
Dose Rate:	The amount of radiation dose delivered in a unit amount of time; for example, in rems per hour.
Drillhole:	A hole drilled into rock or other material; also "borehole."
Duplicate (sample):	A sample taken at the same location and time as the sample collected for the primary analysis. See Matrix Duplicate, Field Duplicate, and Matrix Spike Duplicate.
Effluent Monitoring:	The collection and analysis of samples, or measurements of liquid and gaseous effluents for the purpose of characterizing and quantifying contaminants, assessing radiation exposures of members of the public, providing a means to control effluents at or near the point of discharge, and demonstrating compliance with applicable standards and permit requirements (DOE, 1998b).
Elevation:	The vertical distance from a datum, generally mean sea level, to a point on the earth's surface. The terms "elevation" and "altitude" are sometimes used synonymously; but in modern surveying

earth's surface, whereas "altitude" is used to indicate the height of a point in space above the spheroid representing the sea-level surface of the earth.

Elevation Datum: A point of known elevation at the well site from which the depth-to-water measurement is referenced. An elevation datum point may be a permanent reference point or a temporary datum.

Environmental Monitoring: The collection and analysis of samples or direct measurements of environmental media. Environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance (DOE, 1988b).

Environmental Surveillance: The collection and analysis of samples or direct measurements of air, water, soil, foodstuff, biota, and other media from DOE sites and their environs for the purpose of determining compliance with applicable standards and permit requirements; assessing radiation exposures of members of the public; and assessing the effects, if any, on the local environment (DOE, 1988b).

Equipment Rinsate: A sample of analyte-free media which has been used to rinse the sampling equipment. It is collected after completion of decontamination and prior to sampling, and is intended to see if the decontamination process is adequate.

Fault: A fracture that is vertically extensive (below the ground surface) along which displacement has occurred (i.e., blocks on either side of the fault plane have moved relative to each other).

Field Duplicates: Independent samples that are collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently.

Formation, Geologic: A distinctive or consistently recognizable unit of rocks selected from a succession of beds for purposes of mapping, description, and reference (e.g., Timber Mountain Tuff, Paintbrush Tuff, Eleana Formation). Abbreviated "Fm."

Gamma Ray: [Symbol γ (gamma)] High-energy, short wavelength electromagnetic radiation. Gamma radiation frequently accompanies beta particle emissions. Gamma rays are very penetrating and are stopped most effectively by dense materials such as lead or uranium. They are essentially similar to x-rays but are usually more energetic and originate from the nucleus. Cobalt-60 is an example of a radionuclide that emits gamma rays.

Geodetic Survey:	A survey in which account is taken of the figure and size of the earth. Geodetic surveys are usually prescribed where the areas of distances involved are so great that results of desired accuracy and precision cannot be obtained by processes such as use of measuring tapes.
Groundwater:	Subsurface water filling the pore spaces and fractures in rocks. The upper surface of this saturated zone is called the water table.
Half-Life, Radioactive:	The time required for half of the atoms of a radioactive material to decay to another nuclear form.
Hydrology:	The study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.
Ion:	An atom or molecule that has acquired an electrical charge by gaining or losing electrons.
Isotope:	One of two or more nuclides which have the same number of protons, but have different numbers of neutrons in their nuclei. Therefore, the isotopes of an element have the same atomic number, but different atomic weights. Isotopes usually have very nearly the same chemical properties but somewhat different physical properties.
Laboratory Control Sample:	A known matrix spiked with compound(s) representative of the target analytes.
Limestone:	A rock consisting mainly of grains or crystals of calcite, CaCO_3 ; the consolidated equivalent of limey mud, calcareous sand, or shell fragments deposited on the sea-bottom.
Lithology:	The physical character of a rock, including such factors as mineralogic composition and grain size.
Log:	A record of measurements or observations, especially those made in a borehole. Often termed "well log." As a verb, to record those measurements ("to log a hole").
Matrix:	The component or substrate (e.g., surface water, drinking water) which contains the analyte of interest.
Matrix Duplicate:	A sample split in the laboratory, the analysis of which is used to document the precision of a method in a given sample matrix.

Matrix Spike:	An aliquot of sample spiked with a known concentration of target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix.
Method Detection Limit (MDL):	The minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.
Millicurie: (mCi)	A unit of activity which is equal to one-thousandth (1×10^{-3}) of a curie.
Millirem: (mrem)	A special unit for measuring dose equivalents which is equal to one-thousandth (1×10^{-3}) of a rem.
Perched Water:	Groundwater located above the regional water table, and separated from the underlying body of groundwater by material with no free water.
Permeability:	The measure of fluid flow (gas or water) through a substance under unequal pressure. Rock permeability is an indication of the degree of interconnection of void spaces in the rock. The permeability of the rock, of fractures, or of a drillhole ("whole hole") can be measured. Commonly expressed in millidarcies.
pH:	A measure of the relative acidity or alkalinity of a solution. It is reported as the negative logarithm of hydrogen ion activity in a sample. A neutral solution has a pH of 7, acids have pHs less than 7, and bases have pHs greater than 7.
Picocurie: (pCi)	A unit of activity which is equal to one-trillionth (1×10^{-12}) of a curie.
Playa:	The central part of a desert basin where water accumulates after a rain and then evaporates; a "dry lake" (e.g., Yucca Lake and Frenchman Lake at the NTS).
Porosity:	The portion of a given mass of rock that consists of void space or pores, expressed as a percentage. The pores may be filled with water, air, or other gases, and may be either interconnected or isolated from each other.
Precision:	The agreement among a set of replicate measurements without assumption of knowledge of the true value. Precision is estimated by means of duplicate/replicate analyses.

Pressure Transducer:	A common water-level sensing probe which detects changes in hydrostatic head. Pressure data are transmitted to the surface electronically via a wire or cable.
Purge:	The removal of potentially stagnant water from a wellbore and from the gravel pack.
Quality Assurance Project Plan (QAPP):	An orderly assemblage of detailed procedures designed to produce data of sufficient quality to meet the DQOs for a specific data collection activity.
Radioactive Waste:	Equipment and materials that are radioactive and for which there is no further use. Radioactive wastes are generally classified as high-level waste (those resulting from reprocessing reactor fuel or the used reactor fuel itself), as low-level waste, or as low-level waste containing transuranic elements or uranium-233.
Radionuclides:	Atoms that exhibit radioactive properties. Standard practice for naming radionuclides is to use the name or atomic symbol of an element followed by its atomic weight (e.g., cobalt-60 or Co-60, a radionuclide of cobalt). Also see “isotope.”
Radsafe:	Radiological safety. The system of monitors and techniques used to assure safety from radiation effects. Also used informally to refer to the persons who employ these techniques and to their office location.
RCRA:	Resource Conservation and Recovery Act.
Rem:	A unit of measure used to indicate the amount of radiation exposure a person receives (an acronym for roentgen equivalent man).
Rhyolite:	A very fine-grained extrusive igneous rock compositionally equivalent to granite.
Rinsate Blank:	A volume of rinse solution (e.g., deionized/distilled water) used to rinse a sampling tool after it has been cleaned. The sample is used to demonstrate that no residual contamination remains on the tool.
Specific Conductance:	A measure of water’s capacity to conduct an electric current. The standard unit for low-conductivity natural waters is the micromho.
Split Samples:	Aliquots of sample taken from the same container and analyzed independently.
Standard Operating Procedure (SOP)	A document issued by an agency or company outlining methods of operation. Any common method of operation.

Stratigraphy:	That part of descriptive geology which pertains to the composition, thickness, sequence, age and correlation of layered rocks (cf. structure)
Structure:	That part of the descriptive geology which pertains to joints, faults, shear zones, folding, and other types of rock deformation.
Surface Ground Zero (SGZ):	That point on the surface directly above Ground Zero (GZ) or the Working Point (WP) in an underground nuclear test.
Tertiary:	A period of geologic time that lasted from about 65 million to 1 million years ago. The Cenozoic era of geologic time includes the Tertiary and the Quaternary (most recent million years) periods.
Trip Blank:	A sample of analyte-free media taken from the laboratory to the sampling site and returned to the laboratory unopened. A trip blank is used to document contamination attributable to shipping and field-handling procedures.
Tritium:	A radioactive isotope of hydrogen with atoms that are three times the mass of ordinary light hydrogen atoms.
Tuff:	A rock formed primarily of compacted volcanic materials, such as ash and/or pumice. Common additional components of tuff include various phenocrysts (quartz, feldspar, biotite, etc.) and lithic rock fragments.
Underground Test (UGT):	Term for the nuclear explosion(s) beneath the surface.
Vadose Zone:	The unsaturated region of soil located between the ground surface and water table.
Water Table:	The upper surface boundary of an unconfined aquifer, below which groundwater is present or resides. It is usually defined by the levels at which water stands in wells that barely penetrate the aquifer.
Welded Tuff:	An ash-flow tuff in which the combined action of heat retained by the particles and the enveloping hot gases has resulted in cohesion or molding together of the glassy fragments. A welded tuff may be partially, moderately, or densely welded, and its hardness increases with its degree of welding.
Wireline:	An armored cable containing one or more conductors mounted on a reel. The reel typically is powered by an electric motor and has a means for controlling the reel speed. Ideally, the cable passes over

a calibrated wheel so that the length of cable may be measured as it leaves the reel.

Working Point (WP): A reference to the location of a nuclear device in an underground nuclear test. Also Ground Zero (GZ).

Zeolite Minerals: A group of hydrous aluminosilicate minerals containing the elements Na, Ca, Ba, Sr, and K. Includes the minerals clinoptilote, mordenite, phillipsite, and analcime. Zeolites are characterized by their high cation exchange capacity.

Zeolitized: Describing a tuff that has been altered in the presence of ground water, producing zeolites.

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Attachment B1

Monitoring Well Construction Information

Table B1-1 Preliminary Compilation of Well Construction Information for the Onsite Monitoring Wells

Table B1-2 Preliminary Compilation of Well Construction Information for the Onsite Reserve Monitoring Wells

Table B1-3 Preliminary Compilation of Well Construction Information for the Potential Onsite Monitoring Wells Requiring Remedial Work

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Table B1-1 Preliminary Compilation of Well Construction Information for the Onsite Monitoring Wells

Well Name	Hole TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Completion Dia (in)	Comple Material	Slot/screen info slot top	bottom	Pump Info Type	Depth	Sample Methods Prefer	2nd	Comments
AREA 1													
UE-1q	2600	1656	12.25	1	7.625	CS			none		Pump	Bailer	
AREA 2													
UE-2ce WW	1650	1447	12.25	1	8.625	CS					Pump		
WW-2	3422	2054	7.875	1	6.625	CS	2700	2950	bj	2762	Pump	Bailer	Pump inoperable
AREA 3													
ER-3-2	3000	1607	12.25	3	1.9	SS	1630	1660			Bennet	Bailer	
							1716	1749					
				2	2.875	SS	2614	2634	Moyno	2538	Pump		
				1	2.875	SS	2897	2917	Moyno	2821	Pump		
UE-3e #4	2300	1136	17.5/12.25	1	2.875		2150	2161	transducers		Bennet	Bailer	HRMP hole near
				2	2.875		1887	1908	transducers		Bennet	Bailer	ALEMAN
				3	2.875		1619	1640			Bennet	Bailer	
U-3cn #5	3030	1991	6.625	1	5.75	CS	open hole		Centrilift	2243	pump		Variable
			liner				2832	3030	Tandem				diameters
U-3cn PS#2	2603	1550	9.625	1	4.5	Hydril	1680	1729	Reda	1652	pump		Casing collapse
													at 1926 ft
WW A	1870	1605	12.25	1	10.75	CS	1606	1870	none		pump		Inactive supply well
AREA 4													
TW-D	1950	1724	12.5	1	9.875	CS			none		Pump	Bailer	
				2	10.75		1772	1882	none				
U-4u PS#2A	2280	1526	9.875	1	2.875	j-55 tubing			none			Bailer	Otis plug at xx ft
													Re. DALHART
UE-4t	2413	872	9.875	1	2.875	CS	1963	1992	none	Bennett	Bailer		
				2	2.875	Hydril	1664	1724					
U-4t PS3A	2280	1526									Bailer		Re. GASCON test
AREA 5													
WW-5b	900	687	12	1	10.75	CS	700	900			pump		
WW-5c	1200	719	12.25	1	10.75	CS	887	1187			pump		

B-[1-1]

Table B1-1 (continued)

Well Name	Hole TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Completion Dia (in)	Comple Material	Slot/screen info slot top bottom		Pump Info Type Depth		Sample Methods Prefer 2nd		Comments
UE-5c WW	2682	807	17.5	1	10.75	CS	1100	1300	none		pump		
			12.25										
UE-5n	1687	705	11.61	1	10.75	CS	no perforations				pump		completion to 1532
RNM #1	1302	789	9.875	1	5.5	Hydril			Reda	1032	pump		10k pCi/L tritium transducer
RNM #2S	1156	724	17.5	1	9.6		1038	1119	Reda	~1000	pump		
				a	2.875								
				a	2.875								
UE5 PW-1	839	771	9.3	1	2.875	SS	762	822	none		Bennett	Bailer	
UE5 PW-2	919.5	840	9.3	1	2.875	SS	830	890	none		Bennett	Bailer	
UE5 PW-3	955	890	9.3	1	2.875	SS	878	938	none		Bennett	Bailer	
			7.875										
AREA 6													
ER-6-1	3206	1474	12.25	1	2.875	Hydril	1479	1510	none		pump		Bridge plug
		1545	variable										Recom. completing
UE-6e	4209	1508	8.75	0					none		pump		Bridge plug
			variable										
WW-C	1701	1544	15	1	12.75	CS	~1558	1624	?		pump		
WW-C1	1707	1542	22.63	1	16.6	CS	1536	1650	?		pump		
WW-4	1479	835	20	1	13.375	CS	902	1438	?	1374	pump		
WW-4A	1516	842	20.5	1	13.375	CS	1066	1281			pump		
							1365	1457					
WW-3	1799	1538	8	1	6.625	CS	1535	1765	none		pump		
AREA 7													
UE-7ns	2205	1965	10.625	1	7.6	CS	1992	2196	none		pump		
				a	2.875	CS			none		Bennett		
				a	2.875	CS			none				Transducer lost

B-[1-2]

Table B1-1 (continued)

Well Name	Hole TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Completion Dia (in)	Comple Material	Slot/screen info slot top bottom		Pump Info Type Depth		Sample Methods Prefer 2nd		Comments
AREA 11													
UE-11a	1400	1131	9.125	0					none		pump		
AREA 12													
ER-12-1	3588	1538	12.25	1	5.5	CS	1693	1821	none		pump		Packers/sleeves
							1920	1960					
							2509	2594					
							2990	3162					
							3358	3442					
HTH#1	4206	1464	9	1	8.625	CS	1910	1950	none		pump		
			variable				2030	2050					
							2100	2160					
							2230	2370					
AREA 18													
WW-8	5499	1083	15	1	11.75	CS	1250	1300			pump		Bridge plug
			variable				1450	1500					
							1630	1780					
UE-18r	5004	1365	9.875	0					none		pump		
AREA 19													
ER-19-1	3595	1007	20/15	1	5.5	SS	3249	3309			pump		
			variable				3451	3510					
				2	2.875	SS	2700	2720	Moyno	2663	pump		
				3	2.875	SS	1360	1381	Moyno	1342	pump		
UE-19c WW	8489	2340	?	1	13.4	CS			none				Csg pinched
			variable		10.5	CS			none				
U-19v PS#1	4082		12.25			CS			none		Bailer		
U-19bh	2148	2100	96	0					none		pump		Emplacement hole
AREA 20													
ER-20-1	2065	1988	20.5	0					none		pump		
ER-20-2#1	2520	2271	9.875	0		Hydril	2368	2495	none		pump		

B-[1-3]

Table B1-1 (continued)

Well Name	Hole TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion		Comple Material	Slot/screen info		Pump Info		Sample Methods		Comments
				Strg #	Dia (in)		slot top	bottom	Type	Depth	Prefer	2nd	
ER-20-2#1	2520	2271	9.875	0		Hydril	2368	2495	none		pump		
ER-20-5 #1	2823	2055	12.25	1	5.5	SS	2301	2332	Moyno	2241	pump		
							2362	2392					
							2422	2452					
							2482	2513					
							2543	2573					
				a	2.875	fiberglass	2315	2374					access line
ER-20-5 #3	4294	2060	12.25	1	5.5	SS	3430	3461	Moyno	3383	pump		
							3491	3521					
							3551	3581					
							3611	3642					
							3672	3702					
							3732	3762					
							3792	3822					
							3852	3882					
ER-20-6 #1	3200	2028	12.25	1	5.5	fibergl/	2507	2742	Moyno	2477	pump		
						SS	2832	2892					
				2	2.875	fibergl	2548	2753	alternating				
						access	2841	2929	alternating				
ER-20-6 #2	3200	2029	12.25	1	5.5	fibergl/	2516	2720	Moyno	2467	pump		
						SS	2811	2900					
				2	2.875	fibergl	2522	2727	alternating				
							2815	2903	alternating				
ER-20-6 #3	3200	2020	12.25	1	5.5	fibergl/	2510	2802	none		pump		
						SS							
				2	2.875	fibergl	2496	2786	alternating				
U-20 WW	3268	2057	17.5	1	13.375	CS	2271	3035	?		pump		
PM-1	7858	2095	10.75	1		CS			none		pump		
UE-20n #1	3300	2041	12.25	1	9.625	?					pump		Bridge plug
			variable										

B-[1-4]

Table B1-1 (continued)

Well Name	Hole TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Dia (in)	Comple Material	Slot/screen info slot top	bottom	Pump Info Type	Depth	Sample Methods Prefer	2nd	Comments
AREA 23													
Army #1 WW	1945	689	12.25 variable	1	10.75	CS	900	1050			pump		
SM 23-1	1338	1165	no data	1	4.5	SS	1302	1332			pump		
AREA 25													
UE25p #1	5923	1188				?					pump		
UE25 WT #6	1259	874				?					pump		
USW H-1	6000	1876				?					pump		
J-12	1139	743	15	1	12.75	CS	793	868	pump	?	pump		
J-13	3488	928.5	17.25 variable	1	13.374	CS	1006	1400	pump	?	pump		
PROXIMAL													
PM-3	3019	1458	9.875	1	2.875				pump	1758	pump		
				a	2.375								
¹ TD = Total Depth			⁴ String Number			⁵ completion materials				⁶ sampling methods			
² ft = feet			a = access tube			CS = carbon steel				Prefer = Preferred			
³ in = inches			1 =string number			SS = Stainless steel				2nd = acceptable second			
			0 = No completion tube										
Regular font = Monitoring wells			Underline = Regulatory mandates				Italic = Source-term wells			Bold = Water supply wells			

B-[1-5]

Table B1-2 Preliminary Compilation of Well Construction Information for the Onsite Reserve Monitoring Wells

Well Name	Well TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Completion Dia (in)	Comple Material	Slot/screen info slot top	bottom	Pump Info Type	Depth	Sample Methods 1st	2nd	Comments
AREA 1													
UE-1h	3358	1557	8.75	0							pump	bailer	
			variable										
UE-1r	4182	1626	12.25	1	5.5	CS			submers	2149	pump	bailer	
			variable										
UE-1k	2338	1609	9.875	0							pump	bailer	
			variable										
AREA 3													
U-3cn #1	2460	1670	variable	1	10.75	CS					pump	bailer	
U-3mi	1784	1564	96	0							pump	bailer	Emplacement Hole
ER-3-1	2807	2016	12.25	1	2.33	SS	2562	2592	Moyno	2487	pump		
				2	2.33	SS	2260	2290	Moyno	2183	pump		
TW-7	2272	1667	15	1	11.75						pump	bailer	
			10.62		9.6	CS	1910	2251					
AREA 4													
UE-4av	2815	1567	17.5	1	13.375	CS					pump	bailer	
			12.25										
AREA 5													
WW-5a	910	712	?	1	10	CS					pump		Inactive water supply well
AREA 6													
UE-6d	3896	1513	9.875	1	7.625	CS					pump	bailer	
TW-B	1675	1501	15	1	10.75	CS	1512	1637			pump	bailer	
			10				1637	1656					
WW-3	1799	1538	8	1	6.625	CS	1535	1765	no pump		pump		casing corroded, oil reported in water
ER-6-2	3400	1789	11.75	0	10.625						pump	bailer	
AREA 7													
U-7cd	1625	1440	96	0							pump		Over pressure zone
													Emplacement Hole

B-1-6]

Table B1-2 (continued)

Well Name	Well TD (ft)	SWL Depth (ft)	Borehole Diam (in)	Completion Strg #	Completion Dia (in)	Completion Material	Slot/screen info slot top	Slot/screen info bottom	Pump Info Type	Pump Info Depth	Sample Methods 1st	Sample Methods 2nd	Comments
AREA 9													
U-9ct	1710	1680	96	0					None		pump	Bailer	Emplacement Hole
AREA 12													
UE-12t #6	1461	845	3.937	0					None		pump	bailer	
U-12s	1480	941	52	0					None		pump		52" Dia. Empl. Hole
AREA 15													
UE-15d	6001	668	6.25	1	4.5	CS	2900	5400	?		pump		Inactive water supply well
UE-18t	2600	915	3.875 variable	1	2.375	CS			None		pump	bailer	
AREA 19													
U-19bj	2150	2135	96	0					None		pump		Emplacement hole
UE-19h	3705	2111	? 9.875	1	13.375	CS			None		pump	bailer	plugged with cement to 2293 ft
AREA 20													
PM-2	8782	851	12.25	1	9.625	CS	2500	5290			pump	bailer	Ten separate slotted intervals
UE-20bh #1	2810	2213	13.375	0	12.25	CS					pump	bailer	
AREA 27													
HTH-F	3400	1736	7.5	1		CS			None		Benett	bailer	Warm water, 27 pCi/L H-3 reported
AREA 30													
ER-30-1	1426	451	17.5 variable	1 2	2.875 2.875	SS SS	745.4 587.5	765.4 607.5	Moyno Moyno	649 571	pump pump		
¹ TD = Total Depth ⁴ String Number ⁵ completion materials ⁶ sampling methods ² ft = feet a = access tube CS = carbon steel 1st = preferred ³ in = inches 1 = string number SS = Stainless steel 2nd = acceptable second 0 = No completion tube													
Regular font = Monitoring wells			Underline = Regulatory mandates				Italic = Source-term wells			Bold = Water supply wells			

Table B1-3 Preliminary Compilation of Well Construction Information for the Potential Onsite Monitoring Wells Requiring Remedial Work

Well Name	Well TD (ft)	SWL Depth (ft)	Well Diam (in)	Completion		Comple Material	Slot/screen info		Pump Info		Sample Methods		Comments
				Strg #	Dia (in)		top	bottom	Type	Depth	1st	2nd	
AREA 2													
U-2gg PSE3A	2383	1855	9.875	1	5.5	SS	1910	2060	Moyno		pump	bailer	Water yield too low
AREA 5													
UE-5f	1100	890	9.875	0							pump	bailer	Bridge @ 169.9 m (556ft)
AREA 6													
ER-6-1	3206	1474	12.25	1	2.875	Hydril	1479	1510	none		pump	bailer	Bridge Plug
		1545	variable										Recommend completing
ER-6-2	3430	1789	11.75	0					none		pump	bailer	Recommend completing
WW-3	1799	1538	8	1	6.625	CS	1535	1765	none		pump		Casing corroded; 10-22
			variable										cm oil reported on water
AREA 7													
UE-7k	2548	1700	13.38	0	8.75				none		pump	bailer	Bridge at 93.4m (306 ft)
U-7ba PSIAA	2333	1680	9.875	1	2.875	CS	1935	1992	Moyno	1919	pump	bailer	Water yield too low
AREA 9													
U-9ca #1	3210	1780	?	csg	10.75				none		pump	bailer	320 m (1050 ft) of logging
			9.875	0									cable lost downhole
AREA 10													
U-10L #1	2208	1857	?	csg	10.75				none		pump	bailer	hole bridged @ 1858 ft
			9.875	0									
AREA 20													
UE-20e #1	6395	~1850	variable	csg	13.375				none		pump	bailer	Bridge at 18m (60ft)
			6.125	0									
UE-20n #1	3300	2041	variable	csg	9.625				Moyno	2280	pump	bailer	Severe oxidation of csg
			8.5	0									bridge plug at 2841 ft
ER-20-1	2065	1988	20.5	0					none		pump	bailer	Recommend deepening

Table B1-3 (continued)

Well	Well	SWL	Well	Completion		Comple	Slot/screen info		Pump Info		Sample Methods		Comments
Name	TD (ft)	Depth (ft)	Diam (in)	Strg #	Dia (in)	Material	top	bottom	Type	Depth	1st	2nd	
Proximal													
HTH-3	1860	1105	9	1	7		1193	?	none		pump	bailer	Oil reported on top of
				a	2.875								water
¹ TD = Total Depth			⁴ String Number			⁵ completion materials					⁶ sampling methods		
² ft = feet			a = access tube			CS = carbon steel					1st = preferred		
³ in = inches			1 =string number			SS = Stainless steel					2nd = acceptable second		
			0 = No completion tube										
Regular font = Monitoring wells			<u>Underline = Regulatory mandates</u>				<i>Italic = Source-term wells</i>			Bold = Water supply wells			

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Attachment B2

Water-Level Measurement Wells

Table B2-1 Onsite Water-Level Measurement Wells

Table B2-2 Offsite Water-Level Measurement Wells

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Table B2-1 Onsite Water-Level Measurement Wells

Well Name	General Location	NV State Plan North. (ft/m)	Coordinates ¹ Easting (ft/m)	Total Depth (ft/m)	SWL Depth (ft/m)	Date Completed	Saturated Formation	Comments
AREA 1								
UE-1c	W Yucca Flat	837,000	666,000	1,880	1,297	1964	TCU & LCA	TD in LCA
		255,118	202,997	573	395			
UE-1h	SW Yucca Flat	820,000	675,000	3,358	1,557	1968	LCA	TD in LCA
		249,936	205,740	1,024	475			
UE-1r	S Central Yucca Flat	829,853	677,300	4,182	1,626	1984	TCU & LCA	5-1/2" casing to 655m (2149 ft) with pump
		252,939	206,441	1,275	496			
UE-1k	S Central Yucca Flat	833,500	677,500	2,338	1,609	1969	Volcanics	
		254,051	206,502	713	490			
AREA 3								
ER-3-1	Scarp Canyon	826,811	713,336	2,807	2,016	1994	LCA	Two comp. strings
		252,012	217,425	856	614			
U-3cn #1	S Central Yucca Flat	841,630	688,169	2,460	1,670	1963	TCU	BILBY Hydro test hole
		256,529	209,754	750	509			
U-3mi	SE Yucca Flat	821,740	697,060	1,784	1,564	1985	Volcanics	96" dia. Emplacement hole
		250,466	212,464	544	477			
TW-7	E Yucca Flat	843,192	684,654	2,272	1,667	1954	TCU	Low water yield;
		257,005	208,683	693	508			old construction
AREA 4								
UE-4av	W Central Yucca Flat	854,640	674,077	2,815	1,567	1989	TCU & LCA	Stemmed to 605m (1985 ft)
		260,494	205,459	858	478			
AREA 5								
WW 5A	Frenchman Flat	738,361	707,514	910	712	1951	Alluvium	
		225,052	215,650	277	217			
AREA 6								
UE-6d	S Yucca Flat	814,000	677,500	3,896	1,513	1968	Alluvium &	
		248,107	206,502	1,188	461		TCU	
TW-B	S Yucca Flat	812,044	690,713	1,675	1,501	1961	Volcanics	
		247,511	210,529	511	458			
ER-6-2	SW Yucca Flat	805,314	672,494	3,400	1,789	1995	LCA & UCCU	Drilled through thrust fault and
		245,460	204,976	1,036	545			TD'ed in UCCU (Mc)
AREA 7								
U-7cd	Central Yucca Flat	849,000	681,400	1,625	1,440	1992	TCU	96" dia. Emplacement hole
		258,775	207,691	495	439			Loc. in overpressurized zone

B-[2-1]

Table B2-1 (continued)

Well Name	General Location	NV State Plan Coordinates ¹		Total Depth (ft/m)	SWL Depth (ft/m)	Date Completed	Saturated Formation	Comments
AREA 9								
U-9ct	N Yucca Flat	869,600	677,550	1,710	1,680	1981	Volcanics	96" dia. Emplacement hole
		265,054	206,517	521	512			
AREA 12								
UE-12t #6	Rainier Mesa	901,402	638,432	1,461	845	1988	TCU & LCA	Precambrian Quartzite at 425.8m (1397 ft)
		274,747	194,594	445	258			
U-12s	Gold Meadows	902,407	631,260	1,480	941	1966	Granite	52" diameter hole
		275,054	192,408	451	287			
AREA 15								
UE-15d	N Yucca Flat	895,709	682,084	6,001	668	1962	TCU & LCA	
	Climax Stock	273,012	207,899	1,829	204			
AREA 18								
UE-18t	Timber Mt. Moat	865,800	598,400	2,600	915	1978	Volcanics	
		263,896	182,392	792	279			
AREA 19								
U-19bj	Pahute Mesa	925,900	602,900	2,150	2,135	1992	Volcanics	96" dia. Emplacement hole
		282,214	183,764	655	651			
UE-19h	Pahute Mesa	943,901	585,204	3,705	2,111	1965	Volcanics	Plugged w/ cement to 699m (2293 ft)
		287,701	178,370	1,129	643			
AREA 20								
PM-2	Pahute Mesa	944,581	528,656	8,782	851	1964	Volcanics	Contaminants from nearby SCHOONER test noted
		287,908	161,134	2,677	259			
UE-20e #1	Pahute Mesa	934,466	560,958	6,395	1850	1968	Volcanics	Plugged w/ cement 1970-1158m (3600-3800 ft).
		284,825	170,980	1,949	564			
UE-20bh #1	Pahute Mesa	908,250	574,950	2,810	2,213	1991	Volcanics	HRMP Hole
		276,835	175,245	856	675			
AREA 30								
ER-30-1	Fortymile Canyon	837,451	602,276	1,426	451	1994	Volcanics	Two comp. strings
		255,255	183,574	435	137			
¹ Nevada State Plan Coordinates from the NTS Drilling and Mining Summary, NAD 27.								
A conversion factor of 3.2808333 feet per meter was applied to derive meters.								
TD - Total Depth								
TCU - Tuff Confining Unit								
LCA - Lower Carbonate Aquifer								
UCCU - Upper Clastic Confining Unit								

Table B2-2 Offsite Water-Level Measurement Wells

Station Name	Coordinates		Depth to Water		Elevation	Hole TD
	Lat	Long	(feet)	(meters)	(feet)	(feet)
Ash Meadows Network						
IMV Bentonite Mine Well	363153	1162216	96.55	29.43	2374	
White Well	363031	1161047	61.21	18.66	2403	135
MSH-C Deep Well	363008	1161612	-2.99	-0.91	2330	2110
MSH-C Shallow Well	363008	1161612	-3.25	-0.99	2330	2110
Amargosa Flat Playa Well	362936	1161530	5.08	1.55	2322	14.8
Fairbanks Swamp Well	362902	1162022	0.5	0.15	2248	8.6
F-Meadows Well	362859	1162018	1.55	0.47	2249	7.5
Rogers Spring ET2 Well	362856	1161956	3.6	1.1	2252.9	5.83
Rogers Spring Well	362855	1161950	3.52	1.07	2265.9	420
Rogers Spring ET1 Well	362852	1162004	4.98	1.52	2255.46	6.25
Rogers Spring ET1-D Well	362852	1162004	5.49	1.67	2255.46	10.2
Trenary Well	362802	1162239	12.45	3.79	2185	100
Five Springs Well	362755	1161904	0.22	0.07	2367.4	140
Mine Shaft	362755	1162020	18.75	5.71	2257	57
Amargosa Flat Corral Well	362744	1161243	-0.61	-0.19	2328.3	
Cold Spring Well	362743	1162051	7.31	2.23	2207	17.4
Buck Mining Hand Dug Well	362738	1161047	16.62	5.07	2365	19.4
Carson West Well	362709	1162211	6.96	2.12	2153	17.8
Peterson Well	362648	1162014	4.56	1.39	2215	500
Peterson Reservoir Well	362639	1162058	4.08	1.24	2162	10.8
Garners Well	362555	1162053	19.68	6	2157	202
Mercury Farms Well	362536	1162022	7.03	2.14	2178	120
Spring Meadows Rd Well	362536	1162118	6.82	2.08	2140	14.3
Carson Slough Terrace Well	362531	1162147	6.7	2.04	2136	12.8
Carson Slough 3	362531	1162149	6.11	1.86	2133.17	13.25
Devils Hole Well	362530	1161715	48.13	14.67	2404.1	248
Spring Meadows 12	362527	1161608	74.43	22.69	2433	265
Spring Meadows 11	362521	1161608	93.55	28.51	2442	215
SW Drainage North	362519	1162013	8.94	2.72	2175	14.5
Carson Meadows Well	362515	1162020	6.68	2.04	2171	11
SW Drainage South	362450	1162014	7.29	2.22	2166	9.75
Spring Meadows 9	362434	1161811	20.46	6.24	2248	280
Point of Rocks North Well	362432	1161657	21.59	6.58	2318.8	500
Lower Crystal Well	362421	1162007	1.62	0.49	2148	12.25
Point of Rocks South Well	362420	1161637	8.03	2.45	2333.5	818
Big Spring Well	362227	1161631	2.6	0.79	2240	9.35
B-Spring North Well	362227	1161811	4.19	1.28	2180	13.25
B-Spring South Well	362214	1161816	7.06	2.15	2175	14.2
Carson Slough South Well	362207	1161807	5.81	1.77	2182	12.35
American Resources Well	362148	1161757	7.87	2.4	2190	9.67
GS-1 Well	362021	1161330	80.8	24.63	2430.3	1580
NTS offsite regional network						
UC-1-P-2SR	383806	1161254	641.21	195.43	6084	3600
HTH-2	383740	1161247	554.62	169.04	6024.8	1000
HTH-1	383735	1161245	536.27	163.45	6010.8	3704
TTR Reeds Ranch Well	375453	1164505	100.46	30.62	5384	
TTR Sandia 3	375430	1164631	119.5	36.4	5365.9	250
TTR EH-7 WW	375310	1164723	106.1	32.3	5343	660

Table B2-2 (continued)

Station Name	Coordinates		Depth to Water		Elevation	Hole TD
	Lat	Long	(feet)	(meters)	(feet)	(feet)
NTS offsite regional network (continued)						
TTR EH-6	375139	1164605	98.25	29.95	5355	535
TTR 3BB	375055	1164603	109.51	33.38	5358	
TTR 3B WW	375054	1164603	116.5	35.5	5360	300
TTR 3A WW	375045	1164603	201.5	61.41	5362	805
TTR Sandia 4	374739	1164534	338.64	103.21	5468.2	580
TTR Sandia 2	374725	1164527	347.03	105.77	5477.6	525
TTR EH-2 WW	374658	1164641	455.2	138.7	5595	
TTR EH-4	374619	1164354	315.65	96.21	5458	743
TTR Antelope Mine 3	373623	1164347	31.53	9.61	6362	
TTR Antelope Mine 1	373622	1164346	19.87	6.06	6350	
TTR Antelope Mine 2	373622	1164347	24.23	7.38	6356	
TTR Sulfide Mine	373446	1164333	53.73	16.38	6130	
Ralston Well	373320	1170906	309.5	94.33	4756	
TPJ-1	370840	1165101	43.02	13.11	3991	
TPJ-2	370753	1165027	57.67	17.58	4005	
DDL-1	365711	1151152	157.83	48.1	3208	420
DDL-2	365502	1151341	213.06	64.94	3300	460
TW- 3	364830	1155126	1104.36	336.59	3489.3	1853
ASH-B Deep Well	364329	1164029	314.08	95.73	2677	1220
ASH-B Shallow Well	364329	1164029	313.99	95.7	2677	1220
USAF MW-21	363529	1153913	43.96	13.4	3094.5	76
USAF MW-20	363529	1153921	42.29	12.89	3092.8	65
USAF MW-22	363508	1153917	41.32	12.59	3100.4	65
USAF Well 3	363449	1154053	69.72	21.25	3130	600
USAF Well 106-2	363447	1154049	67.68	20.63	3133	604
Army 6A	363437	1160108	1032.81	314.79	3445	1253
Cactus Springs 3	363422	1154337	34.43	10.49	3265	100
DR-1	363328	1152438	815.81	248.65	3579	957
LWS-A Deep Well	363317	1162708	120.07	36.6	2396	2025
LWS-A Shallow Well	363317	1162708	146.55	44.67	2396	2025
Army 2	363255	1155158	497.3	151.57	3813	658
Army 3	363238	1154646	286.64	87.36	3616.9	826
USAF Well 2372-1	362830	1152657	213.15	64.96	3180	300
Oasis Valley network						
Springdale Windmill Well	370157	1164531	14.71	4.48	3870	120
Springdale Upper Well	370131	1164408	24.46	7.46	3775	
Springdale ET Deep Well	370113	1164349	0.38	0.12	3712	9.3
Springdale ET Shallow Wel	370113	1164349	2.48	0.76	3712	5.6
Springdale Lower Well	370113	1164353	6.89	2.1	3710	11.5
MOV ET Well	370039	1164324	4.08	1.24	3688	13.2
Boiling Pot Road Well	365934	1164316	2.69	0.82	3620	12.3
Pioneer Road Seep Well	365929	1164347	1.26	0.38	3650	7.25
Lower Indian Springs Well	365642	1164745	2.95	0.9	4020	
H.B. Layne Well	365640	1164315	20.73	6.32	3460	75
Matheny Well	365604	1164309	100.8	30.72	3510	175
Crowell Well	365431	1164525	14.77	4.5	3300	24
Source: R. Laczniak, 1997, written communication. Coordinates in NAD 27.						

Attachment B3

Additional Monitoring Wells

Table B3-1 Potential Onsite Reserve Monitoring Wells

Table B3-2 Potential Onsite Monitoring Wells Requiring Remedial Work

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Table B3-1 Potential Onsite Reserve Monitoring Wells

Well Name	General Location	NV State Plan Coordinates		Total Depth (ft/m)	SWL Depth (ft/m)	Date Completed	Saturated Interval	Comments
AREA 1								
UE-1h	S/W Yucca Flat	820,000	675,000	3,358	1,557	1968	LCA	TD in LCA
		249,936	205,740	1,024	475			
UE-1r	S Central Yucca	829,853	677,300	4,182	1,626	1984	TCU & LCA	5-1/2" casing to 655m (2149 ft) with pump
		252,939	206,441	1,275	496			
UE-1k	S Central Yucca	833,500	677,500	2,338	1,609	1969	Volcanics	
		254,051	206,502	713	490			
AREA 2								
WW-2	No. Yucca Flat	880,000	668,720	3,422	2,054	1962	TV&LCA	Decommissioned Water Supply
		268m224	203,826	1,043	626	1992	LCA	Well Within a CAU; LCA com. Pump inoperable.
AREA 3								
U-3cn #1	S Central Yucca	841,630	688,169	2,460	1,670	1963	TCU	BILBY Hydro test hole
		256,529	209,754	750	509			
U-3mi	SE Yucca Flat	821,740	697,060	1,784	1,564	1985	Volcanics	96" dia. Emplacement hole
		250,466	212,464	544	477			
ER-3-1	Scarp Canyon	826,811	713,336	2,807	2,016	1994	LCA	Two comp. strings
		252,012	217,425	856	614			
TW-7	E Yucca Flat	843,192	684,654	2,272	1,667	1954	TCU	Low water yield; old construction
		257,005	208,683	693	508			
AREA 4								
UE-4av	W Central Yucca	854,640	674,077	2,815	1,567	1989	TCU & LCA	Stemmed to 605m (1985 ft)
	Flat	260,494	205,459	858	478			
AREA 5								
WW-5a	Frenchman Flat	738,361	707,514	910	712	1951	Alluvium	Inactive water supply well
		225,052	215,650	277	217			
AREA 6								
UE-6d	S Yucca Flat	814,000	677,500	3,896	1,513	1968	AA, TCU	540 pCi/L H-3 noted
		248,107	206,502	1,188	461			
TW-B	S Yucca Flat	812,044	690,713	1,675	1,501	1961	Tpt WTA	
		247,511	210,529	511	458			
ER-6-2	SW Yucca Flat	805,314	672,494	3,400	1,789	1994	LCA & UCCU	Thrust fault
		245,460	204,976	1,036	545			
AREA 7								
U-7cd	Central Yucca	849,000	681,400	1,625	1,440	1992	TCU	96" dia. Emplacement hole
	Flat	258,775	207,691	495	439			Loc. in overpressurized zone
AREA 9								
U-9ca #1	NE Yucca Flat	872,700	679,098	3,210	1,780	1964	TCU & LCA	320m (1050 ft) of logging cable lost in hole
		265,999	206,989	978	543			

Table B3-1 (continued)

Well Name	General Location	NV State Plan Coordinates		Total Depth (ft/m)	SWL Depth (ft/m)	Date Completed	Saturated Interval	Comments
AREA 9 (continued)								
U-9ct	N Yucca Flat	869,600	677,550	1,710	1,680	1981	Volcanics	96" dia. Emplacement hole
		265,054	206,517	521	512			
AREA 10								
UE-10j	No. Yucca Flat	887,033	670,453	2,613	2,161	1993	LCA	Deepened & recomp. by UGTA
		270,368	204,354	796	659			
AREA 12								
UE-12t #6	Rainier Mesa	901,402	638,432	1,461	845	1988	TCU & LCA	Precambrian Quartzite at 426m
		274,747	194,594	445	258			(1397 ft)
U-12s	Gold Meadows	902,407	631,260	1,480	941	1966	Granite	52" diameter hole
		275,054	192,408	451				
AREA 15								
UE-15d	N Yucca Flat	895,709	682,084	6,001	668	1962	TCU & LCA	Inactive water supply well
	Climax Stock	273,012	207,899	1,829	204			
AREA 18								
UE-18t	Timber Mt. Moat	865,800	598,400	2,600	915	1978	Volcanics	
		263,896	182,392	792	279			
AREA 19								
U-19bj	Pahute Mesa	925,900	602,900	2,150	2,135	1992	Volcanics	96" dia. Emplacement hole
		282,214	183,764	655	651			Downgrad of 3 tests
UE-19h	Pahute Mesa	943,901	585,204	3,705	2,111	1965	Volcanics	Plugged w/ cement to 699m
		287,701	178,370	1,129	643			(2293 ft); poss. upgrad. well
AREA 20								
PM-2	Pahute Mesa	944,581	528,656	8,782	851	1964	Volcanics	Contaminants from nearby
		287,908	161,134	2,677	259			SCHOONER test noted
UE-20bh #1	Pahute Mesa	908,250	574,950	2,810	2,213	1991	Volcanics	HRMP Hole on unused
		276,835	175,245	856	675			structural block
AREA 27								
HTH-F	Siskull Mt.	731,853	661,153	3,400	1,736	1962	TCU, LCA	Warm water. 26 pCi/L H3 noted
		240,121	201,560	1,036	529			
AREA 30								
ER-30-1	Fortymile Canyon	837,451	602,276	1,426	451	1994	Volcanics	Two comp. strings
		255,255	183,574	435	137			
WTA - Welded-Tuff Aquifer			TD - Total Depth					
TCU - Tuff Confining Unit			ft - Feet					
LCA - Lower Carbonate Aquifer			m - Meters					
UCCU - Upper Clastic Confining Unit			Tpt - Topopah Spring Tuff					

B-[3-2]

Table B3-2 Potential Onsite Monitoring Wells Requiring Remedial Work

Well Name	General Location	NV State Plan Coordinates		Total Depth (ft/m)	SWL Depth (ft/m)	Date Completed	Saturated Interval	Comments
		North. (ft/m)	Easting (ft/m)					
AREA 2								
U-2gg PSE3A	Central Yucca Flat	871,811	674,111	2,383	1,855	1994	Volcanics	INGOT Post-shot hole
		265,728	205,469	726	565			v/ low water yield
AREA 5								
UE-5f	Frenchman Flat	772,499	710,901	1,100	890	1965	Alluvium	Bridge @ 169.6m (556 ft)
		235,458	216,683	335	271			Downgrad. of tests in N FF
AREA 6								
ER-6-1	S/E Yucca Flat	814,004	696,800	1,545	1,474	1992	TCU & LCA	Recommend completing
		248,108	212,385	471	449			
ER-6-2	S/W Yucca Flat	805,314	672,494	3,400	1,789	1994	TCU & UCCU	Recommend completing
		245,460	204,976	1,036	545			
WW-3	S Yucca Flat	817,795	677,762	1,799	1,538	1952	Alluvium	CSG corrosion; poss. 10-22
		249,264	206,582	548	469			cm of hydrocarbons reported
AREA 7								
UE-7k	Central Yucca Flat	849,200	685,400	2,548	1700	1981	TCU & LCA	Bridge at 93.4m (306 ft)
		258,836	208,910	777	518			Downgrad and within CAU
U-7ba PSIAA	Central Yucca Flat	851,626	682,080	2,333	1,680	1994	Volcanics	BASEBALL post-shot hole
		259,576	207,898	711	512			v/ low water yield
AREA 9								
U-9ca #1	NE Yucca Flat	872,700	679,098	3,210	1,780	1964	TCU & LCA	320m (1050 ft) of logging cable
		265,999	206,989	978	543			lost in hole; near Yucca fault
AREA 10								
U-10L #1	N Yucca Flat	875,918	681,559	2,208	1,857	1962	TCU & LCA	Hole bridged
		266,980	207,739	673	566			
AREA 20								
UE-20e #1	Pahute Mesa	934,466	560,958	6,395	1850	1968	Volcanics	Bridge @ 18m (60 ft)
		284,825	170,980	1,949	564			Upgrad and deep HSU
UE-20n #1	Pahute Mesa	906,545	571,239	3,300	2,041	1987	Volcanics	HRMP hole near CHESHIRE
		276,315	174,114	1,006	622			Severe oxidation of casing
ER-20-1	SW Area 20	900,001	551,000	2,065	1,988	1992	Volcanics	Recommend deepening
		274,320	167,945	629	606			

Table B3-2 (continued)

Well Name	General Location	NV State Plan Coordinates		Total Depth	SWL Depth	Date Completed	Saturated Interval	Comments
		North. (ft/m)	Easting (ft/m)	(ft/m)	(ft/m)			
PROXIMAL								
HTH-3	E of Frenchman	750,189	736,937	1,860	1,105	1962	LCA	("TW-3") Oil reported on top
	Flat	228,658	224,618	567	337			of water in borehole
Regular font = Conventional monitoring wells			<i>Italic = Source term wells</i>		Bold = Water supply wells			
WTA - Welded Tuff Aquifer		LFA - Lava Flow Aquifer		TCU - Tuff Confining Unit		LCA - Lower Carbonate Aquifer		
Tv - Volcanics undifferentiated								

APPENDIX C

QUALITY ASSURANCE, ANALYSIS, AND SAMPLING PLAN FOR NTS BIOTA

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ACRONYMS and ABBREVIATIONS

ASL	Analytical Services Laboratory
BN	Bechtel Nevada
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulation
DCF	Dose Conversion Factor
DF	Dose Factor
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy Nevada Operations Office
DQO	Data Quality Objective
EDE	Effective Dose Equivalent
EM	Environmental Monitoring
EMM	Environmental Monitoring Manager
EOM	Environmental Operations Manager
EPA	U.S. Environmental Protection Agency
FTE	Full-Time Equivalent
FY	Fiscal Year
LDAS	Laboratory Data Analysis
LID	Local Implementing Document
LSR	Laboratory Services Request
MDA	Minimum Detectable Activity
MEI	Maximally Exposed Individual
MDC	Minimum Detectable Concentration
NDOW	Nevada Division of Wildlife
NTS	Nevada Test Site
PC	Personal Computer
PDCF	Pathway Dose Conversion Factor
QA	Quality Assurance
QAASP	Quality Assurance, Analysis, and Sampling Plan
QC	Quality Control
RAMATROL	Radioactive Material Control
RCT	Radiological Control Technician
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
RWP	Radiological Work Permit
SOP	Standard Operating Procedure

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

This Quality Assurance, Analysis, and Sampling Plan (QAASP) is designed to provide guidance in the design and implementation of radiological monitoring of biota at the Nevada Test Site (NTS). Because monitoring efforts have been minimal for biota on the NTS during the recent past (e.g., last five years), few monitoring techniques have been standardized and no QAASP for biota has been implemented. The development of a QAASP for the NTS biota is a recent activity begun in fiscal year (FY) 1997. It is envisioned that the QAASP is a dynamic document that is subject to change as field-sampling procedures are further tested in the field and improved methods are discovered.

The foundation for the QAASP is the findings of the Nevada Applied Ecology Group (U.S. Department of Energy [DOE], 1992), and suggested field methods as described in the environmental regulatory guidance manual DOE/EH-0173T (DOE, 1991b). It draws strength from past radiological monitoring studies conducted on the NTS and at other DOE sites and the development of Data Quality Objectives (DQOs) developed in FY 1997 and FY 1998 that identify purpose and objectives related to the revised mission of the NTS as described in the recently prepared programmatic environmental impact statement (DOE, 1996).

1.2 SAMPLING OBJECTIVES

The purpose of the radiological sampling on the NTS is to comply with regulatory requirements as described in Chapter 3 of the *Routine Radiological Environmental Monitoring Plan* (RREMP). The primary objective of the sampling is to perform confirmatory sampling to satisfy concerns of stakeholders that radiation levels in plants and animals are below regulatory action levels and “to show that the radionuclides are behaving in the environment as expected.” Monitoring is also being done to demonstrate that conscientious and cost-effective sampling is being performed on the NTS to detect any breakdown in control measures to contain and manage radionuclides of concern. This QAASP addresses onsite biological resources. Radiological monitoring or offsite biological resources is described in a separate U.S. Environmental Protection Agency (EPA) document.

1.3 MEDIA TYPES

The QAASP focuses on two media types: plants and animals. The plants consist of native vegetation found on the NTS. No sampling of agricultural crops on the NTS is included in the QAASP because current land-use practices prohibit cultivation or collection of natural edible plants on the NTS. Offsite crops will not be sampled because, under current operations, there is no reasonable pathway for NTS radionuclides to be transported to regional crop-producing farms and then into the crops at levels which would be significantly above analytical detection limits. The animals to be monitored consist of NTS mourning doves, rabbits, and chukar. No sampling of domestic livestock on the NTS is included in the QAASP because current land-use practices prohibit grazing of livestock. Trespass livestock

is rare on the NTS and animals are usually quickly removed. Milk from offsite cows and/or goats will be sampled to document ^{90}Sr levels that have periodically been measured at concentrations above analytical detection limits (EPA, 1996b).

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.1 INDIVIDUALS USING THE DATA

Data from the QAASP will be used primarily by the DOE to verify compliance with DOE Orders and to manage NTS operations based on the principles of ecosystem management. Examples of individuals using the data include:

- DOE Environmental Monitoring Project Manager
- Bechtel Nevada (BN) Environmental Monitoring Project Manager
- EPA Environmental Monitoring Project Manager

Other users of the data include stakeholder such as the state of Nevada, American Indians, land owners and stewards of adjacent lands, and other interested parties.

2.2 PROJECT OFFICERS

Bechtel Nevada will accept responsibilities for project management. Key officers include competent individuals from the following positions:

- The Project Manager – Reviews all work and monitoring efforts.
- Quality Assurance (QA) Manager – Oversees QA.
- Field Biologist – Oversees field work.
- Radiological Control Technician (RCT) – Oversees radiological field procedures.
- Lab Specialist – Oversees lab work.
- Data Specialist/Reviewer – Oversees data Quality Control (QC) and analyzes data accuracy.

3.0 DEFINITIONS

ASL (Analytical Services Laboratory) – The radioanalytical laboratory in Building 650, Mercury.

Blank – A sample with none of the analytes of interest.

Data Qualifiers – A letter assigned to a sample result to indicate something about the quality of the data. See Sections 9.3.1 and 9.3.2 for the meaning of each data qualifier.

DCF – Dose Conversion Factor.

DF – Dose Factor.

Duplicate Sample – A sample taken at the same location and time as the sample collected for one of the established locations.

EM – Environmental Monitoring.

LCS – Laboratory Control Sample.

LDAS (Laboratory Data Analysis System) – The computer program used by ASL to calculate and record sample results.

LID – Local Implementing Document.

MDA – Minimum Detectable Activity.

MDC – Minimum Detectable Concentration.

NIST – National Institute for Standards and Technology.

PC – Personal Computer.

PDCF – Pathway Dose Conversion Factor.

PLUCKY – The name of the VAX computer on which LDAS resides.

Program Numbers – Three-digit numbers used in LDAS and by EM to identify the project or program for which the samples are collected or used.

4.0 DATA QUALITY OBJECTIVES

4.1 PROBLEM DEFINITION

The collection and analysis of vegetation and wildlife samples is intended to serve several purposes such as monitoring trends in environmental contamination and detection of long-term accumulation of radionuclides (DOE guidance document DOE/EH-0173T), and the monitoring of site radiological control measures. Justification for monitoring radionuclides in vegetation and wildlife and protecting the environment from radioactive contamination to the extent practical is provided by DOE Order 5400.5 (DOE, 1991a). Additionally, the monitoring of radionuclides in plants and animals is required by DOE Order 5400.1 (DOE, 1990) at a sampling interval of at least once every five years to confirm low radionuclide levels (more frequently and intensely if levels are higher).

The monitoring is to be conducted to determine the effects, if any, of DOE activities on environmental and natural resources, and to characterize and define trends in the biological condition of environmental media. Another reason for monitoring is to respond to concerns from stakeholders about the effects of radionuclides on NTS plants, the effects to wildlife ingesting contaminated plants, and the risk to humans of consuming contaminated game animals migrating offsite.

Radionuclides of concern are man-made radionuclides present on the NTS, as identified from previous sampling of vegetation, soils, air, or water on the NTS at levels above background, that are most likely to cause direct damage to vegetation, enter the human food chain through migrating game animals, or to be of concern to the public. They include tritium, ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$. The contaminants of primary concern are tritiated water and ^{137}Cs which are relatively mobile and can be taken up by the vegetation and released, possibly entering the food chain. The release of tritiated water by transpiration from deep-rooted plants during the summer (Hunter, 1997) is also a potential source of exposure to humans inhaling such vapors. ^{90}Sr and $^{239+240}\text{Pu}$ are not as mobile as tritiated water and ^{137}Cs and are of lesser concern, especially in a period of nonactive nuclear testing at the NTS, but may be retained in game animals. Because current land uses on the NTS preclude the use of plants or plant parts (e.g., pine nuts, wolf berries, Indian ricegrass, or greens such as desert princessplume) for direct consumption by humans, the primary pathways to man would be (1) through inhalation of transpired tritiated water or through the vegetation and soil to contaminated game animals leaving the site, and (2) through drinking milk from pasture-fed cows and/or goats raised downwind from the NTS in areas where contaminated soils occur.

4.2 DATA QUALITY OBJECTIVES

The DQO process is a systematic planning tool based on the scientific method for establishing criteria for data quality and for developing data collection designs. By using the DQO process to plan environmental data collection efforts, DOE can improve the effectiveness, efficiency, and defensibility of decisions in a resource-effective manner. The DQOs for radiological monitoring of NTS biota are described in Appendix E.

The DQO process consists of seven steps. The first step of that process is to describe the problem (see Section 4.1). The second step is to identify the decisions. The key decisions to be addressed in this QAASP, based on available radionuclide exposure/effects literature, are:

- Determining the concentration limits of radionuclides for selected plant species on the NTS which pose a significant risk to animal populations or humans.
- Determining the concentration limits of radionuclides for selected game animals on the NTS which pose a significant risk to animal populations or humans.

Decision rules that address these decisions were also developed by identifying inputs to the decision, defining boundaries of the study, and establishing a definition of the action levels for plants and animals.

Action levels in plants will be defined as a specific concentration of radionuclides in plant tissues that contribute to maximum acceptable doses in humans. Concentration levels in plants have not been identified for NTS vegetation at this time, but will be determined from pathway models and parameters from the literature describing past radioecology studies on the NTS and pertinent related data. There currently are no regulatory limits on radionuclide concentrations levels in plants on the NTS. Concentration levels of radionuclides in game animals are those established by pathway models.

Action levels in wildlife will be defined as a specific concentration of radionuclide per gram (g) (up to 1-kilogram [kg] samples) of edible game animal tissue leading to an annual effective dose equivalent (EDE) of 5 millirem (mrem). This action level is based on a maximally exposed individual (MEI) dose of 5 mrem EDE if it were sustained for one year, and is established by a DOE guidance document (DOE, 1991). The dose to animals is assumed to be acceptable if the dose to humans consuming the animals meets dose limits for the general public. Another reason why human dose standards were selected for wildlife is that historically few studies have been done to establish standards of acceptable doses for animals. From the few studies that have been done (O'Farrell and Emery, 1976), there is evidence to suggest that wildlife may tolerate higher doses than humans.

Sampling periodicity is also established by a DOE guidance document (DOE, 1991). When sampling finds EDE values greater than 5 mrem EDE, environmental surveillance measurements should be performed at least annually. Values less than 5 mrem EDE require sampling at least every five years to reconfirm the presence of low dose levels. Based on the low reported values in other media and low values reported in most vegetation, it is likely that sampling frequency would be once each five years (i.e., each contaminated site and its control site will be sampled only once every five years).

The boundaries of the sites to be sampled will be determined using maps from prior radiological surveys showing several types of contaminated areas with the highest concentration of radionuclides. Within contaminated areas of the site, only vegetated areas will be sampled, while areas that are not vegetated (e.g., graveled areas; cement- and asphalt-paved areas) will not be sampled. Selected control sites to the contaminated sites will have similar biological and physical features as the contaminated sites. Plants and animals sampled at control sites will be used to document radionuclide levels in biota from areas believed to have received contamination only from worldwide fallout.

Sampling will be conducted each year at one of the five study sites during the spring or summer, when tritium levels in vegetation are historically high, to establish baseline conditions and peak concentrations of radionuclides. This distribution of sampling one site each year will permit adjustments and improvements in sampling techniques to be made after review of each year's sampling results and provide opportunity to document trends over longer periods of time. It will also distribute program costs more evenly over a five-year planning period to facilitate budget projections and project planning. If concentration levels are above the action level at a site, then monitoring at that site will be increased to once each year. Data will be collected in years with sufficient precipitation to produce plant matter. In years of insufficient precipitation or lack of target plant growth, alternative plant species (e.g., annuals) will be selected or sampling will be deferred to years with sufficient precipitation.

There are numerous springs on the NTS at which the Nevada Division of Wildlife (NDOW) may trap chukar for relocation to offsite public hunting areas. One spring site each year will be sampled for chukar to document their body burdens of radionuclides.

4.2.1 VEGETATION

Vegetation to be sampled will be the dominant plant life forms (e.g., trees, shrubs, herbs/forbs, or grasses). The number of plant species available to sample is generally quite restricted in these disturbed habitats due to harsh site conditions (e.g., low nutrients, lack of topsoil, soil compaction, extreme soil temperatures). Examples of plants include such species as rubber rabbitbrush, fourwing saltbush, sagebrush, white burrobush, princesplume, bristly fiddlehead, desert needlegrass, Indian ricegrass, and red brome. Plant parts to be sampled will be aerial stems, leaves, and flowers or seeds, especially parts known to accumulate radionuclides. The sampling of roots is not desirable because roots may contain radionuclides from the soil adhering to the root surface rather than those absorbed into the roots. Biomass will be that produced within the past five years in the case of woody plants, and the current year's growth for herbs/forbs and grasses. Condition of vegetation may be a constraint on data collection in years of drought when there is insufficient precipitation to produce plant matter or when the site is bladed (e.g., Radioactive Waste Management Site [RWMS]-5) for the purpose of vegetation management.

Animals

The animals to be sampled will be game animals that appear to have the highest probability of entering the human food chain. Candidate animals include browsing animals (e.g., deer, desert bighorn sheep, antelopes, and rabbits) and game birds (e.g., mourning doves, chukar, and waterfowl). Because the intent is to sample animals that are relatively abundant (DOE [1991] states that: "Wildlife that is relatively rare locally should not be taken as environmental samples") with the highest concentrations of radionuclides, species will be selected whose home range is relatively restricted to the contaminated sites and which are sufficiently abundant to sample. This selection criteria limits the candidate game animals to mourning doves, rabbits, and chukar.

Mourning doves and rabbits are abundant at most sites on the NTS. Mourning doves are the most likely game bird species to migrate offsite, and chukar may occasionally be trapped and transported off the NTS by NDOW to repopulate areas open to public hunting. The lack of animals may be a constraint on data collection in years of drought when there is insufficient precipitation to produce plant forage or when the site is bladed (e.g., RWMS-5) for the purpose of vegetation management.

Samples will consist of 10-g to 500-kg (amount needed to determine counts) edible portions of the game animals (e.g., legs, loins, liver, and breasts), obtained from trapped birds and rabbits taken by shotgun, with precautions taken to ensure that meat samples are not contaminated by soil or other contaminated materials on the feathers, fur, or fecal material of the animals. Because of the relatively small number of animals at the study sites, the sampling design will not attempt to achieve statistical sampling adequacy for testing significant differences between contaminated and control site sample level means. However, sampling will provide estimates of sample concentration means, variance, and trends over time. Laboratory analyses will conform to standards established by the DOE guidance document (DOE, 1991b).

In the event that action levels are detected, sampling will be expanded to better define the spatial and temporal extent of contamination. For example, should low-frequency sampling (one sample each five-year period) detect concentrations meeting or exceeding the action level in rabbits, additional sampling would be initiated (one sample each one-year period). The site boundary may be enlarged to include additional areas to be sampled, and the species to be sampled may be increased (e.g., deer or antelope may be sampled if present in the area) in an attempt to better define contaminated animals, sources, and potential pathways leading to humans.

Offsite Milk

The offsite foodstuffs to be sampled will be those with the highest likelihood of contamination from NTS operations and the highest likelihood of ingestion by humans. During the years of atmospheric testing, fission products were carried off the NTS and deposited downwind. Longer-lived radionuclides, particularly plutonium and strontium isotopes, are still detected in soil in the areas downwind. Offsite crops and livestock in neighboring communities have been monitored for years to document possible radionuclide exposure to the public (EPA, 1978a,b; EPA, 1996a). Recent radioanalysis of selected fruits and vegetables from some downwind communities to the north and east of the NTS (e.g., Rachel, Alamo, Hiko) have shown levels of ^3H , ^{90}Sr , and $^{239+240}\text{Pu}$ near or below detection limits (EPA, 1996a). Also, livestock or game animals within the same downwind fallout areas could ingest contaminated forage and then be consumed by humans. Levels of ^{90}Sr in the bones of deer, cattle, and bighorn sheep sampled in 1993 off the NTS were above detection limits, but have consistently decreased in samples since the early 1960s as a result of discontinued aboveground testing (EPA, 1996a). The edible portions of these offsite animals historically contain nondetectable levels of radionuclides. However, ^{90}Sr levels in milk from pasture-fed cows and/or goats sampled from neighboring Nevada ranches have been periodically measured at levels above detection limits (EPA, 1996a). For these reasons, cow and/or goat milk was selected as the offsite foodstuff to monitor as part of the RREMP.

5.0 SAMPLING STRATEGY

5.1 APPROACH

For monitoring NTS biota, the intent is to concentrate efforts on NTS sites with the highest known levels of radionuclides where the likelihood is greater for radionuclides to enter plants and subsequently game animals. All other sites would have a lower likelihood of having radionuclides enter plants or wildlife and at lower concentrations. NTS sites have been selected from the five types of contaminated sites present on the NTS; the monitoring of these sites may also satisfy other monitoring requirements that are project specific, including:

- Runoff areas associated with tunnels, drainage ditches, or ponds.
- Plowshare sites in alluvial fill at lower elevations with the highest surface contamination.
- Plowshare sites in bedrock or rocky fill at higher elevation with the highest surface contamination.

- Aboveground atmospheric test areas.
- Safety shot sites.

Criteria for selection of sites within these contaminated areas is further described in Section 6.1.2. Sampling will be conducted during the season when the radionuclide concentration in plants and edible animal tissue are anticipated to be highest.

The approach taken for sampling NTS chukar will be to collect and analyze chukar from the same sites and time of year as NDOW may select for their trapping and removal efforts. This will be done to document radionuclide levels in birds that most closely represent those removed from the NTS and released onto public lands.

The intent of offsite biota monitoring is to focus on only those foodstuffs likely to contain levels of radionuclides that are above analytical detection limits based on current transport models and NTS operations. Foodstuffs have been sampled historically in communities to the north and east of the NTS, downwind of atmospheric tests. Fruit and vegetable crops, as well as livestock for meat products, were excluded from monitoring because their levels of contamination at downwind communities have decreased over time to levels near or below detection limits. However, ^{90}Sr is still periodically measured at detectable levels within milk of downwind offsite cows and/or goats (EPA, 1996a). Downwind milk samples will monitor the transport of radionuclides from offsite contaminated soil into the human food chain. Because cows and/or goats consume plants grazed over large areas of ground and because ^{90}Sr is readily transferred to milk, analysis of milk may yield data on the deposition of small amounts of radionuclides over relatively large areas from historic fallout and resuspension. The milk samples will be from pasture-fed animals only. Sampling will be conducted during the season when ^{90}Sr in surface soils and forage plant species is anticipated to be the highest.

5.2 SCHEDULE

Sampling of the five NTS site types listed in Section 5.1 will be rotated with one of the five site types sampled each year. Spreading the monitoring efforts out over a five-year period with monitoring performed each year will help facilitate budgeting, demonstrate responsiveness to stakeholder concerns, and ensure compliance with DOE guidelines. Chukar samples will be collected from one spring each year. The spring selected will be where NDOW will most likely trap chukar. The offsite dairies or ranches selected as the downwind contaminated and upwind control sites will be sampled once each year.

Key milestones and estimated dates of completion are shown in Table C-1.

5.3 ASSUMPTIONS

Project assumptions, including assumptions that could result in project failure for plants and animals, are included in the sections that follow.

5.3.1 PLANTS

- Concentrations of radionuclides in plants may vary seasonally depending on location and growing conditions, and to a small extent by plant habit and species.
- With the possible exception of tritium, plants generally discriminate against the uptake and accumulation of radionuclides.
- Under current NTS land use, there is no direct pathway for human exposure to radionuclides through ingestion of NTS plants or plant parts. Transpiration in NTS plants, however, may contribute to tritium concentrations in the air and to total radiation exposure through inhalation.
- Radionuclide contamination in plants may serve as an exposure pathway to game animals through ingestion. Game animals may move offsite and be consumed by man.
- Within this plan, significant contamination in plants will trigger radionuclide surveillance of animal species.
- Elevated levels of radionuclides may be found in plants at sites with contaminated soil or water.
- Offsite levels of radionuclides in soils from fallout from NTS atmospheric tests are not currently high enough to contaminate fruit or vegetable crops consumed by the public. Contamination levels in these crops are near or below analytical detection limits.
- DOE is committed to protecting NTS native plant populations from radiation contamination caused by current DOE/Nevada Operations Office (DOE/NV) activities that would impact viability of plant population. This assumption is based on the stated goal for biological resources within the *Framework for the Resource Management Plan, Volume 2*, of DOE, 1996.

5.3.2 ANIMALS

- Animals acquire radionuclides from plants, other animals, water, air, and soil (e.g., rodents and tortoises from digging, cows and/or goats from ingesting soils or contaminated plants while grazing, and other animals during grooming).
- NTS animals with elevated body concentration of radionuclides will be found in proximity to or will routinely ingest radioactively contaminated material (e.g., soil, plants, water).
- Members of the public could potentially hunt and consume a game animal contaminated with radionuclides from DOE activities conducted on the NTS.

- ^3H , ^{137}Cs , and ^{90}Sr are the most likely radionuclides to be retained in tissues of animals from NTS contamination.
- ^{90}Sr in cow and/or goat milk is the most likely radionuclide to enter into the human food chain as a result of offsite contamination from past nuclear testing.
- The dose to animals is assumed to be acceptable if the dose to humans consuming the animals meets dose limits for the general public.
- DOE is committed to protecting NTS animal populations from radiation contamination caused by current DOE/NV activities that would impact population viability. This assumption is based on the stated goal for biological resources within the *Framework for the Resource Management Plan, Volume 2*, of DOE, 1996.

5.3.3 RESOURCES AND SCHEDULING

- Funding for the radiological monitoring of NTS biota is anticipated on an annual basis beginning in FY 1999. A funding commitment of five years is required to sample all of the five NTS types of contaminated sites and to monitor chukar and offsite cow and/or goat milk for five years. For the purpose of consistency in budgeting, it is assumed that one contaminated site would be sampled each year until all five sites have been sampled, rather than sampling all five sites in one year and waiting five years to sample again.
- Field samples will be collected by BN biologists who are familiar with the sites and radiological sampling protocols. It is estimated that two field scientists and one RCT will be needed to perform the work and that field work can be completed with a minimum of four trips to a contaminated site each year.
- Laboratory analyses will require preparation and verification time for biological samples not frequently or routinely analyzed at the ASL. Establishment of initial laboratory protocols is estimated at approximately two full-time equivalents (FTEs) and purchase of additional distillation glassware and supplies.
- Plans are for 24 plant samples and 19 animal samples from contaminated and control sites each year to be analyzed for tritiated water, ^{137}Cs , ^{90}Sr , ^{238}Pu , and $^{239+240}\text{Pu}$; and for two offsite milk samples each year to be analyzed for ^{90}Sr .

6.0 FIELD OPERATIONS

6.1 SITE SELECTION

6.1.1 LITERATURE REVIEW

The foundation for the field sampling plan is the previous radiological studies that have been conducted on and near the NTS and other DOE sites. Important papers and reports were described in the DQO process (Step 1: Statement of the Problem). Most of the prior

radiological monitoring studies by the Nevada Applied Ecology Group are summarized elsewhere (DOE, 1992). The 1996 Environmental Report for the Hanford Site in Washington (Pacific Northwest National Laboratory, 1997) was useful for comparing monitoring programs because of similar problems and analytical sampling and for developing this QAASP.

6.1.2 SELECTION CRITERIA FOR CONTAMINATED SITES

NTS biota sampling sites are to be selected from the five types of contaminated sites present on the NTS; the monitoring of these sites may also satisfy other monitoring requirements that are project-specific including:

- Runoff areas associated with tunnels, drainage ditches, or ponds. These sites have the highest reported levels of radionuclides on the NTS, usually a result of contaminated surface water. The candidate site is the E Tunnel ponds below Rainier Mesa.
- Plowshare sites in alluvial fill at lower elevations with the highest surface contamination. Nuclear detonations at these sites have distributed contaminants over a wide area, usually in relatively low precipitation areas. The candidate site is SEDAN Crater in Yucca Flat.
- Plowshare sites in bedrock or rocky fill at higher elevations with the highest surface contamination. Nuclear detonations at these sites distributed contaminants over a wide area, usually in relatively high precipitation areas. The candidate site is PALANQUIN.
- Atmospheric test areas. These sites had highly disturbed soils with removal of much topsoil materials and sterilization of soils from heat and radiation. Sites were often used for multiple nuclear tests. The candidate site is the T2 site in Yucca Flat.
- Safety shot sites with surface soil contamination, mainly in the form of plutonium and uranium. The candidate site is Plutonium Valley, Area 11.

Because of the unique conditions associated with waste management areas (e.g., RWMS-5 where vegetation is removed mechanically), a specially designed program to monitor radiological isotopes may be required at this site.

The candidate NTS contaminated sites just described will be visited by competent field biologists to determine their appropriateness as future sampling sites. Location of candidate contaminated and control sites on the NTS is shown in Figure C-1 and coordinates are listed in Table C-2. The locations given in Table C-2 are estimates. At the time of sampling, the locations will be established within 30 meters (m) (98 feet [ft]) accuracy. Key criteria for selection of representative NTS contaminated sites include the following desirable features:

- The site should include areas with relatively high radiological contamination as assessed from maps and prior surveys (the site represents the worst-case condition).

- The site should be vegetated with plants as compared to relatively bare areas that have been scraped, compacted, paved, or otherwise treated to remove vegetation (sites with contaminated vegetation provide pathways to animals that are otherwise absent).
- The site should ideally be located near a supply of water accessible to wildlife (water permits more permanent occupation of the site by animals and keeps the animals near the site so that there is less likelihood of picking up contamination from other locations).
- Sites should be relatively accessible, both day and night (collection of plant and animal samples will require driving within close proximity of the site).
- Sites that have been previously monitored or for which monitoring is currently being conducted for other media are preferable for purposes of comparing and correlating data between or among contaminated media.

The spring selected to collect chukar will be the one at which NDOW requests permission to trap and is usually easily accessible, far from any known contaminated sites, and large enough to attract large numbers of chukar. The possible springs to be sampled are shown in Figure C-1.

The milk sample site should possess the following features; possible sample sites are shown in Figure C-2.

- Site should be downwind of historic atmospheric tests conducted on the NTS and be in a community where elevated soil Pu and Sr levels have been documented.
- Site should have pasture-fed animals from which 1-gallon milk samples can be obtained once a year.
- Site should be one that has been previously monitored or for which monitoring is currently being conducted for other media.

6.1.3 SELECTION CRITERIA FOR CONTROL SITES

NTS control sites (Table C-2) are selected to represent background conditions where the only man-made radiological contamination may be due to worldwide fallout during past nuclear testing. Such sites should be distant enough from the contaminated site so as not to receive contamination from the affected site (e.g., from erosion or wind transport). Selection criteria for the control sites include the following:

- The site should be located upwind or gradient from contaminated sites or within uncontaminated watersheds.
- The site should be at least 5 kilometers (km) (3 miles [mi]) away from the contaminated site (mourning doves may fly up to 4 km [2.5 mi] in search of water or food from the roosting area; this places them out of normal reach of contaminated sites).

- Vegetation of the control sites should be somewhat similar to the contaminated site (e.g., disturbed sites from mechanical scraping or burns are suitable as controls for some contaminated sites like SEDAN or T2).
- The site should preferably have a proximal source of water.
- The site should be relatively accessible, both day and night to facilitate harvesting of the animals.
- Preference would be given to sites previously studied or characterized.

The control milk sample site should possess the following features; possible control sample sites are shown in Figure C-2.

- Site should be upwind of historic atmospheric tests conducted on the NTS and be in a community where soil Pu and Sr levels commensurate with worldwide fallout levels have been documented.
- Site should have pasture-fed cows and/or goats from which 1-gallon milk samples can be obtained once a year.
- Site should be one that has been previously monitored or for which monitoring is currently being conducted for other media.

6.2 PREPARATIONS FOR SAMPLING

Sampling of NTS biota and offsite milk requires the following preparatory tasks:

- Permits for harvesting and transporting wildlife need to be obtained from the NDOW by qualified biologists. Provisions may be included in the current year's permit which is renewed in December of each year. Contaminated and control sites should be surveyed to characterize vegetation, wildlife, and physical conditions at the site. Data to be included in the survey will include a list of plant species, canopy cover, photographs of the site, description of soil surface, disturbances, animals, and other site features.
- Food, water, and dispensing containers used to attract wildlife need to be obtained and tested by competent field biologists.
- Traps for catching animals need to be designed, obtained, installed, and tested at selected sites. Details of these traps will need to be prepared by a competent field biologist
- Field personnel should receive training in field sampling procedures and appropriate radiological procedures (e.g., RadWorker II Training).
- A Radiological Work Permit (RWP) and Prejob Hazard Analysis will need to be prepared and approved prior to field sampling.

- Firearms, ammunition, and a permit for their use on the NTS need to be obtained (may include NDOW or other gun safety course).
- Sample bags, jars, rubber gloves, and anticontamination clothing need to be obtained.
- Storage and transportation equipment need to be obtained for processing carcasses, sampling tissues, and transporting (i.e., direct delivery to the lab or next-day freight services such as Federal Express).
- Property Control Passes need to be prepared for samples leaving the NTS. Samples leaving the NTS need to be processed through RAMATROL (Radioactive Material Control).
- Sampling procedures and other written labels (e.g., sample custody forms) should be prepared.
- Transportation and associated support should be arranged (4-wheel drive vehicles with spotlights).
- The Operations and Coordination Center should be notified of scheduled activities to resolve any potential scheduling conflicts and to ensure the safety of other personnel in the area.
- Services of an RCT for sampling in contaminated sites should be arranged.
- Sampling analyses procedures need to be verified by a competent laboratory technician to confirm nominal sample size.
- Potential dairies or private farms where milk samples from pasture-fed cows and/or goats can be obtained should be contacted; select one upwind and one downwind site.
- Collection of milk samples must be arranged with farm/dairy owners.

6.3 FIELD MEASUREMENTS

Samples collected within radiologically controlled sites will be surveyed in the field by a qualified RCT to determine radiation and contamination levels for radiological control purposes, as required by Title 10 Code of Federal Regulations (CFR) 835, the *NV/YMP Radiological Control Manual*, and other applicable procedures.

At NTS control sites and springs, samples will not be field-surveyed by an RCT because samples are assumed to come from areas that contain only background levels of radionuclides contributed by worldwide fallout.

6.4 SAMPLE COLLECTION

6.4.1 VEGETATION

All decisions associated with field sample collection of vegetation will be made by a competent field biologist. Vegetation will be sampled at the contaminated and NTS control sites using the following procedures. If sufficient material is available, 10 percent of the samples should be duplicate samples. Duplicate samples should be taken from the same plant tissue of the same plant. Field biologists are to select the tissue for the duplicate samples and place the tissue in the sample containers.

- The predominant vegetation will be identified at each sampling site and ranked on the basis of canopy cover dominance from highest to lowest.
- The predominant vegetation at contaminated and control sites will be compared to determine species that are common to both sites.
- A selection of species of plants to be sampled will be made and will include two samples of two species of shrubs/trees, two samples of two species of herbs/forbs, and two samples of two species of grasses. If two species of each life form are not common to both sites, then a species from a different life form will be selected (e.g., two samples of one species of herbs/forbs, and two samples of three species of shrubs/trees).
- Selection will favor plant species that are part of the diet of the candidate animal species to be sampled and species that are more dominant at both sites.
- Selection of plant parts to be collected will consist of plant tissues collected from the current year's growth or, in the case that no vegetative growth is available that year, the past five years' woody growth. No roots or plant parts will be collected that are encrusted with mud, dust, or other soil particles (to the extent practical).
- Plant parts will be cut using clean pruning shears, utility knife blades, or other cutting instruments (one instrument for each plant species to be sampled to prevent cross contamination of materials). Control sites will be sampled before contaminated sites.
- Samples, personnel, and materials leaving contamination areas will be surveyed by a competent RCT in accordance with the *NV/YMP Radiological Control Manual* and other applicable procedures.
- Plant samples will be collected in excess of the nominal aliquot amount to ensure adequate amounts of tissues for analyses.
- Samples collected for tritiated water will be from fleshy tissues or in amounts sufficient to ensure adequate liquid volumes.
- Samples will be properly labeled and doubled-bagged to prevent cross contamination and leakage of materials.

- Bagged samples will be stored in air-tight glass sample jars to protect the integrity of the samples.
- Samples will be stored in ice chests with ice and adequate packing to ensure that sample containers do not break or rupture during transit.
- Sample custody procedures (including written forms) will be followed to facilitate desired transfer and processing of samples.
- Contaminated samples will be disposed according to BN Standard Operating Procedures (SOPs).

6.4.2 WILDLIFE

All decisions associated with field sample collection of NTS wildlife will be made by a competent field biologist. Wildlife will be sampled at contaminated and control sites and at the spring location for chukar sampling using the following procedures: If there is sufficient material, 10 percent of the samples should be duplicate samples. Duplicate samples should be from the same tissue of the same animal. If more than one animal is being sampled, duplicate samples may be prepared using equal portions from each animal in each portion of the duplicate sample. Field biologists are to select the tissue for the duplicate samples and place the tissue in the sample containers.

- The presence of wildlife (i.e., mourning doves, chukar, cottontail, or jackrabbits) will be verified at each site.
- In the event that no mourning doves or rabbits exist within the contaminated and control sites, alternative species will be selected (e.g., chukars, quail, kangaroo rats).
- The predominant vegetation at contaminated and control sites will be compared to determine species that are common to both sites.
- Traps will be baited two weeks prior to harvesting animals and checked daily to ensure that animals are attracted in sufficient quantities for collection (i.e., three samples of rabbits and three samples of dove).
- Harvested animals from control sites will be doubled-bagged in plastic bags (e.g., 1-gallon Ziploc[™] freezer bags) and transported to the laboratory in Mercury for sample preparation.
- Animal carcasses will be carefully dissected to minimize cross contamination of meat samples from fur or contents of the gastrointestinal tract.
- Edible meat samples will be dissected from skeletal material, skin, and internal organs.
- Skeletal bone will be taken from carcasses; take care to avoid contact with skin, feathers, or from gastrointestinal organs or feces.

- Samples, personnel, and materials leaving contamination areas will be surveyed by a competent RCT in accordance with the *NV/YMP Radiological Control Manual* and other applicable procedures.
- Animal samples will be collected in excess of the nominal aliquot amount to ensure adequate amounts of tissues for analyses.
- Samples collected for tritiated water will be from muscle tissues or in amounts sufficient to ensure adequate liquid volumes.
- Samples will be properly labeled and doubled-bagged in plastic bags to minimize cross contamination.
- Samples will be stored in ice chests with ice and adequate packing to ensure that sample containers do not break or rupture during transit.
- Sample custody procedures (including written forms) will be followed to facilitate desired transfer and processing of samples.
- Contaminated samples will be disposed according to BN SOPs.

6.4.3 MILK

Cow and/or goat milk will be collected once a year from one upwind and one downwind dairy or private farm following the procedures below.

- Field biologists will verify with dairy/farm owner (or responsible contact person) that the milk will be collected from only local, pasture-fed animals.
- A single 1-gallon (3.8-liter [L]) collapsible cubitainer will be used to collect raw milk from each dairy/farm.
- The milk sample will be preserved with formaldehyde.
- Sample containers will be properly labeled and sample custody procedures (including written forms) will be followed to facilitate transfer and processing of samples.

6.5 EQUIPMENT DECONTAMINATION

Sampling equipment, clothing, and other supplies will be segregated into contaminated and uncontaminated bags based on procedures implemented by a competent RCT and will be decontaminated or disposed in accordance with the *NV/YMP Radiological Control Manual* and other applicable procedures.

7.0 SAMPLE DOCUMENTATION AND CUSTODY

7.1 SAMPLE CUSTODY PROCEDURES

Information about sample handling will be completely documented to allow the details of sample handling to be recreated. All information will be entered in ink at the time the information is being generated in a permanently bound logbook. Errors will not be erased or blocked out, but corrected by putting a line through the erroneous information by entering, initializing, and dating the correct information. Blank spaces will have an obliterating line drawn through to prevent the addition of information. Each set of information will have an identifying printed name, signature, and initials.

7.1.1 SAMPLE DOCUMENTATION

Data forms will be developed to facilitate sample documentation. Proposed checklists for the sample documentation and custody are included in the sections that follow.

7.1.2 SAMPLE HANDLING

- **Field Logs.** Events occurring during field sampling shall be documented in field logs. Elements to be included in the field log are shown in Table C-3.
- **Sample Labels.** At the time of collection, each sample will be placed in separate plastic bag(s) or bottle(s) with a label identifying the LDAS analyses numbers (e.g. 01, 04, 11, 23), the sampling location by name, and the EM number used in the sample description field of the ASL LDAS. The format of the EM number is

AAHHH_WW☐DDDDDD

where AA is the NTS area number, HHH is a unique number for the location assigned by EM called the HPD number, WW is the week number for the calendar year, ☐ is a blank space, and DDDDD is the description of the location, up to 12 characters. An example follows:
10893_14 SEDAN CRATER.

- **Chain-of-Custody.** The Chain-of-Custody will be in accordance with LID L-E10.603.PS, “Sample Receiving Criteria.” The BN Laboratory Services Request (LSR) form also serves as the Chain-of-Custody form for transfer of custody of the sample from the sampler to ASL.
- **Shipping.** Samples will be placed in bags or bottles which are of appropriate size and strength to contain the sample and prevent leaking or cross contamination. Animal samples may be refrigerated or placed on ice to minimize decay prior to delivery to ASL. Samples which have been identified by an RCT as contaminated or present a radiation concern shall be handled and shipped in accordance with the *NV/YMP Radiological Control Manual* and other applicable procedures. The field biologist is responsible for ensuring that the samples are shipped to ASL, and will accompany the samples unless

preempted by radiological concerns. In the event that samples are shipped to an offsite laboratory for confirmatory analysis, the samples will be appropriately packaged, labeled, and shipped for next-day delivery.

8.0 ANALYTICAL DESIGN, PARAMETERS, AND METHODS

8.1 RADIOLOGICAL ANALYSIS

Table C-4 lists the analysis to be performed and the MDCs desired. The radiological analysis parameters are based on procedures used at the Hanford Site (DOE, 1994; and Pacific Northwest Laboratory, 1995). It is assumed that parameters will be confirmed or modified by BN during FY 1998 based on experience. The objective is to attain the lowest MDC reasonably achievable based on practical aliquot sizes and counting times. These MDCs are lower than those needed to detect a committed effective dose equivalent (CEDE) of 1 mrem/yr to the 50th percentile of a member of a critical group consuming wild game from the NTS (see Attachment 1, page C-33).

8.2 PHYSICOCHEMICAL/GEOCHEMICAL ANALYSIS

No physiochemical or geochemical analysis is needed for the biota samples.

9.0 INTERNAL QUALITY CONTROL CHECKS

9.1 FIELD SAMPLING QUALITY CONTROL

9.1.1 ADMINISTRATIVE QUALITY CONTROLS

Adherence to prescribed methods will be facilitated by the use of written field sampling procedures in a BN LID being prepared. Proposed field methods have been compared with methods used by other contractors at DOE facilities such as the Hanford Site in Washington and the Idaho National Engineering Laboratory site in Idaho to ensure that they are consistent with DQO procedures and technically acceptable methods of data collection. Validation of sampling procedures in the field and follow-up training of field scientists will also be used to maintain quality control during field sampling. All field logs and LSRs will be reviewed and initialed by a supervisor or scientist other than an individual involved in the collection and documentation prior to submitting samples to ASL.

Quality control measures will be developed more fully during field testing in the summer of 1998 when potential problems and practices can be identified to minimize field-sampling errors.

9.1.2 DUPLICATE SAMPLES

The process of sample collection and analysis can introduce a variety of statistical errors into the resulting data. A consideration of the sampling and analysis process can identify most of these contributions to the total error associated with a data value. The sample collected may not be representative of the condition being measured; for example, the animal that was

trapped may have recently migrated into the sampling location and not be at equilibrium with the local environment. There can be slight variations in the sample collection procedure, such as not completely cleaning the sampling equipment between samples. There can be variability introduced during the sample preparation in the laboratory; the weighing, drying, dissections, chemical extractions, and many other sample preparation steps. Finally, there is statistical error in the radiological counting process. The errors reported with the data are only estimates of the counting error, and thus do not represent the total error.

Duplicate and replicate samples can be used to obtain estimates of the total error. The individual components of the total error are typically estimated statistically using analysis of variance procedures. These estimates are improved by increasing the number of duplicates available; however, there are practical limits to the number of duplicates that can be collected which range from limited material to sample to limited budget. A generally accepted rule calls for duplication of 10 percent of the samples collected.

Duplicate Evaluation Criteria

If the activity in both the duplicate and original sample is below the instrument detection limit provided by the laboratory, no further evaluation of the results is to be performed.

If the activity in the original or duplicate sample is above the instrument detection limit, the sample results should be within the 3-sigma (standard deviation) range of the value around the original sample result. If duplicate analysis results for a particular radionuclide fall outside of the control window, the results for that radionuclide in all associated samples of the same matrix should be assigned a data qualifier of E or X based on the professional judgment of EM personnel.

9.2 LABORATORY QUALITY CONTROL

Samples collected under the RREMP are expected to be analyzed under a Statement of Work (SOW) with the ASL. Conditions described herein are to be included in the SOW.

Laboratory QA/QC samples will be processed as required by ASL procedures and the following. Analytical results for QA/QC samples will be included in reports.

9.2.1 LABORATORY BLANKS

At least one of every 20 samples (5 percent of samples) shall be a laboratory blank. Laboratory blank results are assessed to determine an appropriate sample background, as well as the existence and magnitude of contamination problems. The criteria for evaluation of blanks applies to any blank associated with EM samples. If problems with a blank exist (e.g., results are greater than MDC), the results for the sample will be assigned a “B” data qualifier by ASL, and ASL will enter a comment into the result record for each result in the chemistry or counting batch indicating that the blank was greater than MDC or has some other problem. Laboratory blank results are to be recorded and plotted by ASL on a QC chart according to sample type and radionuclide and be available for review during audits and surveillances.

9.2.2 LABORATORY CONTROL SAMPLES

Laboratory control samples serve as monitors of the overall performance of all steps in the analysis, including the sample preparation. At least one of every 20 $^{239+240}\text{Pu}$, ^{90}Sr , and ^3H samples (5 percent of samples) shall be an LCS. The ASL shall use LCSs with a matrix as similar as possible to that of the samples being analyzed.

The LCS percent recovery (LCS%R) is calculated using the following equation:

$$LCS \%R = \frac{LCS_{Found}}{LCS_{True}} * 100$$

where:

LCS_{Found} = concentration, in $\mu\text{Ci/mL}$, for each analyte measured in the LCS; and
 LCS_{True} = actual concentration, in $\mu\text{Ci/mL}$, for each analyte in the LCS.

The LCS should contain greater than 10 times the minimum detectable concentration and the LCS%R should be between 80 and 120 percent. If the LCS%R is outside of these ranges, all the results from samples in the same chemistry batch shall be assigned a data qualifier by ASL as follows:

<u>LCS % Recovery</u>	<u>Data Qualifier</u>
< 50	R
50 - 79	L
80 - 120	(none)
> 120	H

LCS results are to be recorded and plotted by ASL on a QC chart according to sample type and radionuclide and be available for review during audits and surveillance.

9.2.3 YIELD

Laboratory performance on ^{90}Sr and $^{239+240}\text{Pu}$ samples is established by means of spiking with a tracer during sample preparation. The laboratory control spike activity should be at least ten times MDA.

Yields for these samples should be within 50 to 105 percent. The evaluation of the yield is not necessarily straightforward. The sample itself may produce effects due to such factors as interferences. Because the effects of the sample matrix may be outside the control of the ASL, and may present relatively unique problems, the review and validation of data based on

specific sample results is frequently subjective and demands analytical experience and professional judgment. Accordingly, this section consists primarily of guidelines, in some cases with several optional approaches suggested. Each yield should be recorded and plotted on a QC chart and be available during audits and surveillance.

The yield (Y) is calculated using the following equation:

$$Y = \frac{CT_{Found}}{CT_{True}} * 100$$

where:

CT_{Found} = measured concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample; and
 CT_{True} = actual concentration, in $\mu\text{Ci/mL}$, of the tracer material in the sample.

Reported results should be qualified as follows:

<u>Yield</u>	<u>Data Qualifier</u>
< 20	R
20 - 50	L
50 - 105	(none)
> 105	H

If the yield for a sample is less than 20 percent, the ASL must investigate to determine the cause. The ASL may, at its discretion, reprocess the sample in an attempt to improve the yield. In any case, the ASL must meet the required MDC for the analysis and may compensate for low yield by increasing the count time.

9.3 DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

9.3.1 LABORATORY DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

The Laboratory should verify the quality of all results in accordance with LID L-E10.601.PS, “Analytical Data Package Review,” and the following guidelines. Reported results should include all appropriate data qualifiers as provided below:

B	=	The result of this laboratory blank was greater than MDC.
H	=	An LCS associated with this sample had a high recovery or this sample had a high tracer yield.
L	=	An LCS associated with this sample had a low recovery or this sample had a low tracer yield.
R	=	The data are unusable.
U	=	The result is less than the MDC.

Because only one of these data qualifiers per record is allowed in the file, data qualifiers H, L, and R have precedence over data qualifier U. Data qualifier R has precedence over all of the other data qualifiers.

9.3.2 EM DATA QUALITY CALCULATIONS AND DATA QUALIFIERS

EM should validate and evaluate the quality of the data in accordance with LID L-E10.606.WEV, "Data Validation and Evaluation," and the following guidelines. Reported results should include all appropriate data qualifiers listed below. Documentation for each result with data qualifiers E or X shall explain the reason for the data qualifier.

A	=	The associated sample result has been reviewed and accepted by EM.
C	=	There is a comment associated with results for this sample. Includes abnormal and potentially invalid results for which the cause has not been determined.
E	=	The associated sample result is an estimated quantity because an input value (e.g., sample volume) was estimated.
X	=	The results of the associated sample are not valid. Sample results are flagged as invalid only for the following reasons.
		1) The ASL flagged the data as unusable.
		2) An uncorrectable error was found in data collection or analysis.
		3) The sample was damaged or contaminated.

10.0 PREVENTIVE MAINTENANCE

In general, all equipment will be maintained in good working order and free from contamination.

11.0 DATA REDUCTION, VERIFICATION, VALIDATION, AND REPORTING

11.1 DATA REDUCTION

Analytical Services Laboratory results from biota samples are resident on LDAS and are available to EM personnel using the standard display and report-generating options available on LDAS. In addition, LDAS has a special report-generating option that creates files

containing data selected by EM personnel in the specified format. The files created can be electronically transferred from VAX node PLUCKY to a PC. Once in the PC, the records are formatted by EM personnel prior to data verification, validation, and reporting functions.

11.2 DATA VERIFICATION

Data received from the lab and data calculations performed after receipt of data from the laboratory will be reviewed by one or more qualified biologists. The data review will include verification of completeness and accuracy of data entered into LDAS. Data involving statistical calculations will be reviewed by a qualified statistician. Pathway or dose exposure calculations will be reviewed by one or more qualified health physicists. Data findings of the sampling event will be compared to data from previous sampling efforts to detect deviations from the range of data values normally found. Significant deviations in data values or calculations from previous values will be flagged and further evaluated to confirm accuracy of the data or calculations.

Published reports will be reviewed internally by qualified BN scientists and by qualified scientists at the DOE. Internal review by BN will conform to procedures described in BN LIDs L-F11.003, "Engineering Analysis and Calculation"; and L-F11.006, "Internal Engineering Technical Review" (BN, 1996).

12.0 NONCONFORMANCES, CORRECTIVE ACTIONS, AND CHANGES

12.1 NONCONFORMANCES

Nonconformances include, but are not limited to, data missing from field logs, data recorded incorrectly in field logs and/or in databases, malfunctioning equipment, inability to obtain a sample, loss of a sample, small sample quantities, and failure to meet field and/or ASL QC/QA criteria. All nonconformances will be documented in the applicable log and/or report.

12.2 CORRECTIVE ACTIONS

The corrective action taken varies with the nonconformance. At a minimum, an investigation will be performed to recover lost data, compensate for lost data, or make a good estimate of the lost data. Significant problems will be identified as deficiencies and entered into the BN's deficiency tracking system. Poor personnel performance will be addressed in accordance with good management practices and company policy. Sufficient resources will be made available and used to resolve equipment problems. Appropriate administrative actions will be taken for QA/QC problems. Investigations and corrective actions will be documented in the applicable log and/or report. Appropriate data qualifiers will be used for data that are affected by nonconformances.

12.3 CHANGES

All changes to this QAASP; sampling locations; types of biota collected; operational procedures; and data reduction, validation, verification, or reporting procedures which may affect data quality or cost must be approved in writing by the EM Project Manager or higher prior to implementation. The manager approving any change will evaluate the significance of the change with respect to the need for DOE involvement and/or concurrence with the change and request involvement/concurrence as appropriate.

13.0 ASSESSMENTS AND SURVEILLANCE

A scientist selected by Environmental Operations Manager (EOM) will review all portions of the sampling and analysis performed under this QAASP at least annually and document this in a report to the EOM and the Environmental Monitoring Manager (EMM). The EOM and EMM will assure these internal surveillances are adequate and request additional audits and surveillances as needed to address areas of concern. It is anticipated that outside organizations such as BN Performance Assurance and DOE will conduct audits periodically.

14.0 REFERENCES

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Table C-1 Estimated Completion of Key Milestones of Radiological Sampling of NTS Biota

Task	Subtask	Completion Date or Period
Obtain required wildlife collection permits		January 30, 1999
Refine laboratory analytical methods		May 1, 1999
Order field supplies		April 1, 1999
Implement testing of field methods	Test animal capture and plant collection methods	June 1 to July 1, 1999
	Perform test run on control animals and plants	June 1 to July 1, 1999
Confirm appropriateness of candidate sites		May 1 to June 1, 1999
Sample Site No.1 and control site	Establish animal traps and confirm presence of plants and animals	August 1 to October 1, 1999
	Sample plants and animals	August 1 to October 1, 1999
	Analyze tissues	August 1 to October 1, 1999
	Data verification, validation, and reporting	September 1 to November 1, 1999
Sample Site No. 2, and control site	(Same subtasks as with Sample Site No. 1)	(Same monthly dates as Sample Site No. 1, but for 2000)
Sample Site No. 3 - 5 and control sites	(Same subtasks as with Sample Site No. 1)	(Same monthly dates as Sample Site No. 1, but for 2001 to 2003)
Sample Sites No. 1 - 5 and control sites	(Schedule repeats for each site with one site sampled each year)	(Same monthly dates as Sample Site No. 1, but for years 2004 to 2008)
Sample spring site for chukar	Establish bird traps and confirm presence of chukar	Same monthly dates as Sample Site No. 1, sampled each year
Offsite milk sample site and control site	Obtain list of potential sample sites	June 1 to July 31, 1999
	Confirm animals to be sampled are pasture-fed	July 1 to July 31, 1999
	Obtain milk sample from owner	July 1 to July 31, 1999
	Analyze milk	August 1 to October 1, 1999
	Data verification, validation, and reporting	September 1 to November 1, 1999
Complete Final QAASP		December 1, 1999

Table C-2 Location of Radiological Sampling Sites for NTS Biota

Name of Site	Estimated UTM (NAD27)* Coordinates of Contaminated Site (m)		Estimated UTM (NAD27)* Coordinates of Preferred Control Site (m)		Estimated UTM (NAD27)* Coordinates of Alternative Control Site (m)	
	Easting	Northing	Easting	Northing	Easting	Northing
Palanquin	542,084	4,126,486	545,585	4,127,348	546,548	4,123,611
E-Tunnel Ponds	572,002	4,115,791	565,500	4,113,039	577,099	4,117,282
Sedan	584,703	4,115,407	573,052	4,092,544	579,464	4,095,182
T2	579,647	4,105,624	573,052	4,092,544	579,464	4,095,182
Plutonium Valley	592,678	4,092,968	585,493	4,068,571	592,680	4,069,900

*All locations are in UTM Zone 11N.

Table C-3 Elements to be Included in the Field Log

Element	Comment
Project name/ID and location	
Sampling personnel	
Site observations including map	
Atmospheric conditions	
Field measurements	
Sample date, time, and location	
Sample identification present	
Sample descriptions (e.g., species and parts)	
Number of samples taken per location	
Description of any QC samples	
Any deviations from the sampling plan	
Difficulties in sampling or unusual circumstances	

Table C-4 Radiological Monitoring Parameters for Monitoring of NTS Biota

Type of Analysis	Approximate Sample Size	Nominal Count Time	Minimum Detectable Concentration	Nominal Analysis Aliquot Size
Dove/Rabbit/Chukar				
Tritiated water	500 g (muscle)	70 min	1.5 pCi/mL	2.5 mL
Gamma Spectrometry (^{137}Cs)	500 g (muscle)	100 min	0.05 pCi/g	500 g
^{90}Sr	500 g (bone)	100 min	0.05 pCi/g	10 g
^{238}Pu , $^{239+240}\text{Pu}$	500 g (liver)	1,000 min	0.0002 pCi/g	100 g
Native Vegetation				
Tritiated water	100 g (leaves/stems)	70 min	1.5 pCi/mL	2.5 mL
Gamma Spectrometry (^{137}Cs)	100 g (leaves/stems)	100 min	0.25 pCi/g	100 g
^{90}Sr	100 g (leaves/stems)	100 min	0.05 pCi/g	10 g
^{238}Pu , $^{239+240}\text{Pu}$	100 g (leaves/stems)	1,000 min	0.0002 pCi/g	100 g
Cow and/or Goat Milk				
^{90}Sr	3.8 L	100 min	2.0 pCi/L	1 L

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Figure C-1
NTS Onsite Surface Biota
Radiological Monitoring Sites

Biota Sampling Sites
Contaminated Site
Preferred Control Site
Alternative Control Site
Chukar Site (springs)

Nevada Test Site Boundaries
NTS Boundary
Operational Area

Radioactive Waste Management Sites
Area 3 and Area 5 RWMS
Nuclear Tests
Surface and Above Ground
Man Made Isotopes (Preliminary Results from 1994 RSL Aerial Gamma Survey)
>27 microrems/hour
Plutonium Contamination (Approximate Area from McArthur, 1991)
>10 PicoCuries/Gram
Tunnel Portals and Vents
3

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Location Map - NTS Region

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Figure C-2
NTS Offsite Surface Biota
Monitoring Sites

Bechtel Nevada

Western US Location Map

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ATTACHMENT C1

CALCULATIONS FOR COMMITTED EFFECTIVE DOSE EQUIVALENT FROM CONSUMPTION OF WILD GAME

1.0 Converting Environmental Radionuclide Concentrations into Committed Effective Dose Equivalent

This attachment describes a method to convert measured radionuclide concentrations in wild game and vegetation into committed effective dose equivalent (CEDE) received by a critical population. The critical population includes all individuals that consume wild game harvested from the Nevada Test Site (NTS). The CEDE received by the critical population is a stochastic variable, as the CEDE will vary between individual hunters and household members consuming wild game. This represents natural variation in the population referred to as variability. There is also a lack of knowledge or uncertainty in the correct dose received by each individual in the critical population. The method below separates these two sources in variability.

1.1 Estimating the Committed Effective Dose Equivalent from Consumption of Wild Game

The CEDE received by a person consuming wild game is estimated below using a concentration factor method. The method is based on Kennedy and Streng's (1992) method for converting residual contamination into dose through agricultural pathways. The method assumes that radionuclide concentrations in the environment are constant over the year of assessment and that all organisms are in equilibrium with these concentrations. The ^3H models assume that no fractionation of hydrogen isotopes occurs.

The CEDE to a person from the consumption of wild game can be estimated as:

$$H_{WG} = \sum_{j=1}^n \sum_{q=1}^m (C_{WG,j,q} PDCF_{WG,j,q}) \quad (1)$$

where:

H_{WG}	=	CEDE from consumption of wild game, mrem/yr;
$C_{WG,j,q}$	=	measured concentration of radionuclide j in animal q, Ci/kg (wet); and
$PDCF_{WG,j,q}$	=	wild game ingestion pathway dose conversion factor (PDCF) for radionuclide j and animal q, mrem/yr per Ci/kg wet tissue.

The CEDE from a particular radionuclide in a particular species is the product of the edible tissue concentration and a fixed pathway dose conversion factor. Calculation of the PDCFs is described below.

The CEDE to a hunter from the consumption of wild game contaminated through the ingestion of contaminated vegetation can be estimated as:

$$H_{VG} = \sum_{j=1}^n \sum_{p=1}^k \left\{ C_{VG,j,p} \left(\sum_{q=1}^m PDCF_{VG,j,q,p} \right) \right\} \quad (2)$$

where:

- H_{VG} = CEDE from consumption of wild game contaminated by consumption of contaminated vegetation, mrem/yr;
- $C_{VG,j,p}$ = measured concentration of radionuclide j in plant p, Ci/kg (wet); and
- $PDCF_{VG,j,q,p}$ = vegetation-wild game ingestion PDCF for radionuclide j, animal q, and plant p, mrem/yr per Ci/kg wet tissue.

1.1.1 Estimating Pathway Dose Conversion Factors for Wild Game

The game-hunter PDCF is calculated as:

$$PDCF_{WG,j,q} = DFG_j U_{a,q} \quad (3)$$

where:

- $PDCF_{WG,j,q}$ = wild game ingestion PDCF for radionuclide j and animal q, mrem/yr per Ci/kg wet tissue;
- DFG_j = ingestion dose factor (DF) for radionuclide j, mrem/Ci; and
- $U_{a,q}$ = annual consumption rate of animal q, kg (wet)/yr.

The game-hunter ingestion pathway DF is calculated as the product of the ingestion DF and the annual consumption rate. The PDCF for ^3H can be estimated using Equation 3 above.

The vegetation-game-hunter PDCF is calculated as:

$$PDCF_{VG,j,q,p} = DFG_j U_{a,q} F_{a,j,q} Q_{q,p} x_{q,p} \quad (4)$$

where:

$PDCF_{VG,j,q,p}$	=	vegetation-wild game PDCF for radionuclide j, animal q, and plant p, mrem/yr per Ci/kg (wet) plant;
DFG_j	=	ingestion DF for radionuclide j, mrem/Ci;
$U_{a,q}$	=	annual consumption rate of animal q, kg (wet)/yr;
$F_{a,j,q}$	=	food-to-animal transfer factor for radionuclide j and animal q, d/kg (wet);
$Q_{q,p}$	=	animal q consumption rate of plant p, kg (wet)/d; and
$x_{q,p}$	=	fraction of plant p intake by animal q that is contaminated, dimensionless.

The vegetation-game-hunter pathway DF is calculated as the product of the ingestion DF, the annual consumption rate, and the fractional transfer of plant contamination to animal tissue.

The vegetation-game-hunter pathway DF for ^3H is calculated using a specific activity model as:

$$PDCF_{VG,H3,q,p} = DFG_{H3} U_{a,q} f_{H,q} SA_{TaH} \times \frac{Q_{q,p} x_{q,p} t_{f,p}}{f_{H,p} Q_{q,p} t_{f,p} + Q_{w,q}/9} \quad (5)$$

where:

$PDCF_{VG,H3,q,p}$	=	vegetation-game-hunter PDCF for ^3H and animal q, mrem/yr per Ci/kg (wet) vegetation;
DFG_{H3}	=	ingestion DF for ^3H , mrem/Ci;
$U_{a,q}$	=	annual consumption rate of animal q, kg (wet)/yr;
$f_{H,q}$	=	mass fraction of H in animal q, kg H/kg (wet) tissue;
SA_{TaH}	=	specific activity equivalence, Ci/kg H in animal per Ci/kg H in vegetation (assumed to be 1.0);
$Q_{q,p}$	=	animal q consumption rate of plant p, kg (wet)/d;
$x_{q,p}$	=	fraction of animal q intake of plant p that is contaminated, dimensionless;
$t_{f,p}$	=	time per year animal consumes plant p, d;
$f_{H,p}$	=	mass fraction of H in plant P, kg H/kg (wet plant);
$Q_{w,q}$	=	water consumption rate of animal q, l/d; and
9	=	kg H_2O /kg H.

The vegetation-game-hunter PDCF for ^3H is calculated as the product of the ingestion DF, annual rate of intake, and the fraction of tissue hydrogen that is derived from contaminated plants.

The annual consumption rate of game is not commonly available. Therefore, the consumption rate was calculated as:

$$U_{a,q} = \frac{H_{a,q} M_{a,q}}{S} \quad (6)$$

where:

- $H_{a,q}$ = annual harvest per hunter of animal q, animal/(hunter yr);
- $M_{a,q}$ = mass of edible tissue per animal q, g/animal; and
- S = family size, individuals/hunters.

The numerator in Equation 6 represents the total annual mass of edible tissue harvested by a hunter. This is then divided by the number of individuals in the household.

1.1.2 Calculation of Required Minimum Detectable Concentrations and Sample Sizes

The minimum detectable concentrations and sample sizes required for field sampling programs can be estimated from the PDCF. The minimum detectable concentration required to detect a given CEDE can be estimated as:

$$MDC_{i,j,q} = \frac{H_L}{PDCF_{i,j,q}} \quad (7)$$

where:

- $MDC_{i,j,q}$ = minimum detectable concentration for radionuclide j in animal q and pathway I, Ci/kg wet tissue; and
- H_L = annual dose limit (or monitoring action level), mrem/yr.

Sample size can be estimated by dividing the minimum detectable concentration from Equation 7 into the minimum detectable activity reported by the laboratory.

1.1.3 Model Implementation

The model was implemented with an Excel[®] spreadsheet. Uncertainty and variability were propagated numerically by performing a Monte Carlo analysis. Uncertainty and variability within the critical population were separated by performing a two-stage Monte Carlo analysis (NCRP, 1996). Fifty sets of alternative parameter distributions were generated stochastically to represent parameter uncertainty. For each alternative set of parameter distributions, 100 Monte Carlo simulations were performed to estimate variability within the population.

2.0 Parameter Selection

Parameter values have been selected for three game species: mourning dove, black-tailed jack rabbit, and mule deer. The parameter values selected and the rational of their selection are described in Table C1-1. These parameter values should be considered preliminary. Each parameter, except the dose conversion factor (DCF), the fraction of vegetation consumed by animals that is contaminated, and the fraction of time in a year that an animal consumes contaminated vegetation, were assumed to be stochastic variables with uncertainty. Because the parameters exhibit natural variability, each is described by a statistical distribution. The descriptive properties (distribution shape, mean, standard deviation, etc.) of the distribution are uncertain. This uncertainty is expressed by assigning statistical distributions to the descriptive properties of the parameter. The three parameters excluded above are assumed to have zero variability and zero uncertainty. These parameters are likely to exhibit significant uncertainty and variability. Uncertainty and variability in the DCF is unknown but expected to be large. The fixed values used are those reported by Eckerman *et al.* (1988). Assuming a fixed DCF implies that the results are applicable to a population of persons all having the assumed characteristics of reference man (ICRP, 1974). Assuming all vegetation is contaminated restricts the critical group further, implying that the critical group only hunts game feeding on contaminated vegetation from the NTS. A critical group consisting of reference men who only hunt animals that feed in contaminated areas on the NTS does not exist. It is, however, a conservative critical group that should tend to overestimate the doses to real individuals that may harvest game from the NTS.

3.0 Estimated Values of the Pathway Dose Conversion Factors

Preliminary estimates of the PDCFs have been made using the method and parameters described. The range of intrapopulation variability was found to be greater than the range of uncertainty. Intrapopulation variability occurs because individual hunters will harvest different numbers of animals with different masses and share their harvest with different household sizes. In Figure C1-1, the cumulative probability represents natural variability within the critical population. A major source of variability is the number of game animals harvested per year by a hunter. For mourning doves and rabbits, this number ranges from zero to more than 50. At any given cumulative probability, the variability observed between the different plotted lines represents the uncertainty in the PDCF. The uncertainty in the ³H PDCF for the mourning dove-hunter pathway spans approximately one order of magnitude at the 50th percentile level (Figure C1-1). The distribution of the PDCF at a fixed percentile is

approximately lognormal. Table C1-2 gives summary statistics for the PDCF for the game-hunter pathway for each radionuclide at the 50th and 95th percentile level. Figure C1-2 gives the ^3H detection limit for mourning doves estimated from the minimum, maximum and mean PDCF.

The variability and uncertainty of the PDCFs for rabbits are similar to the results for mourning doves (Figures C1-3 and C1-4). Hunters harvest greater masses of rabbit meat and the PDCF is, therefore, larger and the required detection limit lower.

The estimated variability in the ^3H PDCF for mule deer is extremely large because a significant fraction of the critical population is expected to be unsuccessful during any given deer hunt (Figure C1-5). The PDCF for unsuccessful hunters is zero. The PDCF for successful hunters is large because these individuals may consume large amounts of deer meat. The distributions and summary statistics in Table C1-2 for deer are for the non-zero values of the PDCF. Figure C1-6 shows the minimum, maximum and mean detection limits for deer meat.

The PDCFs for the vegetation-game-hunter pathway generally exhibit the same range of variability as those for the game-hunter pathway (see Table C1-3). The uncertainty in the vegetation-game-hunter pathway is much larger, however, spanning more than two orders of magnitude (Figure C1-7). The greater uncertainty is caused by the introduction of the vegetation-meat transfer factors in this pathway. Figure C1-8 shows the ^3H detection limit for mourning doves for the vegetation-game-hunter pathway. Monitoring vegetation is a less sensitive method of detecting radiation doses to man and consequently the required detection limits are higher. Results for ^{90}Sr and ^{137}Cs are similar as observed for ^3H (Figures C1-9 through C1-12). The uncertainty in the $^{239+240}\text{Pu}$ PDCFs are greater because of the greater uncertainty in the Pu vegetation-meat transfer factor (Figures C1-13 and C1-14).

The critical pathway is the pathway that can cause the greatest dose in a receptor per unit of activity released. Among the pathways and radionuclides considered, the mule deer-hunter pathway for ^{90}Sr appears to be the critical pathway. Other sensitive pathways would include the mule deer-hunter pathways for ^{137}Cs and $^{239+240}\text{Pu}$ and the rabbit-hunter pathway for ^{90}Sr . Mule deer appear to be the most useful animal to monitor followed by rabbits and mourning doves. This follows the mass of tissue of each animal consumed by hunters. Vegetation may be a useful surrogate media for monitoring ^{90}Sr and ^{137}Cs in the mule deer-hunter pathway. However, doses estimated from vegetation monitoring data will be at least ten times as uncertain as those estimated from animal tissue samples.

3.1 Estimated Minimum Detectable Concentrations and Sample Sizes

Required detection limits have been estimated for a dose limit of 1 mrem/yr (Table C1-4). The detection limits use the mean PDCF at the 50th percentile level. The minimum detectable activities reported by the laboratory are approximately 3 pCi for ^3H by liquid scintillation, 0.7 pCi for ^{90}Sr by radiochemistry, 90 pCi for ^{137}Cs by a 20 minute gamma analysis, and 0.02 pCi for $^{239+240}\text{Pu}$ by radiochemistry. Using these minimum detectable activities, the required sample sizes are less than 1 g for all analyses except ^{137}Cs by gamma analysis. This suggests that sample sizes should be set by practical limits on the size of sample that the laboratory can reliably manipulate without raising concerns about reproducibility or contamination. For

example, as sample sizes become extremely small, precision in sample aliquot size and sample recovery will decrease and the potential for contamination or dilution will increase. These concerns are likely to limit the minimum sample size, except for gamma analyses. A sample size of 50 g appears adequate to achieve the required ^{137}Cs MDC by gamma analysis. A larger sample size (500 g) may be desirable to match existing laboratory geometries. A sample size of 10 g is probably sufficient for all other analyses.

3.2 Sensitivity of the Pathway Dose Conversion Factors

The sensitivity of the PDCFs to the input variables has been investigated by calculating the correlation coefficient of the rank data or Spearman rank correlation coefficient (Zar, 1974). The mourning dove and rabbit PDCF for the game-hunter pathways are strongly sensitive ($r > 0.8$) to the number of animals harvested per hunter-yr. The mule deer PDCFs for the game-hunter pathways are strongly sensitive to the probability of a successful hunt and the household size.

The ^3H PDCF for the vegetation-game-hunter pathways are not strongly sensitive to any single parameter, but are moderately sensitive to several parameters. The ^3H PDCFs for doves are moderately sensitive to the dove feed consumption rate and the mass fraction of H in animal tissue. The ^3H rabbit PDCFs are moderately sensitive to the mass fraction of tissue that is hydrogen. The ^3H mule deer PDCFs are moderately sensitive to edible mass of tissue per deer and the mass fraction of tissue that is hydrogen. The ^{90}Sr , ^{137}Cs , and $^{239+240}\text{Pu}$ PDCFs for the vegetation-game-hunter pathways are strongly sensitive to the vegetation-animal transfer fraction.

Three parameters in the analysis were held constant: the DCF, the fraction of vegetation consumed that is contaminated, and the fraction of time that game consume contaminated vegetation. The sensitivity of model results to these parameters remains unknown, but is suspected to be large.

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Table C1-1 Stochastic Variables and Distributions

Parameter	Distribution	Selection Rational
Dove Harvest, $H_{a,d}$	Lognormal	The dove harvest was assumed to be lognormally distributed because the distribution of doves per hunter is observed to have a long tail and large standard deviation. The uncertainty in the mean doves per hunter was estimated from mean harvests reported for the State of Nevada for the years 1951 through 1994 (Stiver, 1995). The annual mean harvest per hunter was found to be normally distributed (Kolmogorov-Smirnov $p = 0.25$, $n=40$) with mean 12.4 and standard deviation 2.78. The uncertainty in the standard deviation of the doves harvested per hunter was estimated from State of Nevada frequency data for harvest by individual hunters for the years 1991 through 1994 (Stiver, 1991; 1992; 1993; 1994). The mean standard deviation was estimated to be 22.0 and the standard deviation was 1.59. The uncertainty in the standard deviation was assumed to be normally distributed.
Rabbit Harvest, $H_{a,r}$	Lognormal	The rabbit harvest was assumed to be lognormally distributed because the distribution of rabbits per hunter is observed to have a long tail and a large standard deviation. The uncertainty in the mean rabbit harvest was estimated from mean harvests reported for the State of Nevada for the years 1951 through 1994 (Stiver, 1995). The annual mean harvest per hunter was found to be lognormally distributed (Kolmogorov-Smirnov $p = 0.55$, $n=40$) with mean 6.23 and standard deviation 1.63. The uncertainty in the standard deviation of the rabbits harvested per hunter was estimated from State of Nevada frequency data for harvest by individual hunters for the years 1991 through 1994 (Stiver, 1991; 1992; 1993; 1994). The mean standard deviation was estimated to be 14.5 and the standard deviation was 3.03. The uncertainty in the standard deviation was assumed to be normally distributed.
Mule Deer Harvest/Hunter, $H_{a,dr}$	Binomial	Mule Deer hunters are assumed to participate in one hunt per year with a tag limit of one deer. The distribution was assumed to be a binomial distribution with a single trial. The uncertainty in probability of success was estimated from State of Nevada data for districts adjacent to the NTS (161-164, 171-173, 231, 241-245, 251-253, 261-268, 271-272) for the years 1991 through 1994 (Hess, 1992; 1993; 1994; 1995). The probability of success was assumed to be triangularly distributed (Kolmogorov-Smirnov $p = 0.72$, $n=10$) with mode 0.34 and range 0 to 0.87.

Table C1-1 (continued)

Parameter	Distribution	Selection Rational
Mass of Edible Tissue per Dove, M_d	Normal	The mass of edible tissue was assumed to be normally distributed. The data were estimated by M. Cox of the Nevada Division of Wildlife. The mean edible mass of tissue for a dove was assumed to be triangularly distributed with a minimum, mode, and maximum of 20, 40 and 80 g. The standard deviation was assumed to be triangularly distributed with a minimum, mode, and maximum of 5, 10 and 20 g. This corresponds to a coefficient of variation of 5, 25 and 50 percent of the mode. The mean and standard deviation were assumed to be correlated with a correlation coefficient of 0.8.
Mass of Edible Tissue per Rabbit, M_r	Normal	The mass of edible tissue was assumed to be normally distributed. The data were estimated by M. Cox of the Nevada Division of Wildlife. The mean edible mass of tissue for a rabbit was assumed to be triangularly distributed with a minimum, mode, and maximum of 250, 500 and 750 g. The standard deviation was assumed to be triangularly distributed with a minimum, mode, and maximum of 50, 100 and 250 g. This corresponds to a coefficient of variation of 10, 20 and 50 percent of the mode. The mean and standard deviation were assumed to be correlated with a correlation coefficient of 0.8.
Mass of Edible Tissue per Deer, M_{dr}	Normal	The mass of edible tissue was assumed to be normally distributed. The data were estimated by M. Cox of the Nevada Division of Wildlife. The mean edible mass of tissue for a mule deer was assumed to be triangularly distributed with a minimum, mode, and maximum of 20, 32 and 50 kg. The standard deviation was assumed to be triangularly distributed with a minimum, mode, and maximum of 2, 7 and 14 g. This corresponds to a coefficient of variation of 5, 20 and 30 percent of the mode. The mean and standard deviation were assumed to be correlated with a correlation coefficient of 0.8.

Table C1-1 (continued)

Parameter	Distribution	Selection Rational
Family Size, S	Lognormal	The size of the group consuming a hunter's wild game was assumed to be equal to a typical household unit. The distribution was assumed to be lognormally distributed based on the distribution of household sizes reported in the 1990 census for Nevada (DOC, 1990). No data was identified that could be used to estimate the uncertainty in the mean and standard deviation of household size. The uncertainty in mean household size was assumed to be triangularly distributed with a mode equal to the 1990 Nevada mean of 2.5. A reasonable lower and upper limit for the mean household size was set at 1.5 and 3.5. The uncertainty in the standard deviation of household size was assumed to be triangularly distributed with a mode equal to the current standard deviation of 1.52. A reasonable lower and upper limit for the standard deviation was assumed to be 0.5 and 2.5. The mean and standard deviation were assumed to be correlated with a correlation coefficient of 0.8.
Sr Transfer Factor, $F_{a, Sr, M}$	Lognormal	The transfer factors are assumed to be lognormally distributed. Although data is limited, most reports describe this parameter as lognormally distributed (NCRP, 1984). Uncertainty in the mean and standard deviation is significant as no site specific or species specific data are available. Transfer factors were estimated for mammals and birds using data published for beef cattle and poultry, respectively. These factors typically vary over two orders of magnitude for a specific animal. To account for uncertainty caused by inter-species differences, the range of the mean was assumed to extend one order of magnitude higher and lower than the mean reported for beef cattle and poultry. The range of the mean values for beef cattle was taken from the compilation of Wang et al. (1993). The range of the mean values for poultry were estimated from the single values reported by Kennedy and Streng (1992). The bird transfer factor was assumed to range two orders of magnitude above and below the single available value. The mean Sr transfer factor for mammals was assumed to be loguniformly distributed between 3e-5 and 1e-1 d/kg. The mean Sr transfer factor for birds was assumed to be loguniformly distributed between 4e-4 and 3e1 d/kg. The geometric standard deviation of both parameters was assumed to vary uniformly between 1.3 and 3.8 based on the reported range for beef cattle (NCRP, 1984).
Cs Transfer Factor, $F_{a, Cs, M}$	Lognormal	The Cs transfer factors were estimated as described above for Sr. The mean Cs transfer factor for mammals was assumed to be loguniformly distributed between 2e-4 and 5e-1 d/kg. The mean Cs transfer factor for birds was assumed to be loguniformly distributed between 4e-2 and 4e2 d/kg. The geometric standard deviation of both parameters was assumed to vary uniformly between 1.3 and 3.8 based on the reported range for beef cattle (NCRP, 1984).

Table C1-1 (continued)

Parameter	Distribution	Selection Rational
Pu Transfer Factor, $F_{a,pu, M}$	Lognormal	The Pu transfer factors were estimated as described above for Sr. The mean Pu transfer factor for mammals was assumed to be loguniformly distributed between 5e-8 and 1e-3 d/kg. The mean Pu transfer factor for birds was assumed to be loguniformly distributed between 1e-6 and 1e-2 d/kg. The geometric standard deviation of both parameters was assumed to vary uniformly between 1.3 and 3.8 based on the reported range for beef cattle (NCRP, 1984).
Dove Plant Consumption Rate, $Q_{d, g}$	Normal	Dove feeding rate data were not found. Dove feeding rate was scaled from rabbit feeding rates based on body masses. The mean dove feeding rate was assumed to vary uniformly between 0.01 and 0.05 kg/d. The standard deviation was assumed to vary uniformly from 0.001 to 0.01. This corresponds to a coefficient of variation of approximately 5 to 25 percent of the central value.
Rabbit Plant Consumption Rate, $Q_{r, f}$	Normal	The feeding rates of rabbits were estimated from data reported for jack rabbits (Currie and Goodwin, 1966; Shoemaker et al., 1974). The mean rabbit feeding rate was assumed to be triangularly distributed with a minimum, mode and maximum of 0.1, 0.165, and 0.25 kg/d. The standard deviation was assumed to vary uniformly from 0.01 to 0.05. This corresponds to a coefficient of variation of approximately 5 to 25 percent of the central value.
Deer Plant Consumption Rate, $Q_{dr, f}$	Normal	Deer feeding rate data were not found. The deer feeding rate was scaled from beef cattle feeding rates based on body masses. The mean deer feeding rate was assumed to vary uniformly between 2 and 12 kg/d. The standard deviation was assumed to vary uniformly from 0.6 to 2. This corresponds to a coefficient of variation of approximately 10 to 25 percent of the central value.
Dove Water Consumption Rate, $Q_{w, d}$	Normal	Dove water consumption rates were not found. The water consumption rate was based on data for poultry. The dove water consumption rate was assumed to be triangularly distributed with a minimum, mode and maximum of 0.01, 0.15, and 0.33 l/d. This is based on a 0.33 l/d consumption rate for poultry and the larger body size of poultry (Kennedy and Strenge, 1992). The standard deviation was assumed to be uniformly distributed between 0.01 and 0.05 which represents a coefficient of variation ranging from 10 to 30 percent.

Table C1-1 (continued)

Parameter	Distribution	Selection Rational
Rabbit Water Consumption Rate, $Q_{w,r}$	Normal	Rabbit consumption rates of liquid water were not found. Rabbits can use fodder to derive a significant fraction of their water requirements. It was assumed that rabbits consume 0 to 5 percent of their water intake as liquid water. Total water intake was estimated to be 0.3 l/d for a 2 kg rabbit (Shoemaker et al., 1974). Therefore the mean water consumption rate for rabbits was assumed to vary uniformly from 0 to 0.03 l/d. The standard deviation was assumed to vary uniformly between 0 and 0.02 l/d.
Deer Water Consumption Rate, $Q_{w,d}$	Normal	Mule Deer water consumption rates were not found. Deer water consumption rates were estimated from beef cattle. The mean water consumption rate was assumed to be triangularly distributed with a minimum, mode, and maximum of 2, 10, and 20 l/d. The standard deviation was assumed to be uniformly distributed between 0.1 and 3. This corresponds to a coefficient of variation of approximately 10 to 30 percent of the central value.
Mass Fraction of Animal Tissue as H, $f_{H,q}$	Normal	The mean mass fraction of animal tissue that is H was assumed to be triangularly distributed with a minimum, mode, and maximum of 0.06, 0.1, and 0.12. This is based on an expected value of 0.1 for animals and the range reported for biological materials (Kennedy and Strenge, 1992). The standard deviation was assumed to vary uniformly from 0 to 0.02.
Mass Fraction of Forage as H, $f_{H,f}$	Normal	The mean of the mass fraction of forage that is hydrogen was assumed to vary uniformly between 0.05 and 0.15. This was selected to bound a reported mean of 0.1 for forage (Kennedy and Strenge, 1992). The standard deviation was assumed to vary uniformly from 0 to 0.02. Mule deer and rabbits were assumed to consume forage.
Mass Fraction of Grain as H, $f_{H,g}$	Normal	The mean of the mass fraction of grain as hydrogen was assumed to vary uniformly between 0.1 and 0.15. This was selected to bound a reported mean of 0.07 for grain (Kennedy and Strenge, 1992). The standard deviation was assumed to vary uniformly from 0 to 0.02. Mourning doves were assumed to consume only grain.

Table C1-2 The Distribution, Mean, and Standard Deviation of the Pathway Dose Conversion Factors for the Game-Hunter Pathway for a Critical Population Consuming Wild Game

Nuclide	Species	Pathway Dose Conversion Factor (mrem/yr per pCi/g wet tissue)				
		Distribution	50th Percentile		95th Percentile	
			Mean	Standard Deviation	Mean	Standard Deviation
³ H	Mourning Dove	lognormal	7.25e-6	3.72e-6	5.92e-6	2.70e-5
	Rabbits	lognormal	3.44e-5	1.80e-3	3.98e-4	2.14e-4
	Mule Deer	lognormal	6.20e-4	3.28e-4	1.77e-3	5.97e-4
⁹⁰ Sr	Mourning Dove	lognormal	1.81e-2	1.07e-2	1.50e-01	8.23e-2
	Rabbits	lognormal	8.76e-2	4.93e-2	8.50e-1	4.00e-1
	Mule Deer	lognormal	1.52e0	8.19e-1	4.45e0	2.08e0
¹³⁷ Cs	Mourning Dove	lognormal	6.08e-3	3.73e-3	4.81e-2	2.22e-2
	Rabbits	lognormal	2.82e-2	1.60e-2	2.87e-1	1.61e-1
	Mule Deer	lognormal	4.97e-1	3.26e-1	1.47e0	6.43e-1
²³⁹⁺²⁴⁰ Pu	Mourning Dove	lognormal	6.20e-3	4.09e-3	5.21e-2	3.25e-2
	Rabbits	lognormal	2.96e-2	1.73e-2	3.47e-1	2.40e-1
	Mule Deer	lognormal	4.74e-1	2.36e-1	1.51e0	5.41e-1

Table C1-3 The Distribution, Mean, and Standard Deviation of the Pathway Dose Conversion Factors for the Vegetation-Game-Hunter Pathway for a Critical Population Consuming Wild Game

Nuclide	Species	Pathway Dose Conversion Factor (mrem/yr per pCi/g wet vegetation)				
		Distribution	50th Percentile		95th Percentile	
			Mean	Standard Deviation	Mean	Standard Deviation
³ H	Mourning Dove	lognormal	1.00e-6	9.07e-7	8.98e-6	6.87e-6
	Rabbits	lognormal	3.18e-5	2.68e-5	3.70e-4	2.61e-4
	Mule Deer	lognormal	2.23e-4	1.84e-4	7.95e-4	6.56e-4
⁹⁰ Sr	Mourning Dove	lognormal	2.06e-4	5.16e-4	2.99e-3	7.28e-3
	Rabbits	lognormal	1.73e-3	2.97e-3	3.40e-2	5.88e-2
	Mule Deer	lognormal	8.70e-1	3.59e0	6387e0	1.37e1
¹³⁷ Cs	Mourning Dove	lognormal	5.13e-4	8.80e-4	9.12e-3	1.69e-2
	Rabbits	lognormal	1.05e-3	1.74e-3	1.79e-2	2.76e-2
	Mule Deer	lognormal	3.85e-1	6.72e-1	5.38e0	1.41e1
²³⁹⁺²⁴⁰ Pu	Mourning Dove	lognormal	9.29e-6	2.49e-5	1.59e-4	4.52e-4
	Rabbits	lognormal	8.13e-5	2.59e-4	1.61e-3	5.25e-3
	Mule Deer	lognormal	4.53e-2	1.41e-1	3.49e-1	1.34e0

Table C1-4 Minimum Detectable Concentrations Required to Detect a CEDE of 1 mrem/yr to the 50th Percentile Member of a Critical Group Consuming Wild Game from the Nevada Test Site

Nuclide	Species	Detection Limit (pCi/g wet mass)	
		Game	Vegetation
³ H	Mourning Dove	1e5	1e6
	Rabbits	3e4	3e4
	Mule Deer	2e3	4e3
⁹⁰ Sr	Mourning Dove	5e1	5e3
	Rabbits	1e1	6e2
	Mule Deer	7e-1	1e0
¹³⁷ Cs	Mourning Dove	2e2	2e3
	Rabbits	3e1	1e3
	Mule Deer	2e0	3e0
²³⁹⁺²⁴⁰ Pu	Mourning Dove	2e2	1e5
	Rabbits	3e1	1e4
	Mule Deer	2e0	2e1

Figure C1-1 Uncertainty in the H-3 PDCF for the Game-Hunter Pathway for a Critical Population Consuming Dove Meat from the NTS

Figure C1-2 Uncertainty in the H-3 Detection Limit Required to Detect a CEDE of 1 mrem/yr for the 50th Percentile Member of a Critical Population Consuming Mourning Dove Meat from the NTS

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Figure C1-6 Uncertainty in the H-3 Detection Limit Required to Detect a CEDE of 1 mrem/yr for the 50th Percentile in a Critical Population Consuming Mule Deer Meat from the NTS. Minimum mean and maximum data were calculated for non-zero data only.

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Figure C1-14 Uncertainty in the $^{239+240}\text{Pu}$ Detection Limit Required to Detect a CEDE of 1 mrem/yr for the 50th Percentile Member of a Critical Group Consuming Rabbit Meat from the NTS

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APPENDIX D

QUALITY ASSURANCE, ANALYSIS, AND SAMPLING PLAN FOR DIRECT RADIATION MONITORING

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ACRONYMS and ABBREVIATIONS

ANSI	American National Standards Institute
BN	Bechtel Nevada
CV	Coefficient of Variation
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DQO	Data Quality Objective
ECF	Element Correction Factor
EM	Environmental Monitoring
HP	Health Physicist
HPD	Health Physics Department
NIST	National Institute for Standards and Technology
NTS	Nevada Test Site
PIC	Pressurized Ion Chamber
QC	Quality Control
RCT	Radiological Control Technician
RREMP	Routine Radiological Environmental Monitoring Program
STNG	Sealed-Tube Neutron Generator
TEND	Track-Etch Neutron Dosimeter
TLD	Thermoluminescent Dosimeter

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

People and the environment are constantly exposed to radiation from terrestrial, cosmic, and internal sources. On and near the Nevada Test Site (NTS), people and the environment may be exposed to radiation in addition to the naturally occurring radiation as a result of soil contamination from past weapons testing and the current use of radiation sources and radiation-generating devices. Monitoring is performed to measure the naturally occurring background radiation and to measure radiation from man-made sources. This Quality Assurance, Analysis, and Sampling Plan is for the monitoring of direct radiation from X rays and gamma rays with energies above approximately 60 keV and neutron radiation produced by neutron generating devices such as sealed-tube neutron generators in facilities operated by Bechtel Nevada (BN) for the U.S. Department of Energy/Nevada Operations Office (DOE/NV). Neutron radiation is monitored with track-etch foils, while X rays and gamma rays are monitored by use of thermoluminescent dosimeters (TLDs).

1.2 SAMPLING OBJECTIVES

The purpose for monitoring the direct radiation is to comply with regulatory requirements as described in Chapter 3 of the Routine Radiological Environmental Monitoring Plan (RREMP) and to provide data that can be used in conjunction with the “flyover” data. Direct radiation measurements from TLDs represent continuous monitoring of the radiation levels at the TLD stations (Figure D-1), while flyover data and demarcation study data are collected during a very short time period. Using data from these three sources will contribute to the information needed to make decisions regarding the use of the NTS.

1.3 MEDIA TYPES

Direct radiation can pass through or emanate from any type of media. However, the measurement of direct radiation in the environment is logical only for radiation passing through air.

2.0 PROGRAM ORGANIZATION AND RESPONSIBILITIES

This program is organized into three projects, as described above. The two projects managed by BN are outlined in the following subsections.

2.1 NTS MONITORING

NTS direct radiation monitoring in the environment is managed by Environmental Monitoring (EM) personnel. EM personnel are responsible for project technical direction, records, obtaining annealed TLDs from the Dosimetry Laboratory of the Health Physics Department (HPD), placing them at the designated locations, picking up the exposed TLDs, and returning them to HPD for processing. HPD is responsible for providing EM with the TLD readings, operation and maintenance of the TLD system, and ensuring the TLD system calibration and

performance meet DOE and American National Standards Institute (ANSI) requirements. The TLD system used includes the Panasonic model UD-814 TLD and UD-710 automated TLD reader. Each TLD has one element that can measure low energy radiation, beta particles, and X rays; and three elements for measuring gamma ray exposures. The element for measuring low-energy radiation is not calibrated or used for environmental monitoring on the NTS. The TLDs are deployed for four purposes: environmental monitoring, background monitoring, radioactive waste management site monitoring, and at historical TLD stations to monitor TLD system quality assurance.

2.2 MONITORING AT OTHER BN-MANAGED SITES

This project is conducted by BN HPD. Thermoluminescent dosimeters are placed at fence lines or boundaries of occupied areas to assess the magnitude of X- or gamma ray exposures at areas accessible to the public. Radiological Control Technicians (RCTs) or Health Physicists (HPs) periodically visit the facilities at the North Las Vegas Facility, Remote Sensing Laboratory, Special Technologies Laboratory, and Washington Aerial Measurements Operations to assess possible radiation exposures and to exchange TLDs used to measure quarterly exposures at specified locations. The EM mails freshly annealed and calibrated TLDs to the facilities.

Responsibilities

- **HPD Supervisor** – assesses exposure possibilities; coordinates TLD needs with EM; schedules visits; analyzes data reports from EM for acceptability; prepares reports.
- **HPD Health Physicists** – facilitates exchange of TLDs; performs field surveys as needed, returns properly labeled TLDs to EM.
- **Dosimetry Laboratory Supervisor** – provides annealed, calibrated TLDs; supervises readout; and provides readout results to EM.
- **Field Monitoring Supervisor** – obtains TLDs from Dosimetry Laboratory; issues and receives TLDs; submits TLDs for processing; verifies and accepts data from Dosimetry Laboratory; reports results to HPD HP Supervisor.

3.0 DEFINITIONS

Anneal – thermal treatment of a phosphor, either prior to exposure to erase the effects of previous exposure, or prior to readout to reduce low-temperature TL response.

Control dosimeter – a TLD used to measure exposures extraneous to the site; e.g., during transport or storage.

Error – the difference between a measured and a standard, or true, value.

Exposure – the special unit of exposure is the roentgen (R). $1\text{R} = 2.58 \times 10^{-4}$ coulombs/kg (exactly).

Freshly annealed – TLDs annealed within the past four days.

Neutron dosimeter – a dosimeter that measures neutron radiation.

Thermoluminescent dosimeter (TLD) – a dosimeter that measures X- and gamma rays with energies above about 60 keV..

TLD calibration – establishing the relationship between TL response and exposure in roentgens, and all procedures associated therewith.

Track-etch – a method of making visible the tracks produced in hydrogenous material by the n:p reaction when exposed to neutrons.

4.0 DATA QUALITY OBJECTIVES (DQO) SUMMARY

Data Quality Objectives are commonly described in terms of representativeness, comparability, completeness, precision, and accuracy. Although the assessment of the first two characteristics must be essentially qualitative, definite numerical goals may be set and quantitative assessments performed for the latter three.

4.1 REPRESENTATIVENESS

Representativeness is the degree to which a sample is truly representative of the sampled medium; i.e., the degree to which the measured radiation levels represent the ambient radiation levels in the area where the TLDs were exposed (Stanley and Verner, 1985). Representativeness also refers to whether the locations and frequency of sampling are such that calculational models will lead to a correct estimate of potential EDE to a member of the public when measured exposures are put into the model.

4.2 COMPARABILITY

Comparability refers to the degree of confidence and consistency in analytical results, or defined as “the confidence with which one data set can be compared to another” (Stanley and Verner, 1985). To achieve comparability in measurement data, TLD collection and transport, dosimetry processing, and data analysis and validation are performed in accordance with established Work Instructions. Standard reporting units and a consistent number of significant digits are used. Instruments are calibrated using National Institute of Standards and Technologies (NIST)-traceable sources and TLDs of known quality. Each batch of ≤ 25 TLDs is accompanied by at least one TLD with a known exposure. Extensive QA measures are used for all dosimetric processes.

4.3 COMPLETENESS

Completeness is defined as the percentage of samples collected versus those which had been scheduled to be collected, or the percentage of valid analysis results versus the results which would have been obtained if all samples had been obtained and correctly analyzed. Realistically, samples can be lost during shipping, handling, preparation, and analysis, or not collected as scheduled. Also, data entry or transcription errors can be made. The completeness goals for the TLD network are ≥ 50 percent for a station and ≥ 90 percent for the network.

4.4 PRECISION

Precision refers to “the degree of mutual agreement characteristic of independent measurements as the result of repeated application of the process under specified conditions” (Taylor, 1987). Practically, precision is determined by comparing the results obtained from performing the same analysis on split samples, or on duplicate samples taken at the same time from the same location, maintaining sampling and analytical conditions as nearly identical as possible. For TLDs, precision is assessed from variations in the three CaSO_4 elements of each TLD. Precision is expressed quantitatively as the percent relative standard deviation (%RSD); i.e., the ratio of the standard deviation of the measurements being compared to their mean converted to percent. The smaller the value of the %RSD, the greater is the precision of the measurement. The precision objective is 10 percent at environmental levels.

4.5 ACCURACY

Accuracy refers to how well the true value of a given quantity can be measured and can be defined as “the degree of agreement of a measured value with the true or expected value of the quantity of concern” (Taylor, 1987). For practical purposes, assessments of accuracy for the Dosimetry Laboratory are done on special quality assurance samples prepared by using a gamma-ray calibration range. The accuracy of these measurements, which is assumed to extend to other similar measurements performed by the laboratory, may be defined as the ratio of the measured value divided by the true value, expressed as a percent. Percent bias is the complement of percent accuracy; i.e., $\% \text{Bias} = 100 - \% \text{ accuracy}$. The smaller the percent bias, the more accurate are the measurements. The accuracy objective for the TLD network is 10 percent for exposures ≥ 10 mR/quarter.

The accuracy of the TLD system is determined by two methods. One method is by using Pressurized Ion Chambers (PICs) (with calibration traceable to NIST) stationed continuously at background TLD station(s). The results from the two systems are compared. Unless there is evidence to indicate the accuracy of the PIC readings do not meet the accuracy objectives above, the PIC readings are considered the standard against which the TLD readings are compared. Because of differences in calibration and response of the two types of detectors to the gamma ray energy spectrum, TLD results and PIC results will typically be different. However, the results should be within 20 percent of each other and the bias between two results should be consistent. If there is a statistically significant change in the bias, the cause is to be determined and corrective actions taken.

The other method used to determine TLD system accuracy is by participation in the International Intercomparison Tests of Environmental Dosimeters. This intercomparison is performed once every two to three years and involves a three-part, single-blind performance testing program. The objective for the NTS dosimetry system is to obtain results within 15 percent of the reported correct value. (A larger error margin is allowed for the intercomparison tests than the accuracy objectives stated above due to the error introduced as a result of shipping to and from the intercomparison site and the use of control TLDs to estimate the non-field exposure.)

4.6 DATA REVIEW

Once the data have been finalized, they are compared to the DQOs. Completeness, accuracy, and precision statistics are calculated. If data fail to meet one or more of the established DQOs, they may still be used in data analysis; however, the data and any interpretive results must be qualified. Current and historical data are maintained in an access-controlled database.

5.0 SAMPLING STRATEGY

5.1 OBJECTIVE

The objective is to obtain good quality data that can be used to demonstrate compliance with regulatory requirements, be useful for site characterization, and satisfactorily address stakeholder issues. This objective is to be attained using a program that meets schedules, is fiscally responsible, and technically defensible.

5.2 SAMPLING LOCATIONS

The onsite network is detailed in Table D-1 and contains the following types of TLD monitoring:

- **Historical Station** – Consists of nine stations that have been monitored since 1972.
- **Background Stations** – Stations on the NTS at least 15 kilometers (km) (9 miles [mi]) away from any area with soil contamination (as identified on flyover maps) or other man-made source of radiation. Because the natural background radiation levels on the NTS vary significantly due to elevation variations and geologic variations, at a minimum TLDs are posted at three stations in each of four background radiation ranges.
- **Environmental Stations** – Stations in and near soil contamination areas with fixed contamination. The results from these TLDs are used to monitor trends in the radiation from these areas, and to provide data that can be used in conjunction with flyover data and demarcation study data. Seven TLDs are posted in each of five to seven soil contamination areas.

- **Radioactive Waste Management Sites** – Eleven stations around the perimeter of the radioactive waste management sites in Areas 3 and 5.

The selection criteria for these various types of monitoring were described in Section 4.5 of the RREMP. Except for the historical stations, the locations for several of these stations are expected to change as data becomes available from the demarcation study because resources are available to select background stations and any waste operations activities that may change. Current TLD station locations are depicted graphically on Figure D-1.

5.3 OTHER FACILITY NETWORK

This network monitors radiation-generating activities at four of the six offsite facilities that provide support to DOE/NV operations at the NTS:

- **Special Technologies Laboratory** in Santa Barbara, California – There are two facilities at this site that require monitoring of radiation that may enter public access areas. One facility requires 7 TLDs and the other requires 31 TLDs to properly monitor their radiation output.
- **Washington Aerial Measurements Operations** near Washington, D.C. – This facility requires six TLDs for proper monitoring.
- **North Las Vegas Facility** in North Las Vegas, Nevada – This facility requires two fenceline TLDs for proper monitoring.

The locations of the TLDs at each of the above facilities are shown on Figures D-2 through D-5.

6.0 FIELD OPERATIONS

Onsite Network

The TLDs are normally exchanged on a quarterly basis. A quarterly exposure period ensures that measurable exposures will accumulate, even in low-background areas. Calibrated and annealed TLDs are provided by the Dosimetry Laboratory in the HPD to EM. The network is divided into several routes so that EM can exchange a number of TLDs on each workday. The exposed TLDs are placed in plastic bags and returned to Dosimetry for readout and reporting.

Other Facilities

The operation of this network is similar to the onsite operation. The principal difference is that trip blanks are used during the exchanges because of the shipping time and the use of airplane transport. EM prepares the requisite number of dosimeters for each location and includes a trip blank. The dosimeters are mailed to the facilities where the RCTs exchange the dosimeters for monitoring and exchange the trip dosimeters that are stored onsite in a lead shield.

7.0 SAMPLE DOCUMENTATION AND CUSTODY

7.1 ONSITE MONITORING

Prior to each quarterly exchange, EM requests HPD to anneal the number of TLDs that are to be exchanged in the next day or two. EM places the TLDs in TLD holders labeled with TLD station numbers and records in a spreadsheet the TLD number assigned to the TLD station. Appropriate pages of the updated spreadsheet, which contains the location names, date of deployment of the TLDs currently deployed, the serial number of TLDs to be deployed, and the zone and sequence number for each station, is printed for use by the sampler. (For TLD exchange purposes, the NTS is divided into zones. All of the TLDs in one zone normally can be exchanged in one shift. The sequence number is the order in which the stations should be visited to minimize the distance driven.) The TLD exchange date is recorded on the list as each TLD is exchanged, and subsequently entered into the spreadsheet. Upon return to the office, the TLDs are stored in a lead shield until placed in a tray and delivered to HPD for processing. To meet the criteria of less than 1 mrem per quarter of non-field exposure, as stated in Section 4.5 of the RREMP, TLD storage in the lead shield shall be minimized, and they are to be processed on the day they are delivered to HPD to minimize non-field exposure.

7.2 OTHER FACILITY MONITORING

Each quarter, EM requests offsite facilities indicate the number of TLDs and track-etch neutron dosimeters (TEND) needed. EM requests HPD to anneal the requested number of TLDs and provide the requested number of TENDs. When received from HPD, the freshly annealed TLDs are placed in TLD holders labeled with the station number, a spreadsheet for the facility is updated, and a list printed showing the locations and TLD number. The TENDs and TLDs are promptly mailed to the offsite facilities along with the list. When received at the facility, personnel at each facility promptly exchange the TLDs, record the date of exchange on the list provided, sign the list, and packages and mails the TLDs and TENDs to EM. Two trip TLDs (trip blank) are included in each shipment of TLDs to each facility. The trip TLDs are stored in a lead shield, in a location that will not be affected by operations, and returned to EM at the end of the quarter along with the TLDs posted during the quarter. Upon receipt of the TLDs and TENDs by EM, EM signs the list, promptly places the TLDs in a tray, and submits the TLDs and TENDs to HPD for processing. Upon receipt of the TLD and TEND results from HPD, EM prepares and forwards a report of the TLD and TEND data to the cognizant HPD health physicist.

8.0 ANALYTICAL DESIGN, PARAMETERS, AND METHODS

The following sections pertain to the onsite TLD network and the TLD and neutron dosimeters used at the other BN-managed facilities.

8.1 ANALYTICAL DESIGN AND PARAMETERS

Onsite TLDs

The onsite dosimeters are the Panasonic Model UD-814 TLD that have four elements. One element is of $\text{Li}_2\text{B}_4\text{O}_7$ to measure beta and low-energy X-ray exposure, and three elements are of CaSO_4 (shielded) to measure exposures to X- and gamma rays above about 100 keV. Although all four elements are analyzed, the lithium borate element is not calibrated and results are not reported. If an unusually high reading is obtained, a comment will be made about beta or low-energy photon exposure being detected. Dosimetry provides an electronic file of TLD readings from which EM prepares a report of the readout from the three calcium sulfate elements, each of which represents the total exposure in the deployed location from ionizing radiation with energies from 100 keV to several MeV. The results for the three elements allow calculation of the precision of measurement. A similar procedure is followed for the neutron dosimeters that consist of three track-etch foils for measurement of neutron albedo.

Other Facility Dosimeters

The TLDs and neutron dosimeters mailed to the other BN-managed facilities are based on the same analytical design and use the same TLD model. The neutron dosimeter is a track-etch device where increasing neutron exposure causes increasing numbers of etched tracks in the dosimeter film. The neutron monitor includes three track-etch foils so there are three results for calculating precision of measurement.

8.2 METHODS

The individual elements of each TLD have element correction factors (ECF) that are determined from calibration exposures. When the TLDs are read out by the Panasonic Model 710 automated reader, the readings are corrected by the ECFs. The individual element results are sent to EM. EM applies run correction factors based on the average response of element four of exposed TLDs which have been exposed to a known dose and processed with the environmental TLDs, and calculates precision and mean values and for validation of results.

The track-etch neutron dosimeters require visual readout which can be done on cell-counting equipment. The cell counter picks six random areas on the “A” foil for counting and averages the results for the Dosimetry Technician. If the average result is above a “decision level,” which is determined from background data for each set of foils, then foils “B” and “C” are read to determine neutron exposure.

9.0 INTERNAL QUALITY CONTROL (QC)

Internal quality control for the TLD and neutron monitoring project is divided between the field operations and laboratory operations since the latter are in a different section of BN.

9.1 SAMPLING QUALITY CONTROL

The siting and posting criteria in ANSI N545-1975, DOE Order 5400.5, and DOE/EH-0173T are observed. Non-field exposure is limited to less than 1 mrem per quarter by administrative and engineering controls, or measured by trip TLDs and subtracted from the field TLD results.

9.2 LABORATORY QUALITY CONTROL

When a new set of TLDs is obtained, approximately 50 of the TLDs are retained by the Dosimetry Laboratory as calibration standards. This set of TLDs is used to calibrate the TLD reader and perform calibration checks of the reader.

The exposure the calibration TLDs receive when the TLDs are to be used for reader calibration purposes is verified routinely using an R-meter with calibration traceable to NIST. The R-meter shall be calibrated at the frequency specified in the HPD procedures. Typically, the exposure used to calibrate the TLD reader is 250 mR.

Prior to first use, a TLD shall be tested for acceptance as an environmental monitoring TLD. A TLD can be accepted if it meets the following criteria. Element correction factors for elements 2, 3 and 4 for all TLDs shall be between 0.7 and 1.5, based on at least three exposures. At least twice every year, the ECFs for elements 2, 3, and 4 shall be redetermined and the coefficient of variation (CV) for elements 2, 3, and 4 calculated. The average new ECFs for elements 2, 3, and 4 should be within 3 percent of the former ECFs and the CV should be less than 3 percent. If the CV is greater than 3 percent more than 49 percent of the time, discontinue use of the TLD for environmental monitoring. The desired exposure for determining ECFs and CV is 25 mR, equivalent to a typical quarterly exposure, as recommended by ANSI N545-1975. If the ECF changes by more than 3 percent, discontinue using the TLD for environmental monitoring until it passes the criteria for acceptance testing.

The results from the historical TLDs shall be reviewed quarterly within one month after the end of the quarter and evaluated to determine if the TLD system and TLDs are performing satisfactorily. Specifically, if the result from a historical TLD at one location (prorated to 90 days) is more than 2 mR different than the average quarterly result since 1994, the cause for the variation shall be investigated and documented. If the average for all historical TLDs (prorated for 90 days) is more than 2 mR different than average quarterly results since 1994 for all of the historical TLDs, the cause shall be investigated and documented. If the CV for a posted TLD is more than 5 percent, evaluate the data to determine if the data is valid and what result should be reported, if any. The TLD shall be evaluated to determine if it meets the acceptance criteria for a new TLD before being posted again. Corrective actions shall be taken promptly to correct calibration errors, TLD and TLD reader malfunctions, personnel errors, other deficiencies, and causes for changes in background radiation levels at historical TLD locations.

If PIC data are available, the correlation between the PIC reading and the TLD next to the PIC shall be closely monitored and evaluated to identify changes in TLD system or PIC calibration. If there is a shift of more than 5 percent in quarterly results between the two systems, the cause shall be investigated and documented, and corrective actions taken.

9.3 CALCULATION QUALITY CONTROL

Calculations are performed by use of an Excel[®] spreadsheet format with minimal control of the data. To check the quality, one or two calculations in each group are done by hand, using a standardized format, and compared to the Excel[®] result. Also, the final result of each calculation is checked against previous results for consistency.

10.0 PREVENTIVE MAINTENANCE

Preventive maintenance of dosimeters requires visual inspection to ensure all elements are present, shielding is correct, and no significant damage is apparent.

Preventive maintenance for the TLD reader and the cell counter are specified in the operational manuals supplied by the manufacturer with each instrument.

11.0 DATA REDUCTION, VALIDATION, AND REPORTING

11.1 DATA REDUCTION

Data reduction involves calculation of means, precision, and bias for each of the dosimeters. These items are calculated on a standardized format to minimize omissions and commissions. Finally, daily exposure rates are determined by dividing the mean values by the exposure period (in days). Knowing the daily exposure rate, the exposure for any number of days is easily calculated.

11.2 DATA VALIDATION

Data validation requires a check of all the steps in analysis. Items to be checked include:

- Is the exposure period available and reasonable?
- Are all element values present or an explanation for missing ones?
- Were element correction factors and run correction factors used?
- Was the correction for non-field exposure from trip blanks used correctly, if applicable?
- Are the results consistent with previous data?
- If there is a trend, is it consistent with predicted results? If not, can the cause be determined? Are corrective actions needed?

11.3 DATA REPORTING

Once the calculations are completed and the data have been validated, the results are reported to the EM Health Physicist as mR/day and mR/yr.

12.0 NONCONFORMANCES, CORRECTIVE ACTIONS, CHANGES

Nonconformances cover a variety activities; e.g., insufficient exposure period, use of wrong dosimeter model, erroneous calculation, use of incorrect ECFs, missing QC elements, etc.

Corrective actions are specific to the type of nonconformance. An insufficient exposure period can still lead to a measurable exposure for certain locations, but if there is no measurement possible, then no measurement is entered for that period. If the wrong dosimeter was used, no measurement is entered for that period unless the dosimeter had at least two elements similar to the designated dosimeter and calibration differences were correctly compensated. Erroneous calculations can be corrected by repeating the calculation and/or using the correct format for the calculation. Use of incorrect ECFs will require repeat calculation with the correct ECFs entered. If missing QC steps were not merely overlooked, consistency of the whole batch of involved dosimeters with previous data may permit use of the data, although a qualifier should be included.

Changes in the type of dosimeter, calculational procedures, readout procedures, QA/QC, analytical instruments, or any other significant change to the procedure requires concurrence of higher-level management within BN.

13.0 ASSESSMENTS AND SURVEILLANCES

Assessment of the dosimetry system occurs quarterly when the results are validated. Another assessment occurs by requiring participation in the International Intercomparison Study of Environmental Dosimeters conducted by DOE every two to three years.

Surveillances (audits) are performed periodically by laboratory management, usually on an annual basis.

14.0 REFERENCES

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Table D-1 Onsite TLD Stations

AREA	HPD #	LOCATION	STYLE
01	293	BJY	E
01	381	SANDBAG STORAGE HUT	E
01	428	STAKE C-2	E
01	429	BUNKER 1-300	E
02	296	STAKE M-140	E
02	297	STAKE N-8	E
02	298	STAKE L-9	E
02	321	STAKE TH-58	E
03	275	STAKE OB-20	E
03	280	LANL TRAILERS	E
03	281	STAKE A-6.5	E
03	413	A3 RWMS N	W
03	414	A3 RWMS E	W
03	415	A3 RWMS S	W
03	416	A3 RWMS W	W
03	425	U-3co N	E
03	426	U-3co S	E
03	430	WELL ER 3-1	E
03	444	A3 RWMS CENTER	W
04	294	STAKE A-9	E
04	320	STAKE TH-48	E
04	431	STAKE TH-41	E
05	249	WELL 5B	H
05	253	RWMS NE CORNER	W
05	257	RWMS NW CORNER	W
05	261	RWMS SW CORNER	W
05	263	RWMS S GATE	W
05	264	RWMS E GATE	W
05	434	BLDG. 5-31	W
05	402	3.3 MI SE OF AGGREG PIT	B

Table D-1 (continued)

AREA	HPD #	LOCATION	STYLE
05	421	WEF W	W
05	422	WEF S	W
05	423	WEF E	W
05	424	WEF N	W
06	266	CP-6	H
06	270	YUCCA OIL STORAGE AREA	H
06	274	STAKE OB-11.5	E
06	407	DAF E	E
06	409	DAF W	E
06	417	DECON PAD NW	E
06	419	DECON PAD SE	E
07	314	7-300 BUNKER	E
07	435	STAKE H-8	E
07	634	REITMAN SEEP	E
08	306	STAKE K-25 (K-24)	E
08	436	ROAD 8-02	E
08	437	STAKE M-152	E
09	313	9-300 BUNKER	E
09	386	PAPOOSE LAKE RD	B
09	635	V&G ROAD JUNCTION	E
09	636	CRATER U-9cw	E
10	302	SEDAN W	E
10	303	SEDAN E VISITOR BOX	E
10	312	CIRCLE & L ROAD	E
10	438	GATE 700 SOUTH	E
11	439	STAKE A-21	E
12	323	T-TUNNEL #2 POND	E
12	325	UPPER N POND	E
12	327	UPPER HAINES LAKE	E

Table D-1 (continued)

AREA	HPD #	LOCATION	STYLE
12	427	GOLD MEADOWS SPRING	B
15	305	EPA COMPLEX	E
15	310	SUBSTATION U-15e	E
18	385	STAKE A-83	E
18	440	STAKE F-11 (Airport Road)	E
19	335	STAKE P-41	E
19	343	STAKE C-27	B
19	361	STAKE P-77	B
19	366	STAKE R-26	B
19	387	GATE 19-3P, KAWICH CANY	B
20	377	STAKE J-31	E
20	382	STAKE J-41	E
20	383	STAKE LC-4	B
20	384	STAKE A-118	B
22	400	ARMY WELL #1	B
23	231	BUILDING 650 DOSIMETRY	H
23	232	BUILDING 650 ROOF	H
23	233	POST OFFICE	H
25	240	NRDS WAREHOUSE	H
25	241	25-4P GATE	B
25	247	HENRE SITE	H
25	401	JCT JACKASS FLATS & A27	B
25	403	GUARD STATION 510	B
25	404	YUCCA MTN (west of NTS)	B
27	248	AREA 27 CAFETERIA	H
30	405	JCT CAT CAN & BUGGY T/O	E

B = Background Stations

E = Environmental Stations

H = Historical Stations

W = Waste Management Site Stations

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Figure D-1
NTS Onsite Surface Direct
Radiation Monitoring Sites

Bechtel Nevada

Location Map - NTS Region

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Figure D-2 Location of Dosimeters at the Special Technologies Laboratory, Santa Barbara

Figure D-3 Location of Dosimeters at the Special Technologies Laboratory, Botello Road

Figure D-4 Location of Dosimeters at Washington Aerial Measurements Operations

Figure D-5 Location of Dosimeters at the North Las Vegas Facility

APPENDIX E

DATA QUALITY OBJECTIVES PROCESS

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1.0 INTRODUCTION

This Appendix contains the output generated from a technical design process used during the design phase of the air, surface water, groundwater, soils, plant, and animal components of the integrated Routine Radiological Environmental Monitoring Program (RREMP). The process used was based on the seven-step Data Quality Objectives (DQO) Process developed by the Environmental Protection Agency (EPA) to assist organizations in developing data quality criteria and performance specifications for decision making (EPA, 1994). The process has been modified on a case-by-case basis to address problems unique to this Plan. Teams of investigators were assigned to each media, and each team followed the process steps to help identify their media-specific contaminant problems, identify any information needs, clarify the objectives of monitoring within their media, and select the proper parameters to measure and sampling design to meet their defined monitoring objectives. The outputs from each step of this process were reviewed by all teams, as well as by the U.S. Department of Energy/Nevada Operations Office (DOE/NV) to ensure agreement in defining the problem of radionuclide contamination on and off the Nevada Test Site (NTS) (e.g., radionuclide sources, possible migration pathways, acceptable exposure models, etc.), agreement in design logic, and coordination in data collection and analysis. The raw outputs are documented in this Appendix to support or clarify program design elements presented in Chapter 4.0 of this document, and the outputs are not necessarily consistent in format or detail among the media.

The seven steps of the DQO Process and their definitions, as applied to the design of this radiological monitoring program, are as follows:

Step 1: State the Problem – Describes media-specific radiological problems to be monitored. Prior studies and existing information are reviewed to gain an adequate understanding to define the problem.

Step 2: Identify the Decision – Identifies media-specific objectives of the monitoring program.

Step 3: Identify the Inputs to the Decision – Identifies the information that needs to be obtained and the measurements that need to be taken to address the monitoring objectives.

Step 4: Define the Study Boundaries – Identifies the time periods and spatial area to which the media-specific monitoring will apply and when and where data should be collected.

Step 5: Develop a Decision Rule – Defines the statistical parameter of interest, specifies the action level for the parameter, and presents a single statement that describes the logical basis for choosing between monitoring actions.

Step 6: Specify Tolerable Limits on Decision Errors – Defines the tolerable decision error rates based on a consideration of the consequences of making incorrect monitoring conclusions about the levels of radionuclides in the media of interest. This step was not relevant for most of the media addressed in this document because statistical-based sampling was not reasonable based on knowledge of the variance in measurements from previous sampling.

Step 7: Optimize the Design – Summarizes the previous steps and presents the chosen monitoring design that meets all previously-identified data quality objectives. The detailed designs for media-specific monitoring are presented in the Quality Assurance, Analysis, and Sampling Plans (Appendices A through E).

2.0 DATA QUALITY OBJECTIVE PROCESS FOR AIR MONITORING ON THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination

NTS is an environmental research park at which numerous activities are conducted. Many of the activities involve the use of radioactive materials. The use of these materials could result in contamination accessible to the human environment. The NTS also has a history of nuclear testing, above- and below ground, which has left radionuclide contamination that is accessible to the human environment. There is a possibility of impact to human health as a result of the presence of radionuclides in the environment through air transport. If effective dose equivalent (EDE) to the maximum exposed individual (MEI) should exceed 10 mrem/annum, NTS would violate Title 40 Code of Federal Regulations (CFR) 61 (National Emission Standards for Hazardous Air Pollutants [NESHAPs]).

Sources of Contamination:

- Defense Projects operating facilities (point source emissions from facilities such as the Device Assembly Facility [DAF], U1A, proposed Gas Gun , etc.).
- Calibration sources (point source emissions from buildings or transportainers).
- Analytical Lab (point source emissions from an operating radioanalytic laboratory).
- Diffuse source emissions from operating facilities such as radioactive waste management sites (RWMSs) (vadose zone soils).
- Diffuse source emissions from ground contamination (surface soils, plants).
- Diffuse source emissions from Underground Test Area (UGTA) containment ponds (surface water).
- Diffuse source emissions from underground test cavities (groundwater).

Types of Contaminants and Affected Media

- Man-made and technologically enhanced radionuclides contained in soil, water, sediment, plants, and ambient air.

Known or Potential Routes of Migration

Volatile Radionuclides

- Gases emitted from operating facilities, emitted through air to the receptors.
- Noble gases from sources such as UGTA (Pahute/Rainier Mesa) venting to air to the receptors.
- Tritiated water vapor from containment ponds, waste management sites, calibration sources, and plants emitted through air to the receptors.

- ^{14}C from low-level waste (LLW) sites emitted through air to the receptors.
- Radon generated by uranium decay at waste management sites (not yet generated in sufficient quantities to detect).

Particulate Radionuclides

- Particulates identified through specific process knowledge or inventory, emitted from operating facilities, through the air, to receptors.
- Long-lived isotopes (Pu, Th, U, Am, Cs, Sr, etc.) emitted from soils as airborne particulates through air to the receptors.

Known Human and Environmental Receptors

- Humans on- and offsite; onsite plants and animals.

Exposure Pathways and Scenarios

- Inhalation of radioactive gases and particulates containing radionuclides.
- Ingestion of particulates containing radionuclides, and plants and animals living in contaminated areas.

Current and Future Land Uses

- Assumed to be as stated in 1996 NTS Sitewide Environmental Impact Statement Record of Decision (EIS ROD), using 1996 site boundaries and 1996 offsite land uses.

Sources of Historic Data Associated with Previous Data Collection Activities

- Annual Site Environmental Reports (ASERs).
- Nevada Applied Ecology Group publications.
- BECAMP (Basic Environmental Compliance and Monitoring Program) studies.
- Offsite Environmental Monitoring Reports.
- Aerial Measurements (soils).
- Radiological Inventory and Distribution Program (RIDP) Reports (soils source term).
- Meteorological data reports (Air Resources Laboratory/Special Operations and Research Division [ARL/SORD] reports).
- Demarcation Reports.
- UGTA well pumping data.

Applicable Requirements

- Title 40 CFR 61.
- DOE Orders 5400.1, 5400.5, 5820.

- Agreement in Principle with Nevada.
- DOE guidance document DOE/EH-0173T.

Detailed listings of the citations within each of the above-listed requirements that pertain to specific monitoring plan elements for air are shown in the attached tables.

The Contamination Problem

Behavior of radionuclides in air is uncertain at NTS. Site-wide distribution of radionuclides in air is dependent on many variables. Radionuclides present in ambient air must be measured to assess their risk to the public and the environment. The risk assessment is necessary to support compliance with 40 CFR 61, DOE Orders, and state agreements. The monitoring program must collect the data necessary to assess exposure risks via the air media to the public and adhere to all applicable monitoring guidelines. A monitoring network which provides point source operational monitoring as required under NESHAPs, measures diffuse source emissions (particulate, resuspended particulate, and gaseous emissions from sources which do not individually but do collectively emit 1 percent of the standard), assesses source term areas of NTS not previously characterized, provides analytic data to confirm emissions (to detect and identify local and site-wide trends in air, identify radionuclides emitted to air, and detect accidental and unplanned releases), provides data on the concentration of every radionuclide in air expected to contribute to offsite dose, characterizes the stability of areas onsite NTS where soil is contaminated by radionuclides, establishes measured background values for NTS, provides a means to evaluate the reasonableness of models used in NESHAPs compliance (both to determine total emissions by radionuclide from NTS, and to provide actual data to confirm the reasonableness of offsite EDE calculations prepared as required under NESHAPs), and provides measured background values for offsite areas near NTS.

Regulation: Agreement in Principle with the state of Nevada	Media: AIR
Plan Element	Citation Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	Att. A, 3.b.
Perform exposure pathway analysis	
Perform critical pathway analysis and document in Annual Site Environmental Report (ASER)	
Parameters to be monitored	Att. A, 3.c.
Frequency of monitoring	
Location of monitoring points	Att. A, 3.d.
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	
Predict offsite impact	Att. A, 3.c.

Regulation: Title 40 CFR 61, Subpart H	Media: AIR
National Emission Standards for Hazardous Air Pollutants: Radionuclides	
Plan Element	Citation Location
Use an environmental monitoring program	NA
Verify compliance with applicable environmental laws and regulations	61.94
Verify compliance with environmental commitments	NA
Characterize and define trends in the condition of environmental media	NA
Establish baselines of environmental quality	NA
Identify and quantify new or existing environmental quality problems	NA
Measure releases, migration, subsidence, and performance changes	61.93(b)(4)(i)
Perform exposure pathway analysis	NA
Perform critical pathway analysis and document in ASER	61.92
Parameters to be monitored	61.93(b)
Frequency of monitoring	NA
Location of monitoring points	61.93(b)
Equipment, instrumentation, and facilities to be used for measurements	Appx. B
Method to be used for obtaining environmental samples	Appx. B
Analysis method	Appx. B
Action levels	NA
Quality assurance plan required	Appx. B.4.
Rationale for monitoring required	NA

Regulation: DOE Order 5400.1	Media: AIR
Protection of the Environment	
Plan Element	Citation Location
Use an environmental monitoring program	IV,4.
Verify compliance with applicable environmental laws and regulations	IV,5.(1)(a)
Verify compliance with environmental commitments	IV,5.(1)(b)
Characterize and define trends in the condition of environmental media	IV,5.(1)(c)
Establish baselines of environmental quality	IV,5.(1)(d)
Identify and quantify new or existing environmental quality problems	IV,5.(1)(f)
Measure releases, migration, subsidence, and performance changes	NA
Perform exposure pathway analysis	NA
Perform critical pathway analysis and document in ASER	NA
Parameters to be monitored	IV,4.
Frequency of monitoring	IV,4.
Location of monitoring points	IV,5.(2)(a)
Equipment, instrumentation, and facilities to be used for measurements	NA
Method to be used for obtaining environmental samples	IV,5.(2)(b)
Analysis method	IV,4.
Action levels	NA
Quality assurance plan required	IV,4. & 10.
Rationale for monitoring required	IV,4.
Preoperational monitoring required	IV.3.

Regulation: DOE Order 5400.5	Media: AIR
Radiation Protection of the Public and the Environment	
Plan Element	Citation Location
Use an environmental monitoring program	II, 6.b.(3)
Verify compliance with applicable environmental laws and regulations	II, 6
Verify compliance with environmental commitments	NA
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	I.8.a. & II.6.a.
Perform exposure pathway analysis	II.6.b.(1)
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	
ALARA program	I.4;II.2.;II.6.a.
Protect the environment	II.6.b.
Protection of the public	II.6.a.
Dose limits	I.3.; II.1.

Regulation: DOE Guide DOE/EH-0173T	Media: AIR
Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance	
Plan Element	Citation Location
Use an environmental monitoring program	3
Verify compliance with applicable environmental laws and regulations	3.3
Verify compliance with environmental commitments	5.3.1.1)
Characterize and define trends in the condition of environmental media	NA
Establish baselines of environmental quality	Table 5-1
Identify and quantify new or existing environmental quality problems	NA
Measure releases, migration, subsidence, and performance changes	NA
Perform exposure pathway analysis	Table 5-1
Perform critical pathway analysis and document in ASER	5.3.2
Parameters to be monitored	Table 5-2
Frequency of monitoring	5
Location of monitoring points	5.7.4
Equipment, instrumentation, and facilities to be used for measurements	5
Method to be used for obtaining environmental samples	3.5.8
Analysis method	6.2.5.1
Action levels	3.5.8.5
Quality assurance plan required	3.7, 10.1.1.
Rationale for monitoring required	5.7
Diffuse source assessment	3.3.3.
Preoperational monitoring	3.3.

STEP 2: IDENTIFY THE DECISION

Key Decisions

Radionuclides from source terms located on the NTS exist in ambient air in gaseous and particulate forms. If they can be measured in air onsite at NTS, they may be transported in air off the NTS. Detection of radionuclides attributable to NTS in offsite air samples indicates this may occur. The key decision which will be made through monitoring data is the following: do any NTS activities require modification to ensure that dose received offsite does not impact human health as defined under NESHAPs and, if so, which activities?

Alternative Actions Resulting from Resolution of Decisions

- **High-Risk Alternative:** If an estimated offsite dose exceeds 10 mrem/annum, corrective action will be required, either to control the source term onsite or to protect the population offsite. (See Title 40 CFR 61, Subpart H, paragraph 61.92.)
- **Mid-Risk Alternative:** If an EDE were increasing offsite as a result of a release from an operational site, detection of site-specific radionuclides in air could result in engineering controls or site closure, and/or change waste acceptance criteria.
- **Low-Risk Alternatives:** If the total onsite source term does not have the potential to cause an EDE ≥ 1 percent of the NESHAPs limit, continuous monitoring may not be required.
- **Relationship With Other Decisions:** Under NESHAPs, air data can force action on Environmental Restoration and Waste Management sites without regard for other site issues.

NESHAPs compliance must be considered prior to conduct of any activity that may contribute to the source term(s) onsite at NTS. For example, a Memorandum of Understanding between EPA and DOE requires monitoring of remedial activities at sites containing radioactivity (preoperational, operational, and postoperational monitoring).

Decision Statement

Based on the data, assumptions and models, did the MEI receive an EDE of 10 mrem or more during the calendar year being considered?

If the answer is “No”, compliance with Title 40 CFR 61 is demonstrated.

If the answer is yes, NTS is subject to legal consequences and it may be necessary to change or terminate operations which generated emissions, imposed engineering or administrative controls, undertake remedial action, or relocate residents.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decision(s)

Environmental Variables and Information

- Identification of sources capable of emissions which may contribute to the EDE of the MEI.
- Radionuclide inventory at operational facilities.
- Operational process knowledge.
- Location of air samplers with respect to source term.
- Meteorological data for areas on/offsite.
- Contamination levels in soil and water.
- Surface areas of diffuse source terms.
- Location of offsite residents.
- Population of communities.
- Estimate of uncertainty in the EDE to the MEI.
- Roads and utilities available in areas where monitoring may be desired.

Information on Physical Properties of Media Required

- Assume all particulates are respirable.

Information on Chemical Properties Required

- Assume most hazardous chemical form.

How to Generate the Necessary Data

- ARL/SORD is source for Meteorological Data.
- Contamination levels are available from published measurements (aerial survey validated by surface data).
- Correct use of approved model(s).

Objectives Which Must Be Met

The monitoring network must fulfill the following requirements:

- Provide point source operational monitoring as required under NESHAPs (any facility which has the potential to emit one-tenth of the standard must be monitored).
- Measure diffuse source emissions (particulate, resuspended particulate and gaseous emissions from sources which do not individually but do collectively emit one-tenth of the standard).
- Assess source term areas of NTS not previously characterized (using mobile solar-powered units which may access remote areas where grid power is unavailable).
- Provide analytic data to confirm emissions, to detect and identify local and sitewide trends in air, identify radionuclides emitted to air, detect accidental and unplanned releases.

- Provide data on the concentration of every radionuclide in air expected to contribute to offsite dose.
- Characterize the stability of areas onsite NTS where soil is contaminated by radionuclides.
- Establish measured background values for NTS.
- Provide a means to evaluate the reasonableness of models used in NESHAPs compliance, both to determine total emissions and emissions by radionuclide, from NTS.
- Provide actual data to confirm the reasonableness of offsite EDE calculations prepared as required under NESHAPs.
- Provide measured background values for offsite areas near NTS.

Sources of Environmental Input

Existing Sources of Information that Support Decision

- Information on work process and facilities inventories are available from facility managers/project manager.
- Annual NESHAPs Reports and ASERs for previous years for monitoring data and locations of MEI.
- Soil survey data from published reports (Desert Research Institute (DRI) and Remote Sensing Laboratory) (see below).
- LLW inventory data.

The following table from McArthur serves as the best available inventory of radionuclides in surface soils at NTS.

**Estimated Inventories of Major Manmade Radionuclides in NTS Surface Soil
(McArthur, 1991)**

Area	Radionuclide Inventory (Ci)								
	²⁴¹ Am	²³⁸ Pu	^{239,240} Pu	⁶⁰ Co	¹³⁷ Cs	⁹⁰ Sr	¹⁵² Eu	¹⁵⁴ Eu	¹⁵⁵ Eu
1	4.2	6.5	24	1.1	8.8	15	15	0.1	0.5
2	2.9	8.6	22	1.2	24	46	14	0	0.4
3	4.6	3.1	37	1.0	12	33	18	0.1	0.5
4	6.6	13	40	1.6	12	13	9.1	0	0.2
5	0.6	0.1	4.8	0.6	0.4	0.9	10	0.2	0
6	1.7	3.3	8.4	0.2	2.8	3.5	0	0	0
7	2.2	0.6	16	1.0	5.2	9.2	22	0.2	0.3
8	17	8.0	110	5.7	42	25	4.4	0	0.6
9	4.2	2.2	89	0.7	8.7	13	23	0.2	0.3
10	19	19	110	9.7	84	55	2.2	0.3	5
11	3.3	0.5	29	0	0.5	0.3	0	0	0
12	5.7	8.5	39	1.2	20	17	0	0	0

Area	Radionuclide Inventory (Ci)								
	²⁴¹ Am	²³⁸ Pu	^{239,240} Pu	⁶⁰ Co	¹³⁷ Cs	⁹⁰ Sr	¹⁵² Eu	¹⁵⁴ Eu	¹⁵⁵ Eu
15	8.0	7.8	63	0.3	19	22	0	0	0
16	0.7	1.5	3.7	0.1	2.9	3.7	0	0	0
17	2.8	4.5	18	1.0	15	19	0	0	0
18	19	5.6	100	0.7	10	17	1.1	0.1	0.8
19	21	32	140	1.1	36	31	0	0	0
20	23	30	41	7.9	5.5	4.3	13	1.6	4.8
25	0	0	0	0	0.2	0.1	0.4	0	0
26	0	0	0	0	0	0	0	0	0
30	3.2	4.5	14	0.8	1.5	1.3	00.7	0.1	0.2
Total	150	160	910	35	310	330	130	2.8	14

Are Existing Data Appropriate as an Aid to Decision?

Quality data do exist in the above publications.

Inputs Obtained via Environmental Measurements

A large amount of air and water data is available, as is a somewhat smaller amount of soil data. Air data includes all parameters of interest from 50 to 60 locations, collected continuously for a duration of 20 years.

Basis for Establishing Contaminant-Specific Action Level(s)

Regulatory threshold is set in Title 40 CFR 61 (NESHAPs) and described in DOE/EH-0173T.

Potential Sampling Approaches and Appropriate Analytical Methods

For operational point sources which have the potential to contribute 1 percent of the standard, monitoring can be performed using either in-stack air sampler or upwind-downwind air sampler configurations. A network to monitor ambient air can be developed to detect emissions from diffuse sources. This approach can include selection of background sites for ³H and particulates; selection of sites downwind from contaminated locations and other sources, if possible, with background locations based on the very large and high-quality historical air monitoring data set. Diffuse ³H emissions from ephemeral sources such as contaminated UGTA containment ponds can be estimated based on water sample analyses. Monitoring at critical receptor points can be used to confirm dose estimates developed from onsite monitoring data. Critical receptors can be identified through historical measured (monitored) and modeled information.

Analytical methods must be equalvalent to those specified in Title 40 CFR 61.

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

The area is on and around the NTS, covering several thousand square miles and includes those sites where facility and operations presently handle materials capable of emitting radioactivity, as well as areas affected by atmospheric and Plowshare cratering nuclear explosive tests, nuclear device safety tests, containment ponds, and LLW sites.

Characteristics that Define the Population of Interest

- Residents and workers on/offsite.

Stratify the Populations

- The offsite resident population.
- The onsite non-rad-worker and resident population.
- The onsite rad-worker population.

Spatial Boundary of the Decision

- Breathing zone height air onsite and within 80 kilometers (km) (50 miles [mi]) of each major onsite source.

Temporal Boundaries of the Decision

Data will be collected and analyzed weekly, monthly, and quarterly. Data will be reviewed as received, and evaluated at least quarterly.

STEP 5: DEVELOP A DECISION RULE

Parameter(s) that Characterize the Population of Interest

- Airborne radioactivity emissions from the NTS.

Action Level(s) for the Decision(s)

The action level is 0.1 mrem EDE to an offsite resident or a regulatory requirement for measurement to confirm low levels of emission.

Decision Rule

If an $EDE \geq 0.1$ mrem occurs to the maximally exposed individual offsite, then monitoring of all sources is required. If DOE Policy or a regulatory rule requires, monitoring will be performed to meet the additional requirement.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

Possible Range of the Parameter of Interest

Per Title 40 CFR 61, the EDE to the MEI must be < 10 mrem/annum, and monitoring is required for any source which could contribute more than 0.1 mrem/annum to the MEI, and any radionuclide which could contribute more than 10 percent of the dose to the MEI.

Potential Consequences of Type 1 and Type 2 Errors

- Be subject to legal consequences of exceeding the EDE to the MEI
- Be subject to legal consequences of failure to monitor when required
- Use resources unnecessarily when monitoring is not needed

Define the True State of Nature as Hypotheses

H_0 = The EDE to the MEI from all sources is $\ll 0.1$ mrem, therefore monitoring is not needed.

H_A = The EDE to the MEI from all sources is ≥ 0.1 mrem, therefore monitoring is needed.

Specify a Range of Parameter Values Where Decision Errors Are Minor

The estimated EDE to the MEI from all sources is < 0.01 mrem/yr or > 10 mrem/yr.

Acceptable Probability of Type 1 and Type 2 Errors

- Failure to comply with legal requirements is unacceptable.
- Unnecessary use of resources is not acceptable.

STEP 7: OPTIMIZE THE STUDY DESIGN

General Sampling and Analysis Design

Monitoring System Design

The design of an air monitoring network to support compliance with NESHAPs includes an on-site air sampling network which monitors radionuclides in ambient air near their source, and an offsite network which monitors radionuclides in ambient air near critical receptor points. In 1998, the predominant radionuclides causing exposure to offsite personnel were plutonium and HTO.

The 1996 ambient air monitoring system on the NTS and Nellis Air Force Range (NAFR) consisted of 49 air particulate samplers and 16 samplers for HTO in atmospheric moisture. The existing air monitoring system was designed to monitor suspected locations of radionuclide emission and to measure radionuclide concentrations in places where people lived or worked. The historical data collected by this onsite system provides information upon which a technical and cost-effective air monitoring network for the NTS can be designed. The present offsite network, originally designed around issues associated with atmospheric testing, also provides data which can be used to support offsite network siting design.

The network design must satisfy the directives noted above and must be based on the following principles:

- Measurement of air emission at sites with known surface soil contamination.
- Air samplers at sites representative of background radioactivity on the NTS.
- Assessment monitoring of sites suspected of being contaminated but for which no data exist.
- Operational monitoring of activities handling radioactivity and of environmental restoration (ER) activities.
- Confirmatory monitoring in offsite communities most likely to be impacted by NTS emissions.

Onsite Station Selection

Operational

Operational air monitoring is conducted at any location where radionuclides are transported, treated, or disposed. Any proposed facility or activity at NTS which involves the transport, treatment, or disposal of radionuclides is reviewed to determine if the operations have the potential to create a dose of 1 percent of the standard to any offsite resident. The radionuclides monitored (particulate, gaseous, or HTO in air) are those which process knowledge and/or assessment of radionuclide inventory indicate have the potential to contribute to offsite dose. This monitoring can either be continuous in-stack air monitoring, conducted where point source emissions can be directly measured, or upwind/downwind diffuse source monitoring. Where upwind/downwind monitoring is deemed inappropriate, pre-operational and post-operational monitoring is conducted to establish background prior to operations and to determine if any residual diffuse source emissions may be occurring. In selected cases, pre-operational monitoring

may provide a background value which can be used in lieu of upwind monitoring. Likewise, in those cases where postoperational monitoring indicates that diffuse sources are still detectable in air, ambient air monitoring is conducted as long as radionuclides are detectable at levels which meet ambient air monitoring criteria. The configuration of operational monitoring is reviewed at least annually to determine if the monitoring data, process knowledge, or radionuclide inventory suggest that the configuration is not optimum, the operational network at the site is reconfigured.

In 1998, operational monitoring was conducted at three Waste Management facilities (Area 5, the Waste Examination Facility [WEF], and Area 3) and at four ER sites. A total of five particulate-in-air monitors were configured around Area 5 and the WEF, providing upwind/downwind monitoring of both facilities. Four HTO-in-air monitoring were also configured around RWMS 5. Two particulate-in-air monitors were located at the Area 3 RWMS, in an upwind/downwind configuration. Two additional particulate-in-air monitors in Area 3 were on standby, pending the disposal of large volumes of soil from ER activities. One HTO-in-air monitor at Area 3 was located in a downwind configuration because only small amounts of tritium are expected to be emitted by that facility. Operational monitoring is also conducted at five ER sites, three on the Tonopah Test Range (CLEAN SLATES I, II, and III) and two on the NAFR (Area 13 [Project 57] and DOUBLE TRACKS). Four solar-powered particulate in-air samplers are deployed at these sites but the configuration of the network at each site is revised based on site-specific criteria during restoration activities. Also, HTO was monitored at the Decontamination Pad. Thus, in 1998, there were 15 operational monitors located at NTS operational sites, 10 at radioactive waste management sites, 4 at ER sites, and 1 at the Decontamination Pad.

Ambient

Two approaches have been considered for the selection criterion for the onsite ambient air sampling network: one based on aerial and ground surveys of radionuclide inventory and distribution in soils on the NTS; and one based on detectability of radioactivity in air, using an evaluation of historical air monitoring data. The latter method, based on actual detection of radionuclides in air, addresses the primary question asked of air monitoring: what and where are detectable concentrations of radionuclides in ambient air? Over the last several decades, ambient and/or operational air monitoring has been conducted at all areas where radionuclides have been believed to exist in air and where grid power has been accessible. More recently, solar-powered air samplers have been used to allow the collection of data in areas suspected of contamination where no grid power has existed. Since the cessation of testing, the air monitoring network has been gradually reduced in size, eliminating areas where radionuclides have not been detected in air and where site activities have ceased. Thus, except for those areas addressed in "Assessments" below, the data set describing the behavior of radionuclides in air at NTS is very large, and is suitable for selection. What remains, then, is defining detection so that a selection criterion can be determined.

For the purposes of this plan, detection was defined as any measurement that exceeded the upper 98 percent confidence limit of background radioactivity. To be conservative, background was chosen to be the upper end of the first quartile of the annual data for 1996 for each measurement made on air samples. Because the 98 percent confidence limit is two standard deviations above the background, the standard deviation was chosen from the air sampling result nearest to the first

quartile. Although nearly all gross alpha and gross beta results were above the minimum detectable concentration (MDC), no sampling location met the selection criterion. For $^{239+240}\text{Pu}$ in air, the background station had a result of $1.56 \pm 0.71 \times 10^{-18} \mu\text{Ci/mL}$, so the selection criterion was any annual average for 1996 that was greater than $3.0 \times 10^{-18} \mu\text{Ci/mL}$.

Using the selection criterion, 20 locations with annual averages greater than the criterion have been identified (Table E-1). Four of those locations are so close to another air monitoring location that the data sets are considered redundant and unnecessary, leaving 16 sites where $^{239+240}\text{Pu}$ in air is considered necessary. Two locations were eliminated for low results and cessation of activity and one was eliminated because other locations provided a preferable upwind/downwind configuration. One additional location has been selected for background monitoring, based on a related criterion: namely, the lowest annual average result. The locations of the onsite environmental air particulate samplers are listed in Table E-2 and are shown on Figure E-1, which is modified from McArthur's publication and also shows the higher-level plutonium distribution on the NTS.

A similar criterion, chosen from tritium-in-air data, was used for the HTO network. Based on 1996 data, the upper part of the first quartile plus two standard deviations yielded a cutoff level of $2.4 \times 10^{-12} \mu\text{Ci/mL}$. Three ambient air sampling locations exceeded the selection criteria and were selected for ambient tritium-in-air monitoring, as well as the BJY (Buster-Jangle Y) because of its central location (Table E-3). No adjustments based on redundant data are made to the tritium-in-air sampling network. As a background station, the 1996 ambient tritium-in-air monitoring station with the lowest observed value was selected (in Area 5 near Water Well 5B). The locations of the HTO-in-air samplers are shown in Table E-4 and Figure E-2.

Ambient Air Monitoring Assessments

Although the data on radionuclides in surface soil on the NTS contained in report DOE/NV/10845-02 (McArthur, 1991) are useful and sufficiently accurate for location of contaminated areas, they are occasionally inconsistent with air monitoring results. To resolve such discrepancies, two solar-powered mobile air samplers will be used to assess airborne radioactivity in locations for which insufficient data exist. These will operate for one year, and those with annual average values that exceed the criterion expressed above will be added to the permanent network. The initial locations that have been chosen are LITTLE FELLER II and BUGGY, both located in Area 18.

The same type of approach will be used to assess previously unsampled areas where tritium in air may exist. Two mobile solar-powered air samplers will be deployed at sites not adequately assessed in previous efforts. The initial locations chosen for this exercise are in Area 20 near SCHOONER (tritium has been detected in adjacent Well PM-1) and in Area 12 on Rainier Mesa near the tunnel vents.

Offsite Station Selection

For offsite air sampling, two factors drive the network design. The first is that the level of EDE at the offsite communities is sufficiently high that positive detection of radionuclides can be achieved. The second factor is concern of offsite residents that emissions from the NTS may be high enough to represent a hazard to them. An important function of offsite air sampling is assessment of the validity of NESHAPs compliance as calculated by onsite data; the first factor is related to this, so locations with a history of radionuclide detection are preferred. A review of annual NESHAPs reports for the NTS noted that the maximally exposed individual was predominantly located in the southwest quadrant from the NTS, although measurable EDEs have been calculated for communities in the northeast quadrant. For the purpose of assessing the validity of onsite data as used for NESHAPs compliance, six offsite sampling locations have been selected. These are the nearest communities in their respective quadrants; those farther away will receive lower exposures.

Most of the offsite samplers are generally at locations where the EDE calculated by CAP88-PC (Clean Air Program [EPA]) is 0.01 mrem or greater. An EDE of 0.01 mrem will result if the air concentration of ^{239}Pu is $3.8 \times 10^{-18} \mu\text{Ci/mL}$, or about the MDC for the onsite air samplers that operate for one week at 3 cfm (cubic feet per minute) of air. To detect plutonium air concentrations of that level, the MDC should be about 10 percent of that value. This would require a higher sampling rate and/or a longer sampling time. Also, to ensure that measurements are not affected by local deposits, each station location will be characterized by soil sampling and analysis and by surveys with a Field Instrument for Detection of Low-Energy Radiation (FIDLER)-type instrument.

Historically, the MEI has been located either to the northeast or to the southwest of the NTS, consistent with the prevailing wind directions. The locations recommended for this network correspond with these wind directions, have populations of 100 or more, and have had calculated EDEs of 0.05 mrem or more during the last four years or fill gaps in offsite coverage. The locations so chosen are Rachel and Alamo to the northeast, Beatty and Amargosa Valley to the southwest, Goldfield to the northwest, and Indian Springs to the southeast. Offsite confirmatory air monitoring also requires HTO-in-air sampling in the predominant downwind direction. Amargosa Valley and Indian Springs are chosen for this function. The locations of these samplers are shown on Figure E-3 and Table E-5. Figure E-3 also contains arcs denoting 80-km (50-mi) distances from various emission sources on the NTS and NAFR, the communities and ranches within these arcs, and the location of air samplers on the NAFR and in the selected communities.

Sampling Frequency and Analytical Procedures

Air Particulate Samples Onsite

These samples will be collected weekly. The filters will be counted for gross alpha and gross beta activity at least seven days after collection to allow radon progeny to decay. These analyses provide a general indication of airborne radioactivity at each location each week. If results show abnormally high gross alpha or gross beta concentrations, additional detailed analyses will be performed. Monthly, the filters from each location will be combined and analyzed by gamma spectrometry for gamma-emitting fission products, and by alpha spectrometry for ^{238}Pu and

²³⁹⁺²⁴⁰Pu. The samples will be analyzed for the plutonium radionuclides because they are the radionuclides with the highest probability for detection. Monthly composites reduce the MDC substantially when compared to weekly samples, thus increasing the probability of detecting environmental concentrations of fission products and plutonium.

Air Particulate Samples Offsite

High-volume particulate samples will be collected biweekly, composited monthly, and analyzed by gamma spectrometry and for ²³⁸Pu and ²³⁹⁺²⁴⁰Pu by alpha spectrometry.

HTO in Atmospheric Moisture Samples Onsite and Offsite

These samples consist of HTO collected on a molecular sieve. After a collection period of two weeks, the HTO is extracted and the tritium concentration is determined by liquid scintillation counting. The onsite and offsite HTO sampling regimes are identical.

Network Summary

The preliminary design is described by use of the maps shown on the following slides.

- **HTO** - Monitoring locations for measuring HTO in air are based on positive results as shown in historical data, with a station at BJY as being the center of Yucca Flat activities, a station adjacent to Water Well 5B representing background, and a judgmental decision to place samplers at the SCHOONER site and on Rainier Mesa near the tunnel exhausts.
- **Particulate** - Gross beta and gamma spectrometric data have not shown elevated levels at any location onsite; gross alpha analyses were only started in 1996, so sufficient data have not accumulated to be useful. The useful data are for plutonium in air. Using the annual mean levels for 1996, a selection criterion was developed for air sampling sites. Again, BJY would be selected and Area 25 as background. Additional sampling will be needed at CABRIOLET because of the poor performance of the existing station.
- **Other Stations** - The above selections are for environmental surveillance. Stations will also be needed for effluent monitoring (at least seven at RWMSs and the Waste Examination Facility and four at the contaminated sites on the NAFR)).

Collection Frequency

- **Weekly** - Filters are collected weekly from each air sampling station and analyzed for gross beta and gross alpha. This frequency is preferred for the gross beta analysis because this activity is the harbinger of conditions in air. Unusual occurrences involving radioactivity will cause a change in this parameter before any other. Gross alpha must also, then, be measured at the same time. Gamma spectrometry can be done on composite collections if the labor costs do not exceed the analytical costs.
- **Biweekly** - This schedule for HTO-in-air collection should not change.

- **Monthly** - At present, plutonium analyses are performed on quarterly composites of weekly air sampling so 13 filters (13 weeks of data) must be dissolved to begin analysis. With quarterly collection and a 6-week turn around for analysis, there is a 19-week delay between collection of a sample and receipt of data points, or almost five months. Therefore, monthly analysis will be performed under this plan. A monthly analysis provides 12 data points so a lost sample or an anomalous result is of little consequence.

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Table E-1 Airborne ²³⁹⁺²⁴⁰Pu Concentrations on the NTS - 1996

<u>Location</u>	<u>Number</u>	<u>²³⁹⁺²⁴⁰Pu Concentration (10⁻¹⁷ µCi/mL)</u>				<u>Mean as %DCG</u>
		<u>Maximum</u>	<u>Minimum</u>	<u>Arithmetic Mean</u>	<u>Standard Deviation</u>	
Area 1, BJY	4	75	2.3	22	36	11
Area 2, Complex	4	1.1	0.23	0.66	0.39	0.33
Area 2, 2-1 Substation	4	5.8	0.13	2.5	2.7	1.2
Area 3, U3AH/AT S	10	25	1.9	11	7.2	5.5
Area 3, U3AH/AT E	10	31	2.5	13	10	6.5
Area 3, U3AH/AT N	10	80	3.9	26	23	13
Area 3, U3AH/AT W	10	36	5.0	16	10	8.0
Area 3, Mud Plant	4	26	0.08	12	11	6.0
Area 3, Well ER-3-1	4	5.4	0.35	2.6	2.4	1.3
Area 4, Bunker T-4	4	8.1	2.1	4.8	2.5	2.4
Area 5, RWMS Pit 5	10	1.0	-0.008	0.32	0.37	0.16
Area 5, RWMS No. 4	10	0.82	-0.015	0.21	0.27	0.10
Area 5, RWMS No. 5	9	3.1	0.12	0.73	0.99	0.36
Area 5, RWMS No. 6	10	1.2	-0.009	0.51	0.36	0.26
Area 5, RWMS No. 7	9	7.3	0.075	1.2	2.3	0.60
Area 5, RWMS No. 8	10	1.4	0.12	0.56	0.40	0.28
Area 5, RWMS No. 9	9	0.67	0.076	0.25	0.19	0.12
Area 5, DOD	4	0.65	0.21	0.43	0.21	0.26
Area 5, RWMS No. 3	9	0.38	0.086	0.18	0.09	0.09
Area 5, RWMS No. 1	10	0.47	-0.026	0.27	0.15	0.13
Area 5, WEF North	1			2.6		1.3
Area 5, WEF South	1			2.3		1.1
Area 5, RWMS TP Bldg. N	10	0.63	-0.026	0.22	0.19	0.11
Area 5, RWMS TP Bldg. S	10	10	-0.020	1.2	3.2	0.60
Area 5, Well 5B	4	0.41	0.28	0.32	0.06	0.16
Area 6, Yucca	4	11	0.81	3.6	5.2	1.8
Area 6, CP-6	4	1.2	0.56	0.86	0.33	0.43
Area 6, Well 3	4	1.6	0.34	1.1	0.54	0.55
Area 7, UE7NS	4	45	0.50	12	22	6.0
Area 9, Area 9-300	4	61	7.9	35	25	1.8
Area 10, Gate 700 S	4	3.1	0.32	1.1	1.4	0.55
Area 10, SEDAN Crater	4	8.4	3.4	5.3	2.4	2.7
Area 11, Gate 293	4	1.9	0.50	1.0	0.65	0.5
Area 12, Complex	4	0.37	-0.007	0.2	0.16	0.1
Area 15, EPA Farm	4	24	2.2	8.7	10.6	4.2
Area 16, 3545 Substation	4	0.18	-0.004	0.095	0.078	0.05
AREA 18, Well UE-18t	4	0.35	0.12	0.20	0.11	0.1
Area 20, SCHOONER	4	0.60	0.19	0.32	0.19	0.15
Area 20, Complex	4	0.30	0.083	0.17	0.093	0.08

Note: Shading indicates locations eliminated from the network.

Table E-1 (continued)

<u>Location</u>	<u>Number</u>	<u>²³⁹⁺²⁴⁰Pu Concentration (10⁻¹⁷ μCi/mL)</u>		<u>Arithmetic Mean</u>	<u>Standard Deviation</u>	<u>Mean as %DCG</u>
		<u>Maximum</u>	<u>Minimum</u>			
Area 20, CABRIOLET	1			0.30		0.15
Area 23, Bldg. 790 #2	4	1.1	0.15	0.44	0.46	0.22
Area 23, H&S Bldg.	4	0.15	0.086	0.13	0.029	0.06
Area 25, E-MAD N	4	0.71	-0.008	0.24	0.32	0.12
Area 25, NRDS	4	0.13	-0.004	0.054	0.056	0.03
Area 27, Cafeteria	4	0.26	0.11	0.16	0.071	0.08

Note: Shading indicates the 12 locations eliminated from the network.

Table E-2 Air Particulate Sampling Station Network for 1998

<u>AREA/NO. LOCATION</u>			<u>ALT</u>		<u>NSTATE</u>	<u>ESTATE</u>	<u>LATITUDE</u>		<u>LONGITUDE</u>	
01	917	BJY	4265	E	842587	679190	37°	3.7933'	116°	3.2017'
02	950	2-1 SUBSTA	4379	E	871556	672782	37	8.5750	116	4.4833
03	964	WELL ER 3-1	4703	E	826499	712747	37	1.1055	115	56.3282
03	918	BUNKER 3-300	4300	E	836967	685407	37	2.8290	116	1.9570
03	823	U3AH/AT N		O	836569	686383	37	3.0833	116	1.6083
03	821	U3AH/AT S		O	835324	686871	37	2.9400	116	1.5750
03	822	U-3bh N		O	836866	688284	37	2.7000	116	1.2980
03	824	U-3bh S		O	835144	688397	37	2.99	116	1.6317
04	603	BUNKER T-4	4400	E	854070	664356	37	5.7032	116	6.2397
05	700	RWMS NE (#4)	3200	O	767997	709401	36	51.4667	115	57.1067
05	709	RWMS W (#7)	3200	O	767963	707412	36	51.3117	115	57.5167
05	716	RWMS S (#9)	3200	O	766036	707410	36	51.1383	115	57.3440
05	961	RWMSTPBLGN	3210	O	766134	708783	36	51.1625	115	57.2355
05	608	WEF NE (RWMS#1)	3300	O	765772	709329	36	51.1200	115	57.0900
05	607	WEF SW	3000	O	765611	708975	36	51.0600	115	57.1900
05	847	DOD	3548	E	772070	709866	36	52.1367	115	57.0033
06	712	YUCCA		E	797908	683207	36	56.4267	116	2.4367
07	705	UE7NS		E	855887	694998	37	5.9683	115	59.9333
09	897	AREA 9-300		E	864602	682310	37	7.4183	116	2.5317
10	893	SEDAN CRATER	4410	E	886679	681275	37	11.0595	116	2.7152
15	706	EPA FARM		E	895614	681865	37	12.5300	116	2.5817
18	610	LITTLE FELLER II N		A			37	7.7130	116	17.6730
20	969	CABRIOLET	5800	E	922616	544590	37	17.0730	116	30.8570
20	601	SCHOONER	5660	E	944477	528552	37	20.6800	116	34.1600
25	889	E-MAD NO	3772	B	748974	606467	36	48.0350	116	18.5517
30	610	BUGGY N		A						
<u>NAFR</u>										
13	604	PROJECT 57	4206	O	941228	721597	37	20.0000	115	54.3200
52		CLEAN SLT II	5642	O	1077300	502620	37	45.7850	116	36.9110
52	967	CLEAN SLT III	5494	O	1099145	489035	37	46.1700	116	42.3300
52	966	DBLE TRACKS	5042	O	1076971	407161	37	42.4900	116	59.3100

NOTE: E = Environmental sampler, O = Operational sampler, B = Background sampler, and A = Assessment sampler.

Table E-3 Airborne Tritium Concentrations on the NTS - 1996

<u>Location</u>	<u>Number</u>	<u>³H Concentration (10⁻⁶ pCi/mL)</u>				
		<u>Maximum</u>	<u>Minimum</u>	<u>Arithmetic Mean</u>	<u>Standard Deviation</u>	<u>Mean as %DCG</u>
Area 1, BJY	25	3.1	-2.0	0.63	0.89	<0.01
Area 3, Mud Plant	24	3.1	-0.81	0.76	0.88	<0.01
Area 3, U-3ah/at N	13	5.0	-2.7	0.54	5.8	<0.01
Area 5, RWMS No. 1	26	5.4	-2.0	2.3	1.7	0.023
Area 5, RWMS No. 4	27	17	0.22	5.4	4.1	0.054
Area 5, RWMS No. 6	26	9.3	-0.30	2.8	2.4	0.028
Area 5, RWMS No. 8	23	7.4	-0.082	2.8	2.2	0.028
Area 10, SEDAN Crater	25	26	1.5	8.5	6.9	0.085
Area 12, Complex	24	5.5	-1.2	0.84	1.3	<0.01
Area 12, E Tunnel Pond #1	25	35	-0.48	12	9.8	1.2
Area 15, EPA Farm	23	14.	1.7	5.3	2.9	0.053
Area 23, H&S Bldg.	24	1.1	-0.85	0.11	0.53	<0.01

Note: Shading indicates the six locations eliminated from the network. Stations RWMS 3, 5, 7, and 9 were eliminated in 1997.

Table E-4 Offsite Air Sampling Networks

<u>Station No.</u>	<u>Location</u>	<u>Sampling Frequency</u>	<u>Types of Analyses</u>
<u>High-Volume Samplers</u>			
001	Alamo, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
--	Beatty, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
119	Rachel, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
--	Indian Springs, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
--	Amargosa, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
--	Goldfield, NV	Monthly	γ , ²³⁸ Pu, ²³⁹⁺²⁴⁰ Pu
<u>Low-Volume HTO Samplers</u>			
--	Amargosa Valley, NV	Biweekly	Tritium
--	Indian Springs, NV	Biweekly	Tritium

Table E-5 Sampling Network for HTO-in-Air, 1998

<u>AREA/NO. LOCATION</u>			<u>ALT</u>		<u>NSTATE</u>	<u>ESTATE</u>	<u>LATITUDE</u>		<u>LONGITUDE</u>	
01	113	BJY	4265	E	842587	679190	37°	3.7950'	116°	3.2033'
05	107	RWMS NE (#4)	3303	O	767997	709401	36	51.4667	115	57.1067
05	110	RWMS W (#7)	3250	O	767963	707412	36	51.3117	115	57.5167
05	112	RWMS S (#9)	3350	O	766036	707410	36	51.1383	115	57.3440
05	134	WEF SW	3000	O	765611	708975	36	51.0600	115	57.1900
05	137	WEF NE	3300	O			36	51.1200	115	57.0900
05	130	WELL 5B	3200	B	747313	704179	36	48.0650	115	58.2067
10	122	SEDAN CRATER	4410	E	886679	681275	37	11.0595	116	2.7152
12	131	STAKE T-18	7649	A			37	11.7340	116	12.9020
12	126	E TUNNEL PD2	5780	E	887774	639249	37	11.2800	116	11.3700
15	115	EPA FARM		E	895614	681865	37	12.5300	116	2.5800
20	132	SCHOONER	5660	A	944477	528552	37	20.6800	116	34.1600

NOTE: E = Environmental sampler, O = Operational sampler, B = Background sampler, and A = Assessment sampler

Distribution of $^{239,240}\text{Pu}$ on the NTS as of January 1, 1990. Isopleth levels are 500, 1,000, and 10,000 nCi/m^2 .

Figure E-1 Proposed Air Sampling Network for the NTS

Figure E-2 Proposed HTO in Atmospheric Moisture Sampling Network for the NTS

Figure E-3 Proposed Offsite Air Sampling Network

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3.0 DATA QUALITY OBJECTIVES PROCESS FOR SURFACE WATER MONITORING

STEP 1: STATE THE PROBLEM

There are no flowing streams at the NTS. Surface drainages for Yucca Flat and Frenchmen Flat are in closed basins, draining into dry lake beds (playas) in each valley. The water collected in these playas is returned to the atmosphere via evaporation. Infiltrated water at the lower elevations does not result in recharging the groundwater. The other parts of the NTS drain via arroyos and dry stream beds that carry water only during intense storms. Rainfall and snow (at higher elevations) quickly infiltrate into permeable sands and gravels and fractured bedrock. The northern portion of the NTS drains out of the NTS boundaries into the NAFR and into the closed basins and playas in Kawich Valley and Gold Flat. The western half and southern part of the NTS drain toward the ephemeral Amargosa River channel, which drains into Death Valley, California. Various springs emerge from perched groundwater lenses at the NTS, with low discharge rates. Surface water (spring water) is not used for DOE activities. Precipitation and surface runoff have an insignificant role in transport of radionuclides to the offsite environment.

Flood waters and storm runoff may also pose a threat to the integrity of the low-level waste disposal facilities. However, the performance assessments for Area 3 and Area 5 RWMSs show that surface water is not a credible pathway for release of radionuclides from these facilities.

Man-made bodies of waters exist at the NTS, including open reservoirs that contain water pumped from wells and used for industrial purposes, containment ponds that hold effluents discharged from tunnels and well development activities, and sewage lagoons that contain effluents discharged from sanitary sewers. These water bodies are secondary source areas of radionuclides from which releases into environmental media are possible. Radionuclides are introduced into these water bodies by discharge of effluents and by deposition of airborne particulates. The radionuclides in the surface waters may migrate into the groundwater or become airborne through evaporation and/or resuspension and be taken up by resident biota.

The current routine surface water monitoring programs at the NTS include sampling of water at various containment ponds, sewage lagoons, open reservoirs, and natural springs onsite and offsite. During 1998, onsite locations were monitored by Bechtel Nevada (BN) under the environmental monitoring program. Offsite springs and water bodies were monitored by the EPA's Center for Environmental Restoration, Monitoring, and Emergency Response of the Radiation & Indoor Environments National Laboratory in Las Vegas, Nevada (R&IE-LV), with support from the DRI, as part of the Long-Term Hydrologic Monitoring Program (LTHMP).

The Clean Water Act establishes ambient water quality standards and effluent discharge limitations for facilities discharging into the waters of the United States. Because there are no wastewater discharges to surface waters onsite and offsite, there are no National Pollutant Discharge Elimination System (NDPES) permits for the NTS. Effluent discharges from NTS operations are regulated by the state of Nevada under the Nevada Water Pollution Control Act

(Nevada Revised Statutes [NRS] 445.131-354). Wastewater influent into sewage lagoons is allowed by the state general permit GNEV93001. The attached tables reference all regulatory drivers germane to radiological monitoring of surface waters.

Containment Ponds

Containment ponds are zero-discharge facilities that include the ponds receiving water from the tunnels in Rainier Mesa in Area 12, where nuclear devices had been tested, and all other ponds built to contain water pumped from wells drilled to characterize groundwater at the NTS.

Perched water – infiltrated rain and snow – in the fractures in the zeolitized rock of the tunnels is the source of the liquid water discharging from the tunnels. Water drains from the tunnels to ponds near the portal. The pond water contains several radionuclides, including ^3H , ^{238}Pu , ^{239}Pu , ^{137}Cs , ^{125}Sb , and ^{106}Ru . When pond water evaporates, tritium vapor is released to the atmosphere. To establish compliance, the concentrations of radionuclides in water samples are compared against the Derived Concentration Guides (DCGs) listed in DOE Order 5400.5.

Tunnel discharge water and pond water has been monitored for at least 25 years on a monthly basis. Fairly constant concentration of tritium has been observed in discharge water. Currently, N and T Tunnels have been sealed, and discharge occurs from E Tunnel only. At the ponds associated with groundwater characterization wells such as those in Area 20, tritium is the only radionuclide detected.

Sewage Ponds

Nine sewage lagoons at the NTS receive effluents from sewage treatment plants permitted by the state. Routine sewage lagoon monitoring is designed to meet regulatory mandates in the state discharge permit.

Open Reservoirs

Fifteen open reservoirs intermittently contain water pumped from supply wells and used for industrial purposes. Reservoir water is sampled to monitor presence of any radionuclides.

Springs

Nine natural springs offsite are sampled when springs provide water sufficient for sampling.

Type of Radionuclide Analysis and Sampling Frequency

The type of analysis currently performed for onsite locations include gamma spectroscopy, gross beta, tritium, ^{238}Pu , $^{239+240}\text{Pu}$, and ^{90}Sr . A grab sample is taken annually at open reservoirs and natural springs, and quarterly at containment ponds and sewage lagoons. Analysis for ^{90}Sr is performed annually at all sites.

At offsite locations, gamma spectrometric analysis is performed on samples taken quarterly, and tritium analysis is performed semiannually.

Regulation: Title 40 CFR 141	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	141.1
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	141.15, 141.16
Frequency of monitoring	141.26
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	141.25
Action levels	141.15, 141.16
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: DOE Order 5400.1	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	Ch IV, Parts 1.5.7.9.10
Verify compliance with applicable environmental laws and regulations	IV 9 (a) , (b), (c)
Verify compliance with environmental commitments	IV 9 (a) , (b), (c)
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	IV 5
Frequency of monitoring	IV 5
Location of monitoring points	IV
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	IV 10(a)
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: DOE Order 5400.5	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	I(8) (b), II (6)
Verify compliance with applicable environmental laws and regulations	I(8) (a)
Verify compliance with environmental commitments	I(8) (a)
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	II (6)
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	III
Quality assurance plan required	III
Rationale for monitoring required	III
Verify compliance with dose limits	II (1), II (6)
Predict offsite impacts	II (1), II (6)

Regulation: DOE Order 5820.2A	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	I (3) (b) (3), III (3) (k)
Verify compliance with applicable environmental laws and regulations	I (3) (b) (3) (e)
Verify compliance with environmental commitments	III (3) (k)
Characterize and define trends in the condition of environmental media	III (3) (k)
Establish baselines of environmental quality	III (3) (k)
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	III (3) (k)
Perform exposure pathway analysis	III (3) (b)
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	I (3) (b) (3)
Quality assurance plan required	III (3) (l)
Rationale for monitoring required	III (3) (k)
Verify compliance with dose limits	III (3) (k)
Predict offsite impacts	III (3) (k)

Regulation: DOE/EH-0173T	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	1. 5
Verify compliance with applicable environmental laws and regulations	1. 5
Verify compliance with environmental commitments	1. 5
Characterize and define trends in the condition of environmental media	1. 5
Establish baselines of environmental quality	1. 5
Identify and quantify new or existing environmental quality problems	1. 5
Measure releases, migration, subsidence, and performance changes	5
Perform exposure pathway analysis	8
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	5.10.2
Location of monitoring points	5.10.1.1
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	5.10.3
Analysis method	6
Action levels	
Quality assurance plan required	10
Rationale for monitoring required	5.1
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: Permit GNEV93001	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	I D
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	I D
Location of monitoring points	III B
Equipment, instrumentation, and facilities to be used for measurements	III B
Method to be used for obtaining environmental samples	I C
Analysis method	I C
Action levels	App II, III
Quality assurance plan required	I A, I B
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: Nevada Administrative Code	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	444.683. -7488. -749
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	444.7487
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: Nevada Revised Statutes	Media: Surface Water
Plan Element	Citation
	Location
Use an environmental monitoring program	534.110 2(a)
Verify compliance with applicable environmental laws and regulations	445.361- 445.399
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

STEP 2: THE DECISION

The principal study question: Are concentrations of radionuclides in surface water bodies at the NTS and its vicinity at levels which are harmful to the public health and the environment, and are permitted facilities in compliance with permit discharge limits?

Alternative actions:

- 1) Yes, they are.
- 2) No, they are not.

STEP 3: THE INPUTS TO THE DECISION

Initiate a sampling program and/or evaluate the existing programs to derive the concentrations of radionuclides in the surface waters and determine whether or not surface water concentrations of radionuclides pose a risk to the public and the environment and/or are in compliance with permit requirements. Other inputs include:

- NTS Discharge permit (Water Pollution Control General Permit GNEV93001), issued by Nevada Division of Environmental Protection per Nevada Pollution Control Act
- Historic discharge and radiological data and analysis
- Site hydrology
- Design features
- Process knowledge
- Derived concentration guides: reference values listed in DOE Order 5400.5, based on 4 mrem committed effective dose equivalent (CEDE) (National Primary Drinking Water Regulations) for the radionuclide taken into the body by ingestion of water during one year (730 liters).

STEP 4: THE BOUNDARIES OF THE STUDY

Spatial: NTS locations with operational discharges and associated engineered impoundments.

Temporal: Operational Period.

STEP 5: DEVELOP A DECISION RULE

Parameters that characterize the population: Concentrations of radionuclides in the surface water bodies.

Action level for the study: Permitted influent and effluent limits on concentrations as specified in the general permit; DCGs.

Decision rule: If concentrations of radionuclides in surface waters exceed the permitted limits or the DCGs, then perform confirmatory monitoring. If it confirms the exceedance of the action level, propose corrective actions. Otherwise, continue monitoring (influent monitoring, and monitoring of surface water body contents) at permitted frequency and using permitted analytical methods.

The decision logic is shown on Figure E-4.

Figure E-4 Surface Water Monitoring Decision Logic

STEP 6: SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

Because the working group has decided that there will not be a statistical design to support the routine radiological surface water monitoring (because of the existence of permits which dictate sampling requirements at the existing facilities), the sampling design error is not addressed.

STEP 7: OPTIMIZE THE DESIGN

The proposed monitoring program was developed after establishing the need for monitoring, and reviewing the current monitoring program's effectiveness in resolving the DQO decision rule. DOE guidance DOE/EH-0173T provides minimum criteria for determining need for environmental surveillance, which are applicable to determining the need for monitoring of surface water bodies (natural and man-made). The criteria include the following:

- **Routine surveillance of all pathways** (ingestion, inhalation, and immersion and submersion doses): When feasible, routine measurements of radiation should be performed at those sites that, as determined by site-specific exposure pathway analysis, might result in an annual dose of site origin at the site boundary, if the total exceeds 5 mrem effective dose equivalent (EDE), or 100 person-rem collective dose equivalent within a radius of 80 km (50 mi) of a central point in the site.
 - ▶ **Periodic confirmation:** Environmental surveillance measurements may be performed periodically, but should be performed at least every five years, to confirm the low dose levels, if the projected annual EDE of site origin is less than or equal to 0.1 mrem.
 - ▶ **Pathway measurements:** Effluent streams which may contribute to critical pathways should be monitored as part of the site routine effluent monitoring and environmental surveillance programs.
- **Use of control data:** Use of data should be based on statistically significant differences between the point of measurement and background (or control) data.
- **Unplanned releases:** Provisions should be made, as appropriate, for the detection and quantification of unplanned releases of radionuclides to the environment.

The proposed monitoring program was developed after establishing the need for monitoring, and reviewing the current monitoring program's effectiveness in resolving the DQO decision rule. The proposed program elements (sampling locations, radiological parameters and action levels, and sampling frequency) are described below.

Sampling Locations

Historic radiological data from the open reservoirs and the onsite springs indicate that the concentrations of radionuclides in these water bodies have been consistently below the DCGs listed in DOE Order 5400.5. These water bodies do not contribute any significant dose to the public and the environment. Furthermore, these onsite springs are not hydrologically connected to any of the aquifers that may be impacted by the underground nuclear tests. Open reservoirs do not receive any significant fallout of airborne radionuclides since a moratorium on atmospheric testing has been in existence since 1963. Therefore, the proposed program does not include sampling of the onsite springs and the open reservoirs. However, the continued monitoring of containment ponds and sewage lagoons which do receive effluent from potentially contaminated sources is proposed, as required under the current state permit. The offsite springs that are

discharge locations for the local and regional aquifers (such as those in the Amargosa Valley) will be included in the proposed program. Sampling locations for the proposed program are listed and shown in Chapter 4 of the RREMP.

Parameters and Action Levels

The proposed parameters include gamma spectroscopy, gross beta, tritium, ^{238}Pu , $^{239+240}\text{Pu}$, and ^{90}Sr . The action levels for permitted sites will be the limits established by the state permits, and for other sites, will be the DCGs listed in DOE Order 5400.5.

Sampling Frequency

The sampling and analysis will be performed quarterly with the exception that ^{90}Sr will be analyzed annually.

The proposed program elements (sampling locations, radiological parameters and action levels, and sampling frequency) are described in Chapter 4 of the RREMP.

4.0 DATA QUALITY OBJECTIVES PROCESS FOR GROUNDWATER MONITORING

STEP 1: STATE THE PROBLEM

Groundwater at the NTS has been impacted by the sources of man-made radionuclides from past DOE operations on the NTS. The sources with potential groundwater impacts are the following: contaminated surface and shallow vadose zone soils (contaminated with radionuclides because of atmospheric testing conducted prior to 1962 and/or current waste management disposal operations), and the deep vadose zone and groundwater (contaminated with radionuclides because of underground nuclear testing). Potential for groundwater contamination from surface and shallow vadose zone sources is shown to be extremely small. Zones of groundwater at the underground nuclear test sites conducted below the groundwater table have already been contaminated with radionuclides. Therefore, expansion of the plumes from the underground test locations may cause further degradation of the groundwater at the NTS and migration of radionuclides offsite.

Groundwater is being monitored on- and offsite NTS by several programs designed to comply with various regulatory drivers. Onsite water supply wells are sampled by BN to determine compliance with the drinking water regulations under the state permit. Routine water level measurements have been performed by the U.S. Geological Survey (USGS). Numerous wells have been installed since the 1950s as part of various programs to characterize the radionuclide content of the underground test cavities, and to simply characterize the groundwater. Some onsite wells and a network of offsite water supply wells have been monitored under the LTHMP. Monitoring wells have been installed to comply with the requirements of permitted facilities. These programs are briefly discussed below to identify the wells that are the candidate monitoring locations for the routine radiological environmental monitoring program for groundwater.

Groundwater is the only local source of drinking water at the NTS. Groundwaters that are sources of drinking water are regulated under the Safe Drinking Water Act (SDWA) by the requirements of Title 40 CFR 141, "National Drinking Water Regulations." The state of Nevada enforces the SDWA regulations under NRS Chapters 445.361 to 445.399. It is the policy of the state to provide water that is safe for drinking and other domestic purposes (NRS 445.361). A public water system is defined as any system that provides the public with piped water for human consumption if the system has 15 or more service connections or regularly serves 25 or more people for 60 or more days per year (NRS 445.376). The state board of health is required to adopt the primary and secondary drinking water standards established by the federal SDWA (NRS 445.379). Nevada Administrative Code (NAC) Chapter 445A.450-445A.492 describes the water quality requirements of public water systems by adopting the primary standards of the National Primary Drinking Water Regulations listed in Title 40 CFR 141. The attached tables show the regulatory drivers germane to radiological monitoring of groundwater.

The state permit for the NTS includes five drinking water supply systems. The water supply system consists of 14 wells, 10 of which supply potable water to the distribution systems. The water is pumped from the wells to the points of consumption. Drinking water is also sampled at seven end-points to provide a check on the integrity of the distribution system. NRS 534.110 requires periodic statements of water elevations, water used, and acreage on which water was used from all holders of permits and claimants of vested rights.

Up to 12 supply wells are sampled quarterly, and 7 consumption points (tap water) are sampled monthly. Tap water samples are analyzed for gamma emitters, gross beta, tritium, ^{238}Pu , $^{239+240}\text{Pu}$, gross alpha (quarterly), and ^{90}Sr (annually). Samples from potable supply wells are analyzed for gamma emitters, gross alpha, gross beta, tritium (by enrichment method), $^{226+228}\text{Ra}$, ^{238}Pu , $^{239+240}\text{Pu}$, and ^{90}Sr . Samples from nonpotable wells are analyzed for gamma emitters, gross alpha, gross beta, tritium, ^{238}Pu , $^{239+240}\text{Pu}$, and ^{90}Sr (annually).

Well water levels have been monitored annually by the USGS at approximately 156 locations onsite and offsite. Data are analyzed for trends, impacts of water usage, and for the calibration input to groundwater flow models. Both USGS and BN monitor water usage, as required by NRS 534.110.

The regulatory driver for environmental restorations at the NTS is the Federal Facility Agreement and Consent Order (FFACO) between the state of Nevada Department of Conservation and Natural Resources, Division of Environmental Protection; the Department of Energy, and the U.S. Department of Defense (DOE, 1997).

The corrective action strategy for environmental restoration in the FFACO includes corrective actions at UGTA sites. For UGTA sites, FFACO requires establishing specific sampling and monitoring requirements, including drilling and subsurface sampling, designed to determine whether releases of pollutants and/or hazardous wastes or potential releases of pollutants and/or hazardous wastes are migrating or potentially could migrate and, if so, identify the constituents, their concentrations, and the nature and extent of that migration. Corrective actions include preclosure and long-term monitoring requirements at closure.

The FFACO identifies 908 historical nuclear detonations which occurred in shafts or tunnels at the NTS. They are categorized into 878 corrective action sites (CASs) assigned to UGTA. These CASs are grouped into six corrective action units (CAUs) which are geographically distinct, and which have different contaminant source, and geologic and hydrogeologic characteristics related to their location. These CAUs are Yucca Flat, Frenchman Flat, Western Pahute Mesa, Central Pahute Mesa, Rainier Mesa/Shoshone Mountain, and Climax Mine.

The objective of the UGTA program is to define boundaries around each UGTA CAU that establish zones of groundwater unsafe for domestic and municipal use. A regional groundwater modeling has been performed to provide an initial basis for assessing flowpaths from the CAUs. A second phase of the modeling and characterizations (including drilling of new wells) will refine the CAU boundaries through CAU-specific models with site-specific data. Wells will be

established and monitored for a minimum of five years for model verifications. The closure activities under UGTA will be accomplished through the year 2014. Postclosure monitoring will continue for 50 years after closure of each CAU.

The hydrologic source term – information about the type and concentration of radionuclides dissolved in groundwater, or potentially available to groundwater – is necessary for current radionuclide migration studies at the NTS. This information is acquired through sampling the groundwater from within or near cavities produced by underground nuclear tests conducted below the water table. This source term or “hot well” sampling has been part of the groundwater monitoring program for the NTS since the mid-1970s. Presently, these efforts are coordinated and funded by the DOE/NV through the Hydrologic Resource Management Program (HRMP) – a multi-agency initiative with participation by Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), DRI, and the USGS – and the UGTA program. Until recently, hot-well sampling activities were not systematic, but based on opportunity rather than proactive initiatives. Consequently, there are fewer than 20 cavity or near-cavity wells available for sampling.

On average, perhaps, three or four wells would be sampled each year. For most wells, sample collection utilizes a modified stainless steel bailer on a wireline. Two-liter capacity pressure tubes collect water samples from discrete depths. Separate runs into the well tubing would be done to sample different depth intervals (typically, two or three intervals) to address the possibility of a heterogeneous distribution due to stratification or fractionation, etc. In recent years, several hot wells have been completed with downhole pumps. The ability to pump the wells is expected to yield high-quality data and allow for more sophisticated and definitive studies. Water samples are usually split and sent to both LLNL and LANL for analyses. In addition to identifying the radionuclides and their concentrations, laboratory studies include radionuclide mobility and attenuation, and colloid investigations.

The LTHMP was established by DOE/NV in 1972 to determine whether or not radioactivity from underground nuclear tests has contaminated the groundwater in the vicinity of the test sites across the nation. The design function of the LTHMP at the NTS is to monitor groundwater and drinking water sources at the NTS and in all communities near the NTS. The onsite network in 1996 included 21 wells; offsite, 12 wells, 9 springs, and a water body. Samples are analyzed quarterly for gamma emitters, and semiannually for tritium.

A 1-gallon sample is collected quarterly and analyzed by high-resolution gamma spectrometry. Two 500-ml samples are analyzed for tritium by the conventional method. If the sample tritium concentration is less than 700 pCi/L, analysis is repeated using the enrichment method, which has a detection limit of about 10 pCi/L.

The Pit 3 Mixed Waste Disposal Unit located in the Area 5 RWMS is under Resource Conservation and Recovery Act (RCRA) Interim Status, in compliance with Title 40 CFR 264. A groundwater monitoring program has been in effect since 1993 and is designed to detect any leakage of hazardous constituents to the groundwater, using three pilot wells drilled into the uppermost aquifer. The groundwater monitoring program, approved by the state of Nevada, has

established parameters, action levels, and protocols for detection monitoring and compliance monitoring. The monitoring wells around the Area 5 RWMS are sampled routinely. A select set of indicator parameters is sampled as detection monitoring parameters, including tritium and gross beta. If samples indicate exceedance of action levels, the facility is required to perform a compliance monitoring and, if necessary, a corrective action program. Compliance monitoring requires at least semiannual monitoring of permitted parameters and constituents in Appendix IX. The concentrations of all compliance monitoring constituents are compared to the action levels to determine if corrective action is required.

To comply with the groundwater protection requirements of the state general permit GNEV93001, a monitoring well was installed (SM-23-1) in 1996 for the Area 23 infiltration basin.

There is a need for an integrated routine radiological monitoring program for groundwater at the NTS and its vicinity that is responsive to applicable DOE Order 5400 series drivers and that provides an early detection capability for the protection of the groundwater resources.

Regulation: Title 40 CFR 141	Media: Groundwater
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	141.1
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	141.15, 141.16
Frequency of monitoring	141.26
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	141.25
Action levels	141.15, 141.16
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: DOE Order 5400.1	Media: Groundwater
Plan Element	Citation Location
Use an environmental monitoring program	Ch IV, Parts 1,5,7,9,10
Verify compliance with applicable environmental laws and regulations	IV 9 (a) , (b), (c)
Verify compliance with environmental commitments	IV 9 (a) , (b), (c)
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	IV 5
Frequency of monitoring	IV 5
Location of monitoring points	IV
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	IV 10(a)
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: DOE Order 5400.5	Media: Groundwater
Plan Element	Citation Location
Use an environmental monitoring program	I(8) (b), II (6)
Verify compliance with applicable environmental laws and regulations	I(8) (a)
Verify compliance with environmental commitments	I(8) (a)
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	II (6)
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	III
Quality assurance plan required	III
Rationale for monitoring required	III
Verify compliance with dose limits	II (1), II (6)
Predict offsite impacts	II (1), II (6)

Regulation: DOE Order 5820.2A	Media: Groundwater
Plan Element	Citation Location
Use an environmental monitoring program	I (3) (b) (3), III (3) (k)
Verify compliance with applicable environmental laws and regulations	I (3) (b) (3) (e)
Verify compliance with environmental commitments	III (3) (k)
Characterize and define trends in the condition of environmental media	III (3) (k)
Establish baselines of environmental quality	III (3) (k)
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	III (3) (k)
Perform exposure pathway analysis	III (3) (b)
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	I (3) (b) (3)
Quality assurance plan required	III (3) (l)
Rationale for monitoring required	III (3) (k)
Verify compliance with dose limits	III (3) (k)
Predict offsite impacts	III (3) (k)

Regulation: DOE Order 6430.1	Media: Groundwater
Plan Element	Citation Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: DOE/EH-0173T	Media: Groundwater
Plan Element	Citation
	Location
Use an environmental monitoring program	1, 5
Verify compliance with applicable environmental laws and regulations	1, 5
Verify compliance with environmental commitments	1, 5
Characterize and define trends in the condition of environmental media	1, 5
Establish baselines of environmental quality	1, 5
Identify and quantify new or existing environmental quality problems	1, 5
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	8
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	5.10.2
Location of monitoring points	5.10.1.3
Equipment, instrumentation, and facilities to be used for measurements	6
Method to be used for obtaining environmental samples	5.10.3
Analysis method	6
Action levels	
Quality assurance plan required	10
Rationale for monitoring required	5.1
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: FFACO	Media: Groundwater
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	III
Verify compliance with environmental commitments	III
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	II.1
Measure releases, migration, subsidence, and performance changes	II.1.b
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	App VI
Location of monitoring points	App VI
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	App VI
Verify compliance with dose limits	App VI
Predict offsite impacts	App VI

Regulation: Permit GNEV93001	Media: Groundwater
Plan Element	Citation
	Location
Use an environmental monitoring program	I A, I B
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	I D
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	III B
Method to be used for obtaining environmental samples	
Analysis method	
Action levels	App II, III
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

Regulation: Nevada Administrative Code	Media: Groundwater
Plan Element	Citation
	Location
Use an environmental monitoring program	445A.22745
Verify compliance with applicable environmental laws and regulations	445A.453, -455
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	
Analysis method	445A.454, -457
Action levels	445A.222725
Quality assurance plan required	
Rationale for monitoring required	
Verify compliance with dose limits	
Predict offsite impacts	

STEP 2: IDENTIFY THE DECISION

Key Decisions

DECISION A:

Principal study question: Are onsite potable and nonpotable wells and offsite wells impacted by man-made radionuclides from past DOE operations on the NTS?

DECISION B:

Principal study question: Is groundwater at the NTS and its vicinity further degraded as a result of the expansion of the radionuclide plumes associated with the underground test areas?

DECISION C:

Principal study question: Are there groundwater impacts from surface and shallow vadose zone sources of radionuclides on the NTS (including waste treatment, storage, and disposal [TSD] facilities: Area 3, Area 6, and U-10c landfills; Area 3 and Area 5 RWMSs; sewage lagoons; tunnel ponds, open reservoirs; contaminated soil sites)?

Alternative Actions Resulting from Resolution of Decisions

A1: No, they are not. Continue with existing monitoring programs.

A2: Yes, they are. Perform confirmatory sampling, which may lead to more frequent sampling including an increased suite of sampling parameters or management assessment leading to recommendations for impacted wells.

B1: Yes. Perform preliminary hydrogeologic evaluations (water levels, water use, and background water quality; source term; and flow and transport). If an upward trend in tritium concentration continues, modify the sampling plan to include other radionuclides and water quality parameters, and coordinate with UGTA for assessment.

B2: No. Continue sampling as planned.

C1: Yes, there are groundwater impacts. Move to compliance monitoring, results of which may lead to continuation of detection monitoring at existing or revised levels (frequency, radionuclides monitored, analytical methods used) or recommend taking corrective action followed by corrective action monitoring.

C2: No, there are no groundwater impacts. Continue monitoring at existing or reduced level; or stop monitoring groundwater and recommend vadose zone or air monitoring.

STEP 3: INPUT TO THE DECISION

DECISION A:

- Water quality data from all current water supply wells (point-of-use wells)
- Statistics of past analytical data at these wells, including temporal and spatial trends
- Water levels and water usage
- Revised monitoring network, including offsite water supply wells

DECISION B:

- Source term
- Nature and extent of plumes
- Hydrogeologic conceptual model
- Potentiometric surfaces
- Source characterization wells (location, type, and activity of radionuclides)
- Existing monitoring programs
- Candidate wells for completion as new monitoring stations
- An optimized monitoring network
- Historic and new water quality, and sampling data statistics and trends

DECISION C:

- RCRA Permit
- Water Pollution Control General Permit GNEV93001
- Sources of radionuclides
- Analysis of source term
- Conceptual model for release of radionuclides
- Climatic data
- Vadose zone modeling
- Sampling data and statistics

STEP 4: BOUNDARIES OF THE STUDY

DECISION A:

Spatial: NTS and its vicinity.

Temporal: Operational period for onsite wells; institutional control period for offsite wells.

DECISION B:

Spatial: UGTA regional model 200-year advective transport boundary.

Temporal: 50 years after last UGTA corrective action plan.

DECISION C:

Spatial: Facility boundary (TSD, lagoon, pond, reservoir).

Temporal: Operational period for non-RCRA units; 30-year postclosure for the RCRA regulated units.

STEP 5: DEVELOP A DECISION RULE

DECISION A:

Parameters that characterize the population: Concentration of tritium in well water.

Action level for the study: 10 percent of the drinking water standard for tritium.

Decision rule: If tritium concentration in well water exceeds the action level, then perform confirmatory sampling. Otherwise, continue monitoring as planned. If confirmatory sampling confirms exceedance, increase sampling frequency to a maximum of one per month. Evaluate the trend; if an increasing trend exists and concentration of tritium is near the action level, then recommend management assessment. Otherwise, continue monitoring at increased frequency.

The decision logic is shown on Figure E-5.

DECISION B:

Parameters that characterize the population: Concentration of radionuclides; well-specific trends.

Action level for the study: 10 percent of the drinking water standard for tritium or current concentration level for tritium, well-specific trends.

Decision rule: If radionuclide concentrations in water do not exceed action levels, then continue monitoring as planned. Otherwise, perform hydrogeologic evaluations (water levels, water use, and background water quality; source term; and flow and transport). If an upward trend in tritium concentration continues, modify the sampling plan to include other radionuclides and water quality parameters, and coordinate with UGTA for assessment.

The decision logic is shown on Figure E-6.

DECISION C:

Parameters that characterize the population: Radionuclide concentrations in well water.

Action level for the study: Permit levels for the Pit 3 RCRA-regulated mixed waste unit; derived concentration guides in DOE Order 5400.5, based on 4 mrem CEDE for the radionuclides taken into the body by ingestion of water during one year (730 liters); or levels specified in the General Permit GNEV93001.

Decision rule: If concentrations of radionuclides in well water do not exceed the action levels determined for each facility, evaluate the program. If this evaluation demonstrates that there is no release potential from the facility, recommend stopping monitoring groundwater, and obtain a

groundwater monitoring waiver and initiate a vadose zone monitoring program. Otherwise, continue with monitoring as planned. If concentrations of radionuclides in well water exceed the action levels determined for each facility, perform confirmatory sampling. If compliance monitoring indicates radionuclides are in the groundwater, then recommend taking corrective action and follow by corrective action monitoring. Otherwise, evaluate the program. If this evaluation demonstrates that there is no release potential from the facility, recommend stopping monitoring groundwater, and obtain a groundwater monitoring waiver and initiate a vadose zone monitoring program. Otherwise, continue with monitoring as planned.

The decision logic is shown on Figure E-7.

Figure E-5 GW Monitoring Decision Logic – Decision A

Figure E-6 GW Monitoring Decision Logic – Decision B

Figure E-7 GW Monitoring Decision Logic – Decision C

STEP 6: SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

The working group has decided that the design of the routine radiological groundwater monitoring program will not be based on statistics (because of large uncertainty associated with site hydrogeology, source term, and limiting budgetary and time constraints). Therefore, no statistical uncertainty and error parameters were developed.

STEP 7: OPTIMIZE THE DESIGN

The design of the routine radiological monitoring for groundwater is based on professional judgment. A set of criteria was established to address the number and location of sampling wells, sampling well construction, sampling frequency, and sampling parameters. Criteria established to support the decision rule A (public health concern at water supply wells) differs from those which support the decision rule B (groundwater impacts due to underground testing areas). The monitoring of wells associated with decision rule C (groundwater impacts from surface activities and disposal operations in shallow vadose zone) are driven by permit agreements; therefore, current data will be sufficient to resolve the alternative actions associated with this decision.

Criteria for selection of point-of-use wells to support Decision A:

No new water demand currently exists at the NTS; therefore, the water supply system onsite (potable and nonpotable wells) will not require addition of new wells. The proposed program will include all onsite water supply wells. The offsite point-of-use wells for the routine radiological groundwater monitoring program are selected based on the following criteria (see Figure E-8 for the screening logic):

1. Consider point-of-use wells downgradient of NTS (in the general direction of regional groundwater flow). Current site knowledge eliminates the possibility of transport of radionuclides from source areas to wells upgradient of NTS (opposite to the general direction of regional groundwater flow).
2. Prefer point-of-use wells close to NTS boundary, and in close proximity to the underground testing areas.
3. Give preference to community wells.
4. Give preference to high-yield, high-volume wells.
5. Consider accessibility. Must be able to secure access.
6. Consult with Community Technical Liaison Program/Stakeholder.

Criteria for selection of point-of-opportunity wells to support Decision B:

The screening logic is shown on Figure E-9.

PATH A:

1. Consider point-of-opportunity wells downgradient of source areas.
2. Give preference to wells within 1,000 m (3,280 ft) of underground testing areas which are located below or within two cavity radii of the water table.
3. Select wells assessing relevant hydrostratigraphic units within structural blocks having an upgradient source or sources.
4. Give priority to wells in most transmissive units that also contain most of the underground test locations.

PATH B:

1. Consider point-of-opportunity wells downgradient of source areas.
2. Select NTS point-of-opportunity wells located in the regional aquifer.

After selecting point-of-use wells, wells were further screened based on the following criteria:

- Criteria for construction parameters:
 1. Give priority to wells with immediate access to the aquifer.
 2. Give priority to wells with diameters already appropriate for sampling.
 3. Give priority to wells that are already completed (developed, casing exists, etc.).
- Criteria for sampling frequency:
 1. Require more frequent sampling for water supply wells and wells within close proximity of source areas.
 2. For wells without established background data, require frequent sampling for one year.
- Criteria for analytical parameters:
 1. In addition to sampling for tritium, specific wells may require additional parameters (i.e., source characterization wells, parameters to confirm existence of colloidal transport, etc.).
 2. Require sampling for water quality and indicator parameters at the first year of sampling for wells that do not have a previously established baseline.
 3. Require collection of field indicator parameters and water levels at each sampling event.

Proposed Network of Monitoring Wells: The proposed onsite and offsite wells, and other onsite wells that may be incorporated into the program in the future, will be presented in the sampling and analysis plan for the groundwater portion of the routine radiological environmental monitoring plan.

Water-level measurements will be performed for each sampling event at all wells. The network proposed for water-level measurements will also include onsite wells which are to be monitored only for water levels. The network for the water-level measurements will be presented in the sampling and analysis plan.

Sampling Parameters and Action Levels: Unless changes in permit conditions occur, parameters and action levels for monitoring of water supply wells and the permitted facilities on the NTS will remain the same. All wells will be sampled for tritium and additional parameters. The parameter of interest for the routine radiological monitoring for groundwater is tritium. The action level for tritium is proposed to be 10 percent of the drinking water standard for tritium. Analyzing for tritium by standard method (detection limit ranges from 300 to 700 pCi/L) is a cost-effective means of satisfying the established DQOs. Values of field indicator parameters and water levels will be established at each sampling event. Samples for other parameters will be taken to establish trends. The proposed parameters are summarized in Table E-6.

Sampling Frequency: Sampling frequency for the wells in the proposed network will differ. Water supply wells and wells within close proximity of source areas will be sampled more frequently, and wells without established background data will be sampled more frequently for one year. Proposed sampling frequencies of the wells are summarized in Table E-6. Well-specific information will be provided in the sampling and analysis plan.

Figure E-8 Groundwater Monitoring Criteria for Selection of Offsite Point-of-Use Wells

Figure E-9 Groundwater Monitoring Criteria for Selection of Point-of-Opportunity Wells

Table E-6 Sampling Parameters and Frequencies of Analysis for Supply Wells

WELL TYPE	ANALYSIS	SAMPLE FREQUENCY	REGULATORY DRIVER
Potable Water Supply Within CAU	I & II	QUARTERLY	40 CFR 61 and DOE Order 5400
	III & IV	ANNUAL	40 CFR 61 and DOE Order 5400
Other Potable Water Supply	I & II	QUARTERLY	DOE Order 5400 Series
	III & IV	ANNUAL	DOE Order 5400 Series
CAU Non-Potable Water Supply	I	QUARTERLY	DOE Order 5400 Series
	II, III, & IV	ANNUAL	DOE Order 5400 Series
Other Non-Potable Water Supply	I	SEMI-ANNUAL	DOE Order 5400 Series
	II, III, & IV	BIENNIALY	DOE Order 5400 Series
Monitoring Well (Non water supply)	I	ANNUAL	DOE Order 5400 Series
	II, III, & IV	BIENNIALY	DOE Order 5400 Series
Source Characterization Well ¹	I, II, III, & IV	ANNUAL ²	DOE Order 5400 Series
New Wells	I, II, III, & IV	QUARTERLY ³	DOE Order 5400 Series

Note:

All parameters and frequencies of analysis are subject to revision after data is acquired and reviewed if justified. CAUs are as defined by UGTA Project.

- 1) Source Characterization Wells are currently known as the Hot Well Network. Additional sampling parameters will be specified for each hot well.
- 2) Annual frequency can be modified for well-specific sampling program.
- 3) After four quarterly samples are acquired, sampling parameters and frequency will be based on the well type.

Type I Analysis includes Standard Tritium; at select wells, enriched tritium analysis will be performed.

Type II Analysis includes Gross Alpha and Gross Beta.

Type III Analysis includes Gamma emitters, Plutonium, ⁹⁹Tc.

Type IV Analysis includes pH, Specific Conductivity, Temperature, Cations/Anions, Total Dissolved Solids, Alkalinity, and Bicarbonate.

5.0 DATA QUALITY OBJECTIVE PROCESS FOR CONTAMINATED SOILS MONITORING ON THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

Surface soils on the NTS were contaminated with long-lived radionuclides by atmospheric, Plowshare, safety tests, some underground tests that vented radioactive material to the surface, and rocket tests.

Types of Contaminants and Affected Media

Significant radionuclides in surface soils were identified by McArthur (1991) as ^{241}Am , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{60}Co , ^{137}Cs , ^{90}Sr , ^{152}Eu , ^{154}Eu , and ^{155}Eu .

Known or Potential Routes of Migration

Potential routes of migration include resuspension in air and surface water flows and ingestion by game animals that move offsite.

Known Human and Environmental Receptors

Because these sites are under active institutional control, they do not constitute a health threat to either workers or the general public. The sites are located in areas of restricted access and inadvertent human intrusion is prevented by fencing and posting warnings. Potential environmental receptors are game animals, which may ingest contaminated soil; or vegetation which has taken up radionuclides. In addition, resuspension into the air and movement away from the restricted areas could lead to inhalation by humans or animals. These pathways, however, are not considered by the soils media.

Exposure Pathways and Scenarios

The only exposed pathway considered is direct exposure to external radiation from the soil surface. Direct ingestion by humans is considered unlikely. These soils do provide a source of radioactivity to air, water, plant, and animal pathways.

Current and Future Land Use

For the purposes of this monitoring plan, it will be assumed that current land use will continue.

Sources of Historic Data Associated with Previous Data Collection Activities

Existing sources of information found in Bechtel (1996), McArthur (1991), and DOE (1995; 1977; 1975; 1974) include aerial surveys, demarcation surveys, reports from the Radionuclide Inventory Program, and historic thermoluminescent dosimeter (TLD) data.

Applicable Requirements

Applicable requirements are found in DOE Orders 5400.1, 5400.5, and DOE (1991). Detailed listings of specific requirements are shown in the attached tables.

The Contamination Problem

The NTS contaminated soils sites provide a source of radioactive material to air, water, plant, and animal pathways. A correct definition of the areal extent of the contaminated soil sites is required to evaluate transport through air, and secondarily to provide source information for planning monitoring of the surface water, plant, and animal pathways. In addition, monitoring of the contaminated soil sites on the Tonopah Test Range (TTR) would verify stabilization of soils following remediation. While the health threat to workers and the general public to direct exposure to external radiation from surface soils is negligible due to active institutional control, monitoring to verify the boundaries of the sites was determined to be appropriate.

Regulation: DOE Order 5400.1 [11/9/88]		
Plan Element	Citation	Surface
	Location	Soil
Use an environmental monitoring program	Ch IV Par 4.	*
Verify compliance with applicable environmental laws and regulations	Ch IV Par 5(b)	*
Verify compliance with environmental commitments	Ch IV Par 5(b)	*
Characterize and define trends in the condition of environmental media	Ch IV Par 5(b)	*
Establish baselines of environmental quality	Ch IV Par 5(b)	*
Identify and quantify new or existing environmental quality problems	Ch IV Par 5(b)	*
Measure releases, migration, subsidence, and performance changes		
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored	Ch IV Par 4.	*
Frequency of monitoring	Ch IV Par 4.	*
Location of monitoring points	Ch IV Par 4.	*
Equipment, instrumentation, and facilities to be used for measurements	Ch IV Par 4.	*
Method to be used for obtaining environmental samples	Ch IV Par 4.	*
Analysis method	Ch IV Par 4.	*
Action levels		
Quality assurance plan required	Ch IV Par 10(a)	*
Rationale for monitoring required	Ch IV Par 4.	*

Regulation: DOE Order 5400.5 [1/7/93]		
Plan Element	Citation Location	Surface Soil
Use an environmental monitoring program	Ch I Par 8	*
Verify compliance with applicable environmental laws and regulations	Ch I Par 2	*
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media		
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes	Ch I Par 8	*
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored		
Frequency of monitoring		
Location of monitoring points		
Equipment, instrumentation, and facilities to be used for measurements		
Method to be used for obtaining environmental samples		
Analysis method		
Action levels		
Quality assurance plan required		
Rationale for monitoring required		

Regulation: DOE/EH-0173T [January 1991]		
Plan Element	Citation Location	Surface Soil
Use an environmental monitoring program	Section 1.0	*
Verify compliance with applicable environmental laws and regulations		
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media	Section 5.9	*
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes		
Perform exposure pathway analysis	Section 5.1.1	*
Perform critical pathway analysis and document in ASER	Section 5.1.1	*
Parameters to be monitored	Section 5.9	*
Frequency of monitoring	Section 5.9.1	*
Location of monitoring points	Section 5.9.1	*
Equipment, instrumentation, and facilities to be used for measurements	Section 5.9.2	*
Method to be used for obtaining environmental samples	Section 5.9.2	*
Analysis method	Section 5.9	*
Action levels		
Quality assurance plan required	Section 10	*
Rationale for monitoring required	Section 5.1.1	*

STEP 2: IDENTIFY THE DECISION

Key Decision

Are the boundaries of the contaminated soil sites on the NTS and the remediated soils sites at TTR changing?

Alternative Actions Resulting from Resolution of Decision

If the boundaries do change, the specification of source terms in the air pathway exposure model should be modified.

Decision Statement

Determine if the location or areal extent of the contaminated surface soils at the NTS and TTR are changing and modify specification of source term for airborne radionuclide exposure evaluations accordingly.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decision(s)

The information needed to meet the environmental monitoring program objective is the location of site boundaries consistent with the requirements of Title 10 CFR 835, Appendix D.

Sources of Environmental Input

The boundary location data required by the Environmental Monitoring Program will be provided by surveys of contaminated soils sites presently being conducted by BN's Demarcation Project.

Basis for Establishing Contaminant-Specific Action Level(s)

The basis for verifying contaminant boundaries is the sensitivity of the air pathway exposure model to variations in the areal extent of the contaminated zone. No action level will be established.

Potential Sampling Approaches and Appropriate Analytical Methods

Sampling and analysis will be conducted according to plans developed by BN's Demarcation Project.

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

The demarcation surveys will be made at contaminated soil sites on the NTS.

Temporal Boundaries of the Decision

Boundary locations obtained from the demarcation surveys will apply to current conditions at the contaminated soil site. At present, BN's Demarcation Project plans to resurvey each site every five years.

Practical Constraints on Data Collection

Constraints on data collection will be determined by BN's Demarcation Project.

STEP 5: DEVELOP A DECISION RULE

Parameter(s) that Characterize the Population of Interest

These parameters are the location of site boundaries consistent with the requirements of Title 10 CFR 835, Appendix D.

Action Level(s) for the Decision(s)

No action levels will be set.

Decision Rule

Determine if the location or areal extent of the contaminated surface soils at the NTS and TTR are changing and modify specification of source term for airborne radionuclide exposure evaluations accordingly.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

This step is not applicable.

STEP 7: OPTIMIZE THE STUDY DESIGN

Design of the demarcation surveys will be conducted by BN's Demarcation Project.

REFERENCES

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6.0 DATA QUALITY OBJECTIVE PROCESS FOR VADOSE ZONE MONITORING ON THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

Radioactive waste disposal operations began at the NTS in 1961. Radioactive wastes consisting of low-level, transuranic, mixed, and classified materials were disposed in selected pits, trenches, landfills, and greater confinement disposal boreholes. The Area 3 RWMS accepts bulk and packaged low-level waste for disposal. The Area 5 RWMS accepts low-level waste, and NTS-generated mixed waste for disposal and packaged transuranic and NTS-generated transuranic mixed waste for storage. Both sites are presently active.

CASs have been designated on the NTS for environmental restoration. These sites fall into the four categories of Industrial, UGTA, Soil, and Offsites. Industrial sites range from landfills, mudpits, and leachfields to discarded or abandoned materials. These sites are identified in the FFACO of March 15, 1996. A total of 908 historical nuclear detonations occurred in shafts or tunnels at the NTS. These detonation sites are grouped into 878 CASs in the UGTA. The UGTA sites are in the process of being characterized and will not be considered for routine monitoring at this time. Contaminated soil sites were discussed previously and offsites are not in this group's scope.

Types of Contaminants and Affected Media

Radionuclides of concern for ER sites were identified as ^3H , ^{90}Sr , ^{137}Cs , ^{152}Eu , ^{155}Eu , ^{238}Pu , ^{239}Pu , and ^{240}Pu . Radionuclides of concern for waste management sites were identified as ^3H , ^{14}C , ^{90}Sr , ^{99}Tc , ^{238}U , ^{239}Pu , and ^{240}Pu .

Known or Potential Routes of Migration

Potential routes of migration include upward movement from the waste packages to the soil surface through advection, gaseous diffusion, plant uptake and bioturbation. Downward movement to the water table is considered unlikely at the RWMSs.

Known Human and Environmental Receptors

Because these sites are under active institutional control, they do not constitute a health threat to either workers or the general public. The sites are located in areas of restricted access and inadvertent human intrusion is prevented by fencing and posted warnings. Potential environmental receptors are game animals, which may ingest contaminated soil; or vegetation which has taken up radionuclides. In addition, resuspension into the air and movement away from the restricted areas could lead to inhalation by humans or animals. These pathways, however, are not considered by the soils media.

Exposure Pathways and Scenarios

Performance Assessments (PAs) completed for both the Area 3 and Area 5 RWMSs have determined exposure pathways and scenarios. These sites are currently under active institutional control and do not constitute a health threat to either workers or the general public. Scenarios considered by the PAs assumed loss of institutional control. Exposure to radionuclides while in the vadose zone is unlikely; however, migration in the vadose zone can provide a source of radioactivity to direct, air, water, plant, and animal pathways.

Current and Future Land Use

For the purposes of this monitoring plan, it will be assumed that current land use will continue.

Sources of Historic Data Associated with Previous Data Collection Activities

Existing sources of information consist of site characterization studies, PAs, and a Composite Analysis (CA) listed in the reference section. These studies focused on the RWMSs located in Areas 3 and 5 of the NTS. While site-specific differences will be found, the characteristics and hydrologic conceptual models developed for these sites are, in general, typical of alluvial valleys on the NTS.

Applicable Requirements

Applicable requirements are found in DOE Orders 5400.1, 5400.5, 5820.2A, Title 40 CFR 191, and DOE (1991). Detailed listings of specific requirements are shown in the attached tables.

The Contamination Problem

Radioactive Waste Management and Industrial Sites on the NTS provide potential sources of radioactive material to direct, air, water, plant, and animal pathways. Monitoring is required for maintenance of the PAs and CAs, performance assurance and regulatory compliance, and for other risk assessments.

Regulation: DOE Order 5400.1 [11/9/88]		
Plan Element	Citation Location	Vadose Zone
Use an environmental monitoring program	Ch IV Par 4.	*
Verify compliance with applicable environmental laws and regulations	Ch IV Par 5(b)	*
Verify compliance with environmental commitments	Ch IV Par 5(b)	*
Characterize and define trends in the condition of environmental media	Ch IV Par 5(b)	*
Establish baselines of environmental quality	Ch IV Par 5(b)	*
Identify and quantify new or existing environmental quality problems	Ch IV Par 5(b)	*
Measure releases, migration, subsidence, and performance changes		
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored	Ch IV Par 4.	*
Frequency of monitoring	Ch IV Par 4.	*
Location of monitoring points	Ch IV Par 4.	*
Equipment, instrumentation, and facilities to be used for measurements	Ch IV Par 4.	*
Method to be used for obtaining environmental samples	Ch IV Par 4.	*
Analysis method	Ch IV Par 4.	*
Action levels		
Quality assurance plan required	Ch IV Par 10(a)	*
Rationale for monitoring required	Ch IV Par 4.	*

Regulation: DOE Order 5400.5 [1/7/93]		
Plan Element	Citation Location	Vadose Zone
Use an environmental monitoring program	Ch I Par 8	*
Verify compliance with applicable environmental laws and regulations	Ch I Par 2	*
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media		
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes	Ch I Par 8	*
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored		
Frequency of monitoring		
Location of monitoring points		
Equipment, instrumentation, and facilities to be used for measurements		
Method to be used for obtaining environmental samples		
Analysis method		
Action levels		
Quality assurance plan required		
Rationale for monitoring required		

Regulation: DOE Order 5820.2A [9-26-88]		
Plan Element	Citation	Vadose
	Location	Zone
Use an environmental monitoring program	Ch III Par 3(k)	*
Verify compliance with applicable environmental laws and regulations		
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media	Ch III Par 3(k)	*
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes	Ch III Par 3(k)	*
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored	Ch III Par 3(k)	*
Frequency of monitoring		
Location of monitoring points	Ch III Par 3(b)	*
Equipment, instrumentation, and facilities to be used for measurements		
Method to be used for obtaining environmental samples		
Analysis method		
Action levels	Ch III Par 3(a)	*
Quality assurance plan required		
Rationale for monitoring required		

Regulation: Title 40 CFR 191		
Plan Element	Citation Location	Vadose Zone
Use an environmental monitoring program	§ 191.14 (b)	*
Verify compliance with applicable environmental laws and regulations		
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media	§ 191.14 (b)	*
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes	§ 191.14 (b)	*
Perform exposure pathway analysis		
Perform critical pathway analysis and document in ASER		
Parameters to be monitored		
Frequency of monitoring		
Location of monitoring points		
Equipment, instrumentation, and facilities to be used for measurements		
Method to be used for obtaining environmental samples		
Analysis method		
Action levels		
Quality assurance plan required		
Rationale for monitoring required		

Regulation: DOE/EH-0173T [January 1991]		
Plan Element	Citation Location	Vadose Zone
Use an environmental monitoring program	Section 1.0	*
Verify compliance with applicable environmental laws and regulations		
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media		
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes		
Perform exposure pathway analysis	Section 5.1.1	*
Perform critical pathway analysis and document in ASER	Section 5.1.1	*
Parameters to be monitored		
Frequency of monitoring		
Location of monitoring points		
Equipment, instrumentation, and facilities to be used for measurements		
Method to be used for obtaining environmental samples	Section 5.2	*
Analysis method		
Action levels		
Quality assurance plan required	Section 10	*
Rationale for monitoring required	Section 5.1.1	*

STEP 2: IDENTIFY THE DECISION

The primary vadose zone monitoring decisions are:

- Type of vadose zone site.
- Has the CAS been closed?
- Do data from other media indicate that the unclosed site is a risk?
- What are the significant pathways for release from an RWMS as determined by the PA/CA analyses?
- Have changes occurred in environmental variables that would affect the PA/CA dose assessment?

The decision logic for categorizing sites is shown in Figure E-10.

Decision Diagram for Vadose Zone Monitoring

Figure E-10 Decision Diagram for Vadose Zone Monitoring

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decisions(s)

The environmental variables that may be needed are dependent on the site and will be determined on a case-by-case basis.

Sources of Environmental Input

Existing sources of information include NTS-specific characterization reports and scientific literature.

Basis for Establishing Contaminant-Specific Action Level(s)

The basis for establishing an action level will be determined as a change from baseline conditions. For closed ER sites, the action level will be negotiated. For the RWMSs, the action level will be based on analyses of hydrologic characteristics described in the PA/CA.

Potential Sampling Approaches and Appropriate Analytical Methods

Sampling approaches are site-specific.

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

The media monitored can be divided into pore liquid and pore gas categories. The scale of decision making will be limited to the disposal facility, each waste cell monitored, or closure unit, as appropriate.

Temporal Boundaries of the Decision

Monitoring data represent current environmental parameters.

Practical Constraints on Data Collection

Practical constraints include access to appropriate sample locations for the waste cells, the requirement for retroactive installation of monitoring systems in operational cells and cells closed with a temporary cover, ongoing operations at the RWMSs, and closure plans for the RWMSs.

STEP 5: DEVELOP A DECISION RULE

Parameter(s) That Characterize the Population of Interest

Parameters monitored at closed industrial sites will be determined through negotiation under the authority of the FFACO. Parameters monitored at the RWMSs will be those associated with radionuclide migration as determined from the hydrologic conceptual models developed for the PAs. While monitoring requirements for the ER and WM Programs may vary due to differing objectives and processes, a consistent feature is the selection of soil water content as a parameter of interest.

Action Level(s) for the Decision(s)

No generally applicable action levels can be set. These will be determined on a site-specific basis by the WM and ER Programs.

Decision Rule

Decision rules will be determined on a site-specific basis by the WM and ER Programs as required. The framework of a decision rule for vadose zone monitoring consists of choosing a value for the parameter of interest and investigation alternatives to be initiated if monitoring detects a parameter value greater than the trigger value.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

This step is not applicable.

STEP 7: OPTIMIZE THE STUDY DESIGN

Design of monitoring plans will be completed independently by ER and WM to preserve necessary differences in implementation due to the differences in character of these two programs. Monitoring plans will be developed using a consistent process. Consistency will come from using the Area 3 and Area 5 PA hydrologic conceptual model, general principles of vadose zone monitoring, and a checklist as outlined in this document.

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7.0 DATA QUALITY OBJECTIVE PROCESS FOR VEGETATION MONITORING ON THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

Air particulates, surface soils, soil water, or surface water located at aboveground tests, Plowshare tests, safety shots, radiation containment ponds or channels, and waste management storage areas.

Types of Contaminants and Affected Media

Tritium, ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$ as contained in soils, water, and air in or adjacent to source areas on the NTS. The contaminants of primary concern are tritiated water and ^{137}Cs which are relatively mobile and can be taken up by the vegetation, thereby entering the food chain. ^{90}Sr and $^{239+240}\text{Pu}$ are also of concern, but are not as mobile and have not been reported to accumulate in tissues of biota, and are therefore of lesser concern.

Known or Potential Routes of Migration

Soil: Contaminants may be taken up from the soil into vegetation and accumulated by plants. Contaminated plant tissues eaten by animals enter food chains that may transfer to humans by ingestion of game animals. Contaminants are primarily tritium and ^{137}Cs .

Air: Contaminants are distributed by resuspension of soils onto vegetation. Contaminated leaves are eaten by animals, and contaminants enter food chains that may transfer to humans by ingestion of game animals. Contaminants may be $^{239+240}\text{Pu}$, ^{90}Sr , tritium, or ^{137}Cs . Tritium may enter a site with precipitation in small amounts from contaminants that have evaporated from vegetation, soils, or surface water. ^{90}Sr is stored in bone and milk and is considered a minor source of contamination because milk and bone are seldom eaten as part of game animals, and no livestock or milk herds are permitted as a land use on the NTS. $^{239+240}\text{Pu}$ is found as small silt-sized particles that are washed off the soil surface and over time are mixed into the soil diluting the original contamination resulting in very low or near background levels in vegetation and animals.

Media Exchanges: Plants may accumulate tritium during the summer and release tritium into the air where it may increase exposure doses to humans working near such vegetation.

Known Human and Environmental Receptors

Receptors include native annual and perennial plants colonizing contaminated sites, animals that eat these plants, and humans that may eat animals foraging on the contaminated vegetation. Animals with the highest potential for entering the food chain available to man are game animals, which include deer, antelope, desert bighorn sheep, rabbits, water fowl, doves, chukars, and quail. Many of these game animals are relatively uncommon on the NTS or are found infrequently. Animals with the highest potential for entering the food chain of man are doves because they are relatively ubiquitous and have longer resident times on or near contaminated sites. Should the public be allowed access to the NTS in the future, then the possibility also presents itself for humans to eat contaminated edible plants (e.g., pine nuts, wolf berries, Indian ricegrass, or greens such as desert princesplume).

Exposure Pathways and Scenarios

Plants growing in contaminated sites may take up radionuclides that can be passed on to animals eating the plants. Game animals feeding on contaminated vegetation may accumulate radionuclides and migrate offsite where they could be taken and eaten by humans. The most likely game animals would be doves or chukars. Other game animals have lower resident times at contaminated sites and would likely transmit lower radionuclide doses to humans. The most likely radionuclide would be tritium, then ^{137}Cs .

Another potential pathway for animals and humans may be tritiated water transpired from deeply rooted shrubs during summer months when other water is scarce in contaminated soils. While such concentrations of tritium would be relatively low, they would add to the dose of the worker on the NTS.

The human exposure scenario is: Onsite plants take up radionuclides from the soil, groundwater, or air, or accumulate resuspended nuclides on the leaves and stems. Game animals eat contaminated plants and move offsite where they are harvested and eaten by humans. Onsite humans may also inhale tritiated water released by plants.

Current and Future Land Uses

The current land use at the NTS has been described in the NTS EIS (DOE, 1996). Current land uses recognize the contaminated nature of selected areas of the NTS and establish approved land use zones on the NTS such as (1) nuclear test zone, (2) nuclear and high-explosive test zone, (3) radioactive waste management zone, (4) Yucca Mountain site characterization zone, (5) solar enterprise zone, (6) reserved zone, and (7) defense Industrial zone. Other previously defined uses include the hazardous waste spill test facility, land use activities associated with Nellis Air Force Base and the U.S. Bureau of Land Management (BLM), and the Desert National Wildlife Refuge. All current land uses restrict uncontrolled public access to the NTS.

Because of the long-term nature of the radionuclide contamination on the NTS, it is very unlikely that future land uses would alter the current land practices without extensive and costly cleanup. It is assumed, therefore, that future land uses would be rather restricted and recognize the risks associated with contaminated sites on the NTS. Adjacent uncontaminated areas would likely be developed according to scenarios described in the NTS EIS (DOE, 1996) which include Nuclear Test Readiness, waste management and storage, and limited commercial development of selected areas of the NTS.

Sources of Historic Data Associated with Previous Data Collection Activities

Existing sources of information are listed in the Reference section of this DQO. Attachment E1 to this Appendix, “Tritium in Vegetation on the NTS,” contains previously unpublished data on tritium in plants at the NTS.

Applicable Requirements or Regulations

DOE Orders: DOE Order 5400.1, “General Environmental Protection Program” (DOE, 1988), Chapter IV – Environmental Monitoring states: “Environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on onsite and offsite environmental and natural resources Environmental surveillance shall be designed to satisfy one or more of the following program objectives: . . . Characterize and define trends in the physical, chemical, and biological condition of environmental media”

DOE Order 5400.5, “Radiation Protection of the Public and the Environment” (DOE, 1990) states: “. . . it is DOE’s objective to protect the environment from radioactive contamination to the extent practical.”

DOE Guidelines: DOE/EH-0173T, “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance” (DOE, 1991) states: “Collection and analysis of vegetation samples can serve three useful purposes: . . .; and monitoring trends in environmental contamination and possible long-term accumulation of radionuclides.”

Stakeholder Concerns: Stakeholders are concerned about radiation exposures to plants and wildlife as seen in comments in Appendix G of Volume 1, NTS EIS (e.g., from the Native American Tribes and U.S. Fish and Wildlife Service).

The attached tables provide the citation (i.e., section or paragraph, etc.) within each driver listed above where guidance is given regarding a radiological monitoring program pertaining to NTS vegetation.

The Contamination Problem

Surface soils, air, groundwater, and vegetation on the NTS were contaminated with long-lived man-made radionuclides by atmospheric, Plowshare, and safety tests. These media provide a source of contamination to the biota. Past studies focused on man-made transuranics and showed declining levels of radionuclides in plants and animals over time, but still above background levels. There is currently no routine monitoring of radionuclides in NTS biota. Most studies were site-specific and of limited duration. Documentation of numerous historical studies found in many reports has not been summarized for the purposes of developing DQOs.

Radionuclides of concern are those present on the NTS that are most likely to enter the human food chain, or are of concern to the public, including ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$. Other radionuclides are either too short-lived or in concentrations that pose little risk to the public. A recent reconnaissance study conducted in 1996 showed that tritium from contaminated soil appears to be concentrated by plants in the foliage, particularly during the summer months when soil water is limited. Plants containing radionuclides may be ingested by animals and contribute to human health risks through animals such as deer and game birds leaving the site. Tritium may also be released by vegetation into the air as tritiated water posing a potential risk to animals or humans near the vegetation. A monitoring program is required at the NTS for compliance with DOE Order 5400.1. Additionally, public concern about these and other radionuclides such as plutonium and strontium in plants and animals and pathways to man, as documented in the NTS EIS, establishes a nonobligatory driver for monitoring biota on the NTS.

Regulation: DOE Order 5400.1 [11/9/88]	Media: Plants
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	Ch IV Par 5(b)
Verify compliance with environmental commitments	Ch IV Par 5(b)
Characterize and define trends in the condition of environmental media	Ch IV Par 5(c)
Establish baselines of environmental quality	Ch IV Par 5(b)
Identify and quantify new or existing environmental quality problems	Ch IV Par 5(b)
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	Ch IV Par 4.
Frequency of monitoring	Ch IV Par 4.
Location of monitoring points	Ch IV Par 4.
Equipment, instrumentation, and facilities to be used for measurements	Ch IV Par 4.
Method to be used for obtaining environmental samples	Ch IV Par 4.
Analysis method	Ch IV Par 4.
Action levels	
Quality assurance plan required	Ch IV Par 10(a)
Rationale for monitoring required	Ch IV Par 4.

Regulation: DOE Order 5400.5	Media: Plants
Plan Element	Citation Location
Use an environmental monitoring program	Ch I Par 8(b)
Verify compliance with applicable environmental laws and regulations	Ch II Par 6(a)
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	Ch II Par 6 (a)
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	Ch II Par 6(a)
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	Ch II Par 6(a)
Analysis method	
Action levels	
Quality assurance plan required	
Rationale for monitoring required	

Regulation: DOE -EH-0173T	Media: Plants
Plan Element	Citation
	Location
Use an environmental monitoring program	Ch 5.8
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	Ch 5.8.1
Establish baselines of environmental quality	Ch 5.8.1
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	Ch 5.8
Perform exposure pathway analysis	Ch 5.8.2.2
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	Ch 5.8
Frequency of monitoring	Ch 5.8
Location of monitoring points	Table 5-1
Equipment, instrumentation, and facilities to be used for measurements	Ch 6.2.5.4
Method to be used for obtaining environmental samples	Ch 5.8.2
Analysis method	Ch 6.2.5.4
Action levels	Ch 5.8
Quality assurance plan required	
Rationale for monitoring required	

STEP 2: IDENTIFY THE DECISION

Key Decisions

Decision 1: Determine if radionuclide levels in plants at and near known NTS radioactive sources exceed concentration limits.

Alternative Actions Resulting from Resolution of Decisions

Action Corresponding to Decision 1: If any radionuclide concentrations in plants exceed concentration limits, examine concentrations in other media samples collected from the site and gather additional samples to confirm the radiation source. Through further sampling and analysis, determine the temporal and spatial extent of contamination in plant populations that exceed these concentration limits.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decision(s)

- Data from prior studies (from NTS and worldwide) on radionuclide effects on plant physiology:
 - concentration levels that produce deleterious effects,
 - transport/storage of radionuclides in different plant parts (e.g., seeds, roots, leaves), and
 - seasonal effects of radionuclide transport/storage in plant parts.
- Inventory of radionuclides found from previous studies of NTS plants and their concentration levels.
- List of NTS source sites that have contaminated plants, soils, or water.
- The distribution of contaminated plants at/near each site.
- Location of possible control sites for NTS contaminated sites with similar plants/site conditions.

Sources of Environmental Input

- Previous NTS radionuclide inventories in soils/plants.
- Existing literature (NTS and worldwide) on dose/effects of radionuclides in plants.
- Existing Geographical Information System (GIS) vegetation map.
- NTS source term map of radiation contamination.
- Distribution of contaminated plants at NTS sources (where not previously determined).

Basis for Establishing Contaminant-Specific Action Level(s)

The action levels will be established based on their contribution to human radionuclide doses via ingestion. The action levels will be those specific concentrations of each monitored radionuclide per milliliter of liquid or per gram of dry ash of biotic material which leads (through the food chain) to an annual EDE in humans of 5 mrem. These action levels are based on an MEI dose of 5 mrem EDE if it were sustained for one year and are recommended by the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE, 1991).

Potential Sampling Approaches and Appropriate Analytical Methods

Conduct initial sampling of plants at NTS sources by taking a minimal number of replicate samples per site from two to three plant species, taken at the most favorable season for detection of radionuclides in plant parts. Samples can be collected at five source sites and their corresponding control sites.

Onsite plants would be those species that are adapted to disturbed site conditions and tend to accumulate radionuclides. Plant parts to be sampled would be those that tend to accumulate highest concentrations of radionuclides through both uptake and through surface deposition of resuspended contaminated soil (e.g., aboveground stems, branches, leaves, and seeds, but *not* roots). The plants to be sampled would also be the most predominant (based on biomass and cover) species at a site. Vegetation strata would likely include:

- shrubs (e.g., rubber rabbitbrush, fourwing saltbush, sagebrush, and burrowbush),
- herbs (e.g., princesplume and bristly fiddlehead), and
- grasses (e.g., desert needlegrass, Indian ricegrass, and red brome).

Analytical methods appropriate for radionuclide detection in plant tissue would follow the recommended laboratory procedures (e.g., sample ID, sample preservation and handling practices, analytical methods, equipment calibration, reference source practices, frequencies, and methods and other quality assurance procedures) of the Environmental Regulatory Guide [DOE/EH-0173T, 1991]) and would include:

1. Tritium in free water by scintillation counter.
2. Cesium by gamma scan after ashing.
3. Strontium by beta spectroscopy after ashing.
4. Pu by ashing, dissolution, separation, alpha spectroscopy.

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

Sampling will focus on areas with known high levels of surface contamination in soils and vegetation. The intent is to select “worst case” sites with a high likelihood of having elevated levels of radionuclides in plants. One sample site will be located within each of the following five types of areas of the NTS:

- Radiation containment ponds or runoff areas associated with radiation-contaminated tunnels, drainage ditches, or ponds
(Candidate site: E Tunnel ponds)
- Plowshare sites with high surface contamination at lower elevations.
(Candidate site: SEDAN Crater)
- Plowshare sites with high surface contamination at higher elevations.
(Candidate site: PALANQUIN)
- Aboveground atmospheric nuclear test areas.
(Candidate site: T2)
- Safety shot test areas.
(Candidate site: Plutonium Valley, Area 11)

The spatial sampling boundaries will be the boundary of each of the five selected contaminated NTS sites. These boundaries will be determined from maps developed by aerial surveys of ground-level radiation and detailed radiological surveys. Samples will be taken from the area within each site boundary having the highest radiation concentrations, if such areas are known and delineated.

Temporal Boundaries of the Decision

The data will apply to a five-year time frame. Sampling will be conducted once every five years at each study site on the NTS. If concentration levels are above the action level at a site, then monitoring at that site will increase to once each year.

Data will be collected in years with sufficient precipitation to produce plant matter. In years of insufficient precipitation or lack of target plant growth, sampling will select alternative plant species (e.g., annuals) or will defer sampling to years with sufficient precipitation. Data will be collected in the spring (to establish baseline conditions) and summer (to establish peak concentrations) during the first year and during summer thereafter for selected plant species.

Practical Constraints on Data Collection

The condition of the onsite vegetation may be a constraint on onsite data collection in years of drought when there is insufficient precipitation to produce plant matter. Selection of plant species will vary by site according to the predominant vegetation present at the site. For example, sampled plant species may be restricted to herbs at RWMS where shrubs are routinely removed mechanically, while sampled plant species at E Tunnel ponds (in more mountainous areas) may be restricted to shrubs because herbs and grasses are less abundant.

STEP 5: DEVELOP A DECISION RULE

Parameter(s) that Characterize the Population of Interest

Variables of concern are man-made radionuclides that have been identified from previous sampling of vegetation, soils, air, or water on the NTS at levels above background. Radionuclides of concern are those present on the NTS that are most likely to enter the human food chain, or are of concern to the public and include tritium, ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$. One additional analysis has been included which is a gamma scan to detect other gamma-generating radionuclides.

Action Level(s) for the Decision(s)

Action levels for each radionuclide will be identified from use of acceptable pathway/exposure/dose models applied by a qualified health physicist and radiation ecologist. The action levels will be those specific concentrations of each monitored radionuclide per milliliter of liquid or per gram of dry ash of biotic material which leads (through the food chain) to an annual EDE in humans of 5 mrem.

Decision Rule

If mean concentrations of tritium, ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, or gamma scans at sample locations are below the concentration action level, then:

- Values will be documented in the ASER, but no additional evaluations, assessments or special studies will be implemented. Environmental surveillance measurements on the NTS will be performed at least *every five years* to confirm the contamination levels.

If mean concentrations of tritium, ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, or gamma scans at sample locations are equal to or above the concentration action level, then:

- Management will be advised of the elevated levels and additional sampling and analyses will be performed. These may include additional validation of laboratory analysis results, further statistical sampling, further plant sampling to determine the spatial or temporal boundaries of the problem area, or sampling of other related media to confirm source levels and document trends. Additional plant species may be sampled to better define radionuclide sources and human exposure pathways. Monitoring will continue for radionuclides found in excess of the concentration action level on an annual basis.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

Possible Range of the Parameter of Interest

Initial field sampling will help determine if a statistically-based approach will be used. If sample variability is great, then the monitoring approach will be nonstatistical and monitoring efforts will not establish statistical limits, but may report the power or limitations of statistical tests based on limited sampling. If sampling variability is low, then a statistically based approach may be used with the following assumptions to be used as starting points for statistical testing.

The lower bounds of the variables of interest (^{137}Cs , tritium, ^{90}Sr , and $^{239+240}\text{Pu}$) are the natural background concentrations (yet to be determined) for these radionuclides in vegetation. The mean background levels and sampling variance will be established by documenting levels measured in plant species at ecologically similar control sites with no history of radionuclide contaminants. Background values for tritium in water were verbally reported by the BN radiological laboratory staff to be $6.3 \times 10^{-8} \mu\text{Ci/ml}$. The BN laboratory's standard procedure had an estimated minimum detectable concentration for tritium of $7.31 \times 10^{-7} \mu\text{Ci/ml}$, and the enriched tritium procedure has a minimum detectable concentration of $13.5 \times 10^{-9} \mu\text{Ci/ml}$.

The upper bounds of these variables will be determined from published literature of previous NTS studies and from estimated values determined from outside literature, values reported for other DOE sites, or other media at the NTS (e.g., surface water or surface soils). Historically reported laboratory values as high as 265 pCi/g ($^{239+240}\text{Pu}$) for Indian ricegrass stems and leaves and 298 pCi/g ($^{239+240}\text{Pu}$) for fourwing saltbush stems and leaves have been reported using uniformly spiked (i.e., relatively homogeneous) soils (White, Dunaway, and Wireman, 1977a), which values are described as being "higher than most of those previously reported in the literature." A more recent study reports maximum values of 2.9, 0.4, and 1.1 (Ln[pico Ci]) for $^{239+240}\text{Pu}$, ^{137}Cs , and ^{90}Sr , respectively (Romney, Hunter, and Wallace, 1985). The maximum plant concentrations for tritium on the NTS (near SEDAN ground zero) were verbally reported by the BN radiological laboratory staff to be $5.02 \times 10^{-2} \mu\text{Ci/ml}$, and the maximum ^{137}Cs was reported to be $6 \times 10^{-7} \mu\text{Ci/g}$.

Potential Consequences of Type 1 and Type 2 Errors

The two types of errors are defined below for the null hypothesis that no man-made radionuclides are present. The action level is that observed concentration of a man-made radionuclide which will trigger an action, such as the decision to better define the extent of increased concentration. The alternative hypothesis is that man-made radionuclides are present at concentrations above the action level.

False negative errors: (alpha [α] or Type 1 error) would occur when acceptance of mean sampling values for selected radionuclides in plants (at selected probability levels) lead the decision maker to conclude that the population means of radionuclides in plants are below the action level when they truly are not. This is the more severe error.

False positive errors: (beta[β] or Type 2 error) would occur when acceptance of mean sampling values for selected radionuclides in plants (at selected probability levels) lead the decision maker to conclude that the population means of radionuclides in plants are above the action level when they truly are not. This is the less severe error.

Acceptable Probability of Type 1 and Type 2 Errors

Proposed error margins are:

α = 10 percent for false positive with a 90 percent confidence

β = 20 percent for false negative with an 80 percent confidence

In practice, these error margins may have to be adjusted (e.g., α = 20 percent), based on variability encountered during sampling, because the sampling numbers and associated costs required to satisfy these error margins may otherwise be cost prohibitive.

STEP 7: OPTIMIZE THE STUDY DESIGN

General Sampling and Analysis Design

Preliminary Estimate of Variability

Variability for most parameters is not known and will be estimated during the initial field sampling to evaluate radionuclide concentrations in plant species present at selected highly contaminated sites.

Sampling Strategy

Identify Action (Threshold) Contamination Levels: The contamination levels of the target radionuclides that must be in plants in order to produce unacceptable radionuclide exposures in humans who are consuming game animals that eat the contaminated vegetation will be determined. Radionuclide and ecology data obtained from the literature and acceptable human pathway/dose models executed by a qualified health physicist and ecologist will be used to determine these levels.

Select “Worst-Case” Contamination Sites: From historic literature, reports, maps, and personal knowledge, one representative site with high levels of radionuclides from each of five categories of contaminated sites present on the NTS will be selected. These five categories, listed in descending order of highest reported levels of radionuclides and highest perceived threat to biota include:

- surface-contaminated ponds and ditches (e.g., containment ponds at E Tunnel)
- Plowshare site in a low precipitation area such as Yucca Flats (e.g., SEDAN crater)
- Plowshare site in a high precipitation area such as the mesas (e.g., PALANQUIN)
- aboveground test site (e.g., T2 or T3)
- safety shot site (e.g., Plutonium Valley, Area 11)

Sites of lower priority include nuclear rocket test sites where the contaminated area is small compared to other types of contamination categories. The intent of monitoring conditions at the five categories of sites would be to select the “worst-case” sites with potentially high levels of radionuclides in the soil, water, air, and vegetation. Budget constraints may limit the number of sites than can be adequately monitored. Following the initial sampling of these sites, concentrations levels at each site will be determined and recommendations for future monitoring activities will be made.

Select Control Sites: From NTS ecological site data, the control sites for each of the categories of contaminated sites present on the NTS will be selected. These sites should represent good ecological “control” sites for establishing background levels of radionuclides in the vegetation.

Vegetation, climate, and other ecological site conditions should be close to those at the selected contamination sites.

Field Verify Acceptable Conditions at Contaminated and Control Sites: Treatment and control sites will be visited to ensure that site conditions are acceptable and consistent with DQOs. A list of potential plants to be sampled will be developed and any disqualifying site conditions noted. A list of sampling sites with acceptable site conditions will be developed.

From NTS Literature, Select Plant Species to be Sampled, Location of Sampling, and Period of Sampling: From results of field visits and NTS literature, the predominant species of plants (i.e., species that are abundant and represent a majority of the biomass at the site) that will be sampled during the future monitoring efforts will be identified. Such plants will be selected because they are abundant at the site and have a high probability of containing high levels of radionuclides in their tissues. From two to three species will be selected at each site. Plant species may include life forms such as shrubs, forbs, and grasses. Some sites (e.g., RWMS) may have restricted or managed vegetation (e.g., bladed to reduce shrub cover) such that not all life forms may be present or sampled.

Prepare a Detailed Sampling and Analysis Plan: After completing steps above, the plan will be prepared and reviewed prior to field sample collection and sample analysis. This plan is scheduled for completion by the second quarter of fiscal year (FY) 1998.

Collect and Analyze Plant Samples: Three composited samples, consisting of aboveground plant matter (stems with attached branches, leaves, flowers or seeds) from three plants of each species, will be collected and analyzed during the period of the year when radionuclides appear to be highest (e.g., June or September). Data from plant samples will be evaluated to determine sampling and analytical variances. Based on evaluations, recommendations will be made regarding adequacy of sample size and estimates of error terms.

Modify the Sampling Program Based on Recommendations and Decision Rules: As new information becomes available, or when action levels are exceeded during monitoring, the monitoring program will be modified to increase cost efficiency, while ensuring that DQOs are satisfied. One site will be sampled and results reported each year until all sites have been sampled. Each of the sites will be sampled a minimum of once every five years and results reported in the ASER. Recommendations will be made to modify the sampling program at sites where changes in site conditions, regulatory requirements, or DOE orders no longer satisfy the data quality objectives.

Operational Details and Theoretical Assumptions of Study Design

Details and theoretical assumptions of the selected design will be developed as soon as the sampling design is finalized and results of initial sample screening are received.

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8.0 DATA QUALITY OBJECTIVE PROCESS FOR ANIMAL MONITORING ON THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

Air particulates, surface soils, soil water, or surface water located at aboveground tests, Plowshare tests, safety shots, radiation containment ponds or channels, and waste management storage areas.

Types of Contaminants and Affected Media

Tritium, ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$ as contained in soils, water, and air in or adjacent to source areas on the NTS. The contaminants of primary concern are tritiated water and ^{137}Cs which are relatively mobile and can be taken up by the vegetation, thereby entering the food chain. ^{90}Sr and $^{239+240}\text{Pu}$ are also of concern, but are not as mobile and have not been reported to accumulate in tissues of biota, and are therefore of lesser concern.

Known or Potential Routes of Migration

Soil: Contaminants may be taken up from the soil into vegetation and concentrated by plants. Contaminated plant tissues eaten by animals enter food chains that may transfer to humans by ingestion of game animals. Contaminants are primarily tritiated water and ^{137}Cs . Soil may also be ingested directly by digging or grazing game animals.

Air: Contaminants are distributed by resuspension of soils onto vegetation. Contaminated leaves eaten by animals and contaminants that enter food chains may transfer to humans by ingestion of game animals. Contaminants may be $^{239+240}\text{Pu}$, ^{90}Sr , tritium, or ^{137}Cs . Tritium may enter a site with precipitation in small amounts from contaminants that have evaporated from vegetation, soils, or surface water. ^{90}Sr is stored in bone and milk and is considered a minor source of contamination because milk and bone are seldom eaten as part of game animals, and no livestock or milk herds are permitted as a land use on the NTS. $^{239+240}\text{Pu}$ is found as small silt-sized particles that are washed off the soil surface and over time are mixed into the soil diluting the original contamination resulting in very low or near background levels in vegetation and animals.

Media Exchanges: Plants may accumulate tritium during the summer and release tritiated water vapor into the air where it may increase doses to animals near such vegetation.

Known Human and Environmental Receptors

Receptors include native annual and perennial plants colonizing contaminated sites, animals that eat these plants, and humans that may eat animals foraging on the contaminated vegetation. Animals with the highest potential for entering the food chain available to man are game animals, including deer, antelope, desert bighorn sheep, rabbits, water fowl, doves, chukars, and quail. Many of these game animals are relatively uncommon on the NTS or are found infrequently. Animals with the highest potential for entering the food chain of man are doves because they are relatively ubiquitous and have longer resident times on or near contaminated sites. Should the public be allowed access to the NTS in the future, then the possibility also presents itself for humans to eat contaminated edible plants (e.g., pine nuts, wolf berries, Indian ricegrass, or greens such as desert princesplume).

Exposure Pathways and Scenarios

Plants growing in contaminated sites may take up radionuclides that can be passed on to animals eating the plants. Game animals feeding on contaminated vegetation may accumulate radionuclides and migrate offsite where they could be taken and eaten by humans. The most likely game animals would be mourning doves or chukars. Other game animals such as ducks, deer, or antelope have lower resident times at contaminated sites and would likely transmit lower radionuclide doses to humans. The most likely radionuclides would be tritiated water and ^{137}Cs .

Another potential pathway for animals and humans may be tritiated water transpired from deeply rooted shrubs during summer months when other water is scarce in contaminated soils. While such concentrations of tritium would be relatively low, they would add to the doses of animals and workers on the NTS.

The human exposure scenario is as follows: onsite plants take up radionuclides from the soil, groundwater, or air, or accumulate resuspended nuclides on the leaves and stems. Game animals eat contaminated plants and move offsite where they are harvested and eaten by humans. Onsite humans may also inhale tritiated water released by plants. Chukar may also be trapped on the NTS and released offsite onto public lands open to hunting (such relocations were conducted by the Nevada Division of Wildlife in 1994 and may occur in the future). There is a slight potential that chukar trapped at contaminated springs may be contaminated.

Current and Future Land Uses

The current land use at the NTS has been described in the NTS EIS (DOE, 1996). Current land uses recognize the contaminated nature of selected areas of the NTS and establish approved land use zones on the NTS such as (1) nuclear test zone, (2) nuclear and high explosive test zone, (3) radioactive waste management zone, (4) Yucca Mountain site characterization zone, (5) solar enterprise zone, (6) reserved zone, and (7) defense Industrial zone. Other previously defined uses include the hazardous waste spill test facility, land use activities associated with Nellis Air Force

Base and the BLM, the Desert National Wildlife Refuge. All current land uses restrict uncontrolled public access to the NTS.

Because of the long-term nature of the radionuclide contamination on the NTS, it is very unlikely that future land uses would alter the current land practices without extensive and costly cleanup. It is assumed, therefore, that future land uses would be rather restricted and recognize the risks associated with contaminated sites on the NTS. Adjacent uncontaminated areas would likely be developed according to scenarios described in the NTS EIS (DOE, 1996) which include Nuclear Test Readiness, waste management and storage, and limited commercial development of selected areas of the NTS.

Sources of Historic Data Associated with Previous Data Collection Activities

Existing sources of information are listed in the Reference section of this DQO.

Applicable Requirements or Regulations

DOE Orders: DOE Order 5400.1, “General Environmental Protection Program” (DOE, 1988), Chapter IV – Environmental Monitoring states: “Environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on onsite and offsite environmental and natural resources Environmental surveillance shall be designed to satisfy one or more of the following program objectives: . . . Characterize and define trends in the physical, chemical, and biological condition of environmental media”

DOE Order 5400.5, “Radiation Protection of the Public and the Environment” (DOE, 1990) states: “. . . it is DOE’s objective to protect the environment from radioactive contamination to the extent practical.” This order limits aquatic animals to 1 R/day. Site-specific quantitative limits have been proposed for game animals at other DOE facilities (e.g., Hanford Site for sportsman’s edible game such as deer, rabbits, carp, and migratory game birds) based on human dose models. For this monitoring program, the quantitative limits in animals will be those concentrations that produce animal and human dose levels specified in DOE/EH-0173T mentioned below.

DOE Guidelines: *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T, January 1991) is the regulatory guide to be followed to comply with DOE 5400.1 and 5400.5. The minimum criteria for Routine Surveillance is:

- “When feasible, all environmental media that, as determined by site-specific radiation exposure pathway analysis, might lead to a measurable annual dose of site origin at the site boundary *should** be routinely sampled and analyzed . . . if the total exceeds 5 mrem effective dose equivalent; or 100 person-rem collective effective dose equivalent within a radius of 80 km of a central point in the site.”

The minimum criteria for Periodic Confirmation is:

- “Environmental surveillance measurements may be performed periodically, but *should** be performed at least every five years, to confirm the low dose levels, if the projected annual effective dose equivalent of site origin is less than or equal to 0.1 mrem.”

Stakeholder Concerns: Stakeholders are concerned about radiation exposures to plants and wildlife as seen in review comments for the draft NTS EIS (e.g., from the Native American Tribes and U.S. Fish and Wildlife Service).

The following tables provide the citation (i.e., section or paragraph, etc.) within each driver listed above where guidance is given regarding a radiological monitoring program pertaining to wildlife.

The Contamination Problem

Surface soils, air, groundwater, and vegetation on the NTS were contaminated with long-lived man-made radionuclides by atmospheric, Plowshare, and safety tests. These media provide a source of contamination to the biota. Past studies focused on man-made transuranics and showed declining levels of radionuclides in plants and animals over time, but still above background levels. Most studies were site-specific and of limited duration. There is currently no routine monitoring of radionuclides in NTS biota. Documentation of these numerous studies is found in many reports and has not been summarized for the purposes of developing DQOs.

Radionuclides of concern are those present on the NTS that are most likely to enter the human food chain, or are of concern to the public, including tritium, ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$. Other radionuclides are either too short-lived or in concentrations that pose little risk to the public. A recent reconnaissance study conducted in 1996 showed that tritium from contaminated soil appears to be concentrated by plants in the foliage, particularly during the summer months when soil water is limited. Plants containing radionuclides may be ingested by animals and contribute to human health risks through animals such as deer and game birds leaving the site. Tritium may also be released by vegetation into the air as tritiated water posing a potential risk to animals or humans near the vegetation. A monitoring program is required by DOE EPD for compliance with DOE Order 5400.1. Additionally, public concern about these and other radionuclides such as plutonium and strontium in plants and animals and pathways to man, as documented in the NTS EIS, establishes a nonobligatory driver for monitoring biota on the NTS.

Regulation: DOE Order 5400.1 [11/9/88]	Media: Animals
Plan Element	Citation
	Location
Use an environmental monitoring program	
Verify compliance with applicable environmental laws and regulations	Ch IV Par 5(b)
Verify compliance with environmental commitments	Ch IV Par 5(b)
Characterize and define trends in the condition of environmental media	Ch IV Par 5(c)
Establish baselines of environmental quality	Ch IV Par 5(b)
Identify and quantify new or existing environmental quality problems	Ch IV Par 5(b)
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	Ch IV Par 4.
Frequency of monitoring	Ch IV Par 4.
Location of monitoring points	Ch IV Par 4.
Equipment, instrumentation, and facilities to be used for measurements	Ch IV Par 4.
Method to be used for obtaining environmental samples	Ch IV Par 4.
Analysis method	Ch IV Par 4.
Action levels	
Quality assurance plan required	Ch IV Par 10(a)
Rationale for monitoring required	Ch IV Par 4.

Regulation: DOE Order 5400.5	Media: Animals
Plan Element	Citation
	Location
Use an environmental monitoring program	Ch I Par 8(b)
Verify compliance with applicable environmental laws and regulations	Ch II Par 6(a)
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	
Establish baselines of environmental quality	
Identify and quantify new or existing environmental quality problems	Ch II Par 6 (a)
Measure releases, migration, subsidence, and performance changes	
Perform exposure pathway analysis	
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	
Frequency of monitoring	Ch II Par 6(a)
Location of monitoring points	
Equipment, instrumentation, and facilities to be used for measurements	
Method to be used for obtaining environmental samples	Ch II Par 6(a)
Analysis method	
Action levels	Ch II Par 3.a(5) Aquatic Animals
Quality assurance plan required	
Rationale for monitoring required	

Regulation: DOE-EH-0173T	Media: Animals
Plan Element	Citation
	Location
Use an environmental monitoring program	Ch 5.8
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	Ch 5.8.1
Establish baselines of environmental quality	Ch 5.8.1
Identify and quantify new or existing environmental quality problems	
Measure releases, migration, subsidence, and performance changes	Ch 5.8
Perform exposure pathway analysis	Ch 5.8.3 & 5.11
Perform critical pathway analysis and document in ASER	
Parameters to be monitored	Ch 5.8
Frequency of monitoring	Ch 5.8
Location of monitoring points	Table 5-1
Equipment, instrumentation, and facilities to be used for measurements	Ch 6.2.5.4
Method to be used for obtaining environmental samples	Ch 5.8.3 & 5.11
Analysis method	Ch 6.2.5.4
Action levels	Ch 5.8
Quality assurance plan required	
Rationale for monitoring required	

STEP 2: IDENTIFY THE DECISION

Key Decisions

Decision 1: Determine if radionuclide levels in animals at and near known NTS radioactive sources terms exceed these concentration limits.

Alternative Actions Resulting From Resolution of Decisions

Action Corresponding to Decision 1: If any radionuclide concentrations in samples exceed concentration limits, examine concentrations in other media samples collected from the site and gather additional samples to confirm the radiation source. Through further sampling and analysis, determine the temporal and spatial extent of contamination in animal populations that exceed these concentration limits.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decision(s)

- Data from prior studies (from NTS and worldwide) on radionuclide effects on wildlife.
 - concentration levels that produce deleterious effects.
 - transport/storage of radionuclides in different animal tissues (e.g., muscle, organs, pelt).
- Inventory of radionuclides found from previous studies of NTS animals and their concentration levels.
- The distribution of contaminated plants on the NTS.
- Inventory of contaminated NTS soils.
- The location of contaminated NTS wildlife water sources and their concentration of radionuclides.
- Location of possible control sites for NTS contaminated sites with similar plant/animal communities/site conditions.
- Life history information for key NTS herbivore species (e.g., life span, preferred forage species or plant part, common predators).

Sources of Environmental Input

- Previous NTS radionuclide inventories in animals.
- Existing soils and surface water radionuclide inventories from NTS.
- Existing literature (NTS and worldwide) on dose/effects of radionuclides in animals.
- Existing GIS plant and animal (i.e., species of concern) distribution maps.
- Inventory of radionuclide concentrations in key game animals at/near NTS contaminated plant sites.
- Analysis of radionuclide concentration levels in different animal tissues (where not done previously).

Basis for Establishing Contaminant-Specific Action Level(s)

The action levels will be established based on their contribution to human radionuclide doses via ingestion. The action levels will be those specific concentrations of each monitored radionuclide per milliliter of liquid or per gram of dry ash of biotic material which leads (through the food chain) to an annual EDE in humans of 5 mrem. These action levels are based on a MEI dose of 5 mrem EDE if it were sustained for one year and are recommended by the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE, 1991).

Potential Sampling Approaches and Appropriate Analytical Methods

The approach will be to sample those game species with the highest probability of entering the food chain (pathway) to humans. This would likely include browsing animals characteristic of big game animals (e.g., deer, desert bighorn sheep, antelopes, and rabbits), and game birds (e.g., mourning doves, chukar, and waterfowl). Game animals include:

- browsing game animals (e.g., rabbits, deer, desert bighorn sheep, and antelope).
- game birds (e.g., mourning doves or chukars).

Alternative animals could include:

- burrowing rodents (e.g., kangaroo rats).
- waterfowl (e.g., ducks).

The two most likely onsite species to be selected for sampling are the mourning dove (a representative migrating game bird with a relatively long resident time in the contaminated sites) and rabbit (a representative browsing mammal which also has a relatively long resident time in the contaminated sites).

Because of the real potential for the Nevada Division of Wildlife to obtain permission to trap and relocate NTS chukar to public lands, chukar will be sampled for radioanalysis to document the levels of radionuclides in the edible tissues of the bird. They will be analyzed in the same manner as mourning doves.

Analytical methods appropriate for radionuclide detection in animal tissues would follow the recommended laboratory procedures (e.g., sample ID, sample preservation and handling practices, analytical methods, equipment calibration, reference source practices, frequencies, and methods and other quality assurance procedures) of the Environmental Regulatory Guide [DOE/EH-0173T, 1991]) and would include:

1. Tritium in free water by scintillation counter.
2. Cesium by gamma scan after ashing.
3. Strontium by beta spectroscopy analysis after ashing.
4. Plutonium by ashing, dissolution, separation, alpha spectroscopy.

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

Sampling will focus on areas with known high levels of surface contamination in soils and vegetation. The basic intent is to select “worst-case” sites with a high likelihood of having elevated levels in animals, especially game animals that potentially migrate offsite. One sample site will be located within each of the following five types of areas of the NTS:

- Radiation containment ponds or runoff areas associated with radiation-contaminated tunnels, drainage ditches, or ponds.
(Candidate site: E Tunnel ponds)
- Plowshare sites with high surface contamination at lower elevations.
(Candidate site: SEDAN Crater)
- Plowshare sites with high surface contamination at higher elevations.
(Candidate site: PALANQUIN)
- Aboveground atmospheric nuclear test areas.
(Candidate site: T2)
- Safety shot test areas.
(Candidate site: Plutonium Valley, Area 11)

The spatial sampling boundaries will be the boundary of each of the five selected contaminated NTS sites. These boundaries will be determined from maps developed by aerial surveys of ground-level radiation and detailed radiological surveys. Samples will be taken from the area within each site boundary having the highest radiation concentrations, if such areas are known and delineated.

NTS chukar will be sampled from one of the numerous springs on the NTS from which the Nevada Division of Wildlife plans to collect them for relocation. One spring will be trapped for chukar each year, and the trap site may change from year to year. The selected spring will be easily accessible, large enough to attract a large number of chukar, and will be farther than 10 km (6 mi) from a contaminated wildlife water source (e.g., E Tunnel ponds).

Temporal Boundaries of the Decision

One NTS contaminated site will be sampled each year until all five sites have been sampled. When concentration levels from the initial sampling are below the action level (tissue concentration projecting annual EDE of site origin of equal to or less than 0.1 mrem), monitoring measurements will continue at one sampling per each five-year period to confirm these low levels, otherwise monitoring will be conducted annually until lower EDE doses are measured. Chukar

will be trapped at one spring each year. If radionuclide levels in edible tissues of chukar are found above action levels, monitoring will continue on an annual basis, but the trap site will be changed to a spring that is farther away from any known source of contamination.

NTS data will be collected in years with sufficient precipitation to produce forage for animals. In years of insufficient precipitation or lack of target animals (mourning doves and rabbits), sampling will select alternative animals (e.g., chukars or kangaroo rats) or will defer sampling to years of sufficient precipitation. Data will be collected during those seasons which published literature suggest the highest concentrations will be encountered. Animals will be sampled at least once every five years.

Practical Constraints on Data Collection

The condition of the onsite vegetation may be a constraint on onsite data collection in years of drought when there is insufficient precipitation to produce plant matter and animals are lacking or are present at levels too low to provide the necessary mass of meat per sample for proper analyses.

STEP 5: DEVELOP A DECISION RULE

Parameter(s) That Characterize the Population of Interest

Variables of concern are man-made radionuclides that have been identified from previous sampling of vegetation, soils, air, or water on the NTS at levels above background.

Radionuclides of concern are those present on the NTS that are most likely to enter the human food chain, or are of concern to the public and include ^3H , ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$. One additional analysis has been included which is a gamma scan to detect other gamma-generating radionuclides.

Action Level(s) for the Decision(s)

Action levels in NTS game animals are radionuclide concentrations in the animal that would create a 5 mrem/yr EDE in humans consuming the animal. While the specific concentration action level in animals that leads to the dose levels described above has not been calculated at this time, the procedure for estimating this concentration level in humans is described in the accompanying procedure: “Estimating the Committed Effective Dose Equivalent from Consumption of Wild Game.”

Decision Rule

If mean concentrations of ^3H , ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, or gamma scans collectively are below levels that would lead to a dose of 5.0 mrem EDE per year to humans, then:

- Values will be documented in the ASER, but no additional evaluations, assessments, or special studies will be implemented. Environmental surveillance measurements will be performed at least *every five years* to confirm the low dose levels.

If mean concentrations of ^3H , ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, or gamma scans collectively are equal to or greater than levels that would lead to a dose to humans equal to or greater than a dose of 5.0 mrem EDE per year, then:

- Management will be advised of the elevated levels and additional evaluations (e.g., further statistical sampling of additional animals such as deer or animals from adjacent areas), assessments (e.g., ecological risk and human pathway assessments), or special studies (e.g., additional field sampling to determine spatial and temporal extent of contamination) will be implemented in concert with monitoring efforts for other related media to confirm levels and document trends. Monitoring will continue on an *annual basis*. Sufficient sampling and analysis will be carried out so that the animals and radionuclides contributing at least

90 percent of this ingestion dose have been evaluated. If chukar samples from a spring are above action levels, no chukar will be trapped from that spring for relocation, and further data collection would occur to identify a trap site where chukar are not contaminated.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

Possible Range of the Parameter of Interest

Initial field sampling will help determine if a statistically-based approach will be used. If sample variability is great, then the monitoring approach will be nonstatistical and monitoring efforts will not establish statistical limits, but may report the power or limitations of statistical tests based on limited sampling. If sampling variability is low, then a statistically based approach may be used, with the following assumptions to be used as starting points for statistical testing.

The lower bounds of the variables of interest (^3H , ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$) are the natural background concentrations (yet to be determined) for these radionuclides in animals. Selected game animal species will be those that have a high probability of eating contaminated vegetation and contributing to the human dose through offsite migration. The mean background levels and sampling variance will be established by documenting levels measured in animal species at ecologically similar control sites with no history of radionuclide contaminants.

The upper bounds of these variables will be determined from published literature of previous NTS studies and from estimated values determined from outside literature, values reported for other DOE sites and other media (e.g., surface water or surface soils) at the NTS.

Potential Consequences of Type 1 and Type 2 Errors

The two types of errors are defined below for the null hypothesis that no man-made radionuclides are present in game animals. The action level is that observed concentration of a man-made radionuclide which will trigger an action, such as the decision to better define the extent of increased concentration. The alternative hypothesis is that man-made radionuclides are present at concentrations above the action level.

False negative errors: (alpha [α] or Type 1 error) would occur when acceptance of mean sampling values for selected radionuclides in animals (at selected probability levels) lead the decision maker to conclude that the population means of radionuclides in animals are below the action level when they truly are not. This is the more severe error.

False positive errors: (beta [β] or Type 2 error) would occur when acceptance of mean sampling values for selected radionuclides in animals (at selected probability levels) lead the decision maker to conclude that the population means of radionuclides in animals are above the action level when they truly are not. This is the less severe error.

Acceptable Probability of Type 1 and Type 2 Errors

Proposed error margins are:

$\alpha = 10$ percent for false positive with a 90 percent confidence

$\beta = 20$ percent for false negative with an 80 percent confidence

In practice, these error margins may have to be adjusted (e.g., $\alpha = 20$ percent), based on variability encountered during sampling, because the sampling numbers and associated costs required to satisfy these error margins may otherwise be cost prohibitive.

STEP 7: OPTIMIZE THE STUDY DESIGN

General Sampling and Analysis Design

Preliminary Estimate of Variability

Variability for most parameters is not known and will be estimated during initial field sampling to evaluate radionuclide concentrations in animal species present at selected sites with relatively high concentration levels of radionuclides previously measured in the plants, soil, water, and air.

Sampling Strategy

Identify Action (Threshold) Contamination Levels: Action contamination levels will be estimated by methods described in the accompanying procedure: “Estimating the Committed Effective Dose Equivalent from Consumption of Wild Game.” This procedure uses an MEI dose of 5 mrem EDE per year and calculates the concentrations of radionuclides in game animals that would lead to this dose in humans. This concentration level is then used in animals as the threshold or action level for decision rules.

Select “Worst-Case” Contamination Sites: From historic literature, reports, maps, and personal knowledge, select one representative site with high levels of radionuclides from each of five categories of contaminated sites present on the NTS. These five categories, listed in descending order of highest reported levels of radionuclides and highest perceived threat to biota, include:

- surface-contaminated ponds and ditches (e.g., containment ponds at E Tunnel).
- Plowshare site in a low precipitation area such as Yucca Flat (e.g., SEDAN crater).
- Plowshare site in a high precipitation area such as the mesas (e.g., PALANQUIN).
- aboveground test site (e.g., T2 or T3).
- safety shot site (e.g., Plutonium Valley, Area 11).

Sites of lower priority include nuclear rocket test sites where the contaminated area is small compared to other types of categories. The intent of monitoring conditions at the five categories of sites would be to select the “worst-case” sites with potentially high levels of radionuclides in the soil, water, air, vegetation, and animals. Budget constraints may limit the number of sites than can be adequately monitored. Following the initial sampling of these sites, concentration levels at each site will be determined and recommendations for future monitoring activities will be made.

Select Control Sites: From NTS ecological site data, a control site for each category of contaminated sites present on the NTS will be selected. These sites should represent good ecological “control” sites for establishing background levels of radionuclides in the vegetation and animals. Vegetation, climate, and other ecological site conditions should be close to those at the selected contamination sites.

Field Verify Acceptable Conditions at Contaminated and Control Sites: Treatment and control sites will be visited to ensure that site conditions are acceptable and consistent with data quality objectives. A list of candidate animals to be sampled will be developed and any disqualifying site conditions noted. A list of sampling sites with acceptable site conditions will be developed.

From NTS Literature, Select Animal Species to be Sampled, Location of Sampling, and Period of Sampling: From results of field visits and NTS literature, identify and select the game animal species that will be sampled during the future monitoring efforts. Such animals will be selected because they are abundant at the site, have a high probability of containing high levels of radionuclides in their tissues, and are capable of migrating from the site. Candidate animals include mourning doves and rabbits (jackrabbit and cottontail).

Prepare a Detailed Sampling and Analysis Plan: After completing steps above, the plan will be prepared and reviewed prior to field sample collection and sample analysis. This plan is scheduled for completion by the second quarter of calendar year (CY) 1998. A separate Sampling and Analysis Plan will be prepared to address offsite monitoring of milk.

Collect and Analyze Animal Samples: Animals will be trapped or shot to provide sample material. Care will be taken to prevent contamination of edible portions of meat with fur or fecal material that may be contaminated with radionuclides. Samples will consist of 1 kg of meat. Several animals may have to be composited to obtain adequate samples. Samples will be refrigerated and processed in a timely manner. Data from animal samples will be evaluated to determine sampling and analytical variances. Based on evaluations, recommendations will be made regarding adequacy of sample size and estimates of error terms.

Modify the Sampling Program Based on Recommendations and Decision Rules: As new information becomes available, or when action levels are exceeded during sampling, the monitoring program will be modified to increase cost-efficiency while ensuring that DQOs are satisfied. One site will be sampled each year until all sites have been sampled. Thereafter, each of the sites will be sampled a minimum of once every five years. During years when animal numbers are insufficient to sample then alternative sites or animals (e.g., kangaroo rats or chukars) will be used. Recommendations will be made to modify the sampling program at sites where changes in site conditions, regulatory requirements, or DOE orders no longer satisfy the data quality objectives.

Operational Details and Theoretical Assumptions of Study Design

Details and theoretical assumptions of the selected design will be developed as soon as the sampling design is finalized and results of initial sample screening are received.

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9.0 DATA QUALITY OBJECTIVE PROCESS FOR OFFSITE BIOTA MONITORING

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

Long-lived radionuclides on airborne particulates and in surface soils off the NTS downwind from historic atmospheric nuclear tests.

Types of Contaminants and Affected Media

^3H , ^{137}Cs , ^{89}Sr , ^{90}Sr , ^{238}Pu , and $^{239+240}\text{Pu}$ as contained in soils, air, vegetation, and animals downwind of the NTS. Tritiated water and ^{137}Cs are relatively mobile and can be taken up by vegetation, thereby entering the food chain. ^{89}Sr , ^{90}Sr , ^{238}Pu , and $^{239+240}\text{Pu}$ are not as mobile, but may bioaccumulate in bone and selected organs of animals. ^{238}Pu and $^{239+240}\text{Pu}$ are found as small, silt-sized particles that are washed off the soil surface and over time are mixed into the soil, diluting the original contamination and resulting in very low or near background levels in edible crops and muscle tissue of animals.

Known or Potential Routes of Migration

Soil: Radionuclides are taken up from the soil into vegetation and accumulated by plants. Contaminated plant tissues may be eaten by humans if the plants are crops or may be eaten by grazing game or livestock. Contaminated milk and meat products of these grazing animals can then be ingested by humans.

Air: Radionuclides are distributed by resuspension of contaminated soils onto vegetation. Contaminated leaves are eaten by game or livestock, and contaminants enter food chains that may transfer to humans by ingestion of game animals or livestock.

Known Human and Environmental Receptors

Receptors include plants growing in contaminated soils, animals that eat these plants, and humans that may eat the plants or the animals which forage on the contaminated vegetation.

Exposure Pathways and Scenarios

Windblown radioactive particles, predominantly from historic atmospheric tests that were conducted on the NTS, may travel offsite and be deposited on soil. Contaminated soils may also be resuspended by wind and deposited onto vegetation. Crops growing in downwind contaminated sites may take up radionuclides from the soil, or may have contaminated soil particles adhere to them. These crops may then be ingested by humans. Also, vegetation in contaminated sites may be ingested by grazing game animals or livestock and radionuclides may be passed on to humans through consumption of meat and milk products of these animals. The most likely contaminated crops would be fruits and vegetables with rough surfaces from which surface soil contamination would be less easy to wash off. The most likely domestic animals to bioaccumulate small amounts of radionuclides deposited over large areas would be pasture-fed cattle, sheep, or goats (or these animals that have been fed locally grown and potentially contaminated hay). The most likely game animals would include deer, desert bighorn sheep, doves, chukars, and quail.

Current and Future Land Uses

The NAFR surrounds the NTS to the northwest and to the east; public access is denied on NAFR. Communities to the northeast and east of the NTS in Lincoln and Clark counties, Nevada; and in southwest Utah and northwest Arizona were downwind of historic atmospheric nuclear tests conducted on the NTS. Within these communities, agricultural activity occurs, including some commercial and private farming and ranching. Land use in offsite areas around NTS and NAFR are not expected to change.

Sources of Historic Data Associated with Previous Data Collection Activities

Existing sources of information are listed in the Reference section of this DQO.

Applicable Requirements or Regulations

DOE Orders: DOE Order 5400.1, “General Environmental Protection Program” (DOE, 1988), Chapter IV – Environmental Monitoring states: “Environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities onsite and offsite environmental and natural resources Environmental surveillance shall be designed to satisfy one or more of the following program objectives: . . . Characterize and define trends in the physical, chemical, and biological condition of environmental media”

DOE Order 5400.5, “Radiation Protection of the Public and the Environment” (DOE, 1990) states: “. . . it is DOE’s objective to protect the environment from radioactive contamination to the extent practical.” This order limits aquatic animals to 1 R/day. Site-specific quantitative limits have been proposed for game animals at other DOE facilities (e.g., Hanford Site for

sportsman's edible game such as deer, rabbits, carp and migratory game birds) based on human dose models. For this monitoring program, the quantitative limits in plant and animal products will be mean concentrations above detection limits.

DOE Guidelines: *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T, January 1991) is the regulatory guide to be followed to comply with DOE 5400.1 and 5400.5. The minimum criteria for Routine Surveillance is:

- “When feasible, all environmental media that, as determined by site-specific radiation exposure pathway analysis, might lead to a measurable annual dose of site origin at the site boundary *should** be routinely sampled and analyzed . . . if the total exceeds 5 mrem effective dose equivalent; or 100 person-rem collective effective dose equivalent within a radius of 80 km of a central point in the site”

The minimum criteria for Periodic Confirmation is:

- “Environmental surveillance measurements may be performed periodically, but *should** be performed at least every five years, to confirm the low dose levels, if the projected annual effective dose equivalent of site origin is less than or equal to 0.1 mrem.” This has been the exposure experienced by the offsite public in past years.

DOE/EH-0173T also specifies other sampling guidelines shown in the table below.

Regulation: DOE/EH-0173T	Media: Biota
Environmental Regulatory Guide for Radiological Effluent Monitoring and	
Environmental Surveillance	
Plan Element	Citation Location
Use an environmental monitoring program	Section 1.0
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Offsite EDE from foodstuffs between 0.1 and 1 mrem, then monitor	Section 5.8
If EDE less than 1 mrem, periodic sampling and analysis of indicators	Section 5.8
Pathway evaluation should consider, in order, milk, vegetables, meat	Section 5.8
Milk samples should be from local cows, not store bought	Section 5.8
Preserve samples to prevent souring or curdling	Section 5.8
Minimum of one background and one potentially affected location sampled	Section 5.8
Quality assurance plan required	Section 10
Rationale for monitoring required, i.e., pathway analysis	Section 5.1

Stakeholder Concerns: Stakeholders are concerned about offsite radiation exposures via contaminated foodstuffs. Periodic monitoring and reporting of radionuclide levels in foodstuffs raised in downwind communities is needed to assure the public that exposure is negligible.

The Contamination Problem

During the years of atmospheric testing, fission products were carried off the NTS and deposited downwind. Longer-lived radionuclides, particularly plutonium and strontium isotopes, are still detected in soil in the areas downwind. Offsite crops and livestock in neighboring communities have been monitored for years to document possible radionuclide exposure to the public (EPA, 1978a,b; 1996a). Recent radioanalysis of selected fruits and vegetables from downwind communities to the north and east of the NTS (e.g., Rachel, Alamo, Hiko) have shown levels of ^3H , ^{89}Sr , ^{90}Sr , and $^{239+240}\text{Pu}$ near or below detection limits (EPA, 1996a). Also, livestock or game animals within the same downwind fallout areas could ingest contaminated forage and then be consumed by humans. ^{90}Sr levels in the bones of deer, cattle, and bighorn sheep sampled in 1993 off NTS were above detection limits but have consistently decreased in samples since the early 1960s as a result of discontinued aboveground testing (EPA, 1996a). The edible portions of these offsite animals historically contain nondetectable levels of radionuclides. However, ^{90}Sr levels in milk from cows sampled from downwind ranches near the NTS have been periodically measured at levels above detection limits (EPA, 1996a). A monitoring program is required for compliance with DOE Order 5400.1. Additionally, public concern about radionuclides in plants and animals and pathways to man, as documented in the NTS EIS, establishes a nonobligatory driver for monitoring offsite foodstuffs.

STEP 2: IDENTIFY THE DECISION

Key Decisions

Decision 1: Through routine monitoring, determine if the public is currently exposed to detectable levels of radionuclides in foodstuffs that are traceable to past or current NTS activities.

Decision 2: Through further sampling and analysis, determine the temporal and spatial extent of radionuclide contamination in foodstuffs that exceed detection limits.

Alternative Actions Resulting From Resolution of Decisions

Action Corresponding to Decision 1: Sample and analyze foodstuffs from a downwind community where fallout is present from past nuclear tests conducted on the NTS. Sample only those foodstuffs that have had mean radionuclide concentrations above detection limits (based on the published results of offsite radiological monitoring conducted over the past 20+ years). Sample similar foodstuffs from a representative upwind community as a control.

Action Corresponding to Decision 2: If any radionuclide concentrations in foodstuffs exceed analytical detection limits, examine concentrations in other media samples collected from the site and gather additional samples to confirm the radiation source. Collect additional foodstuff samples or other media samples to identify the temporal and spatial extent of contamination at the site.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

Information Inputs Needed to Resolve Decision(s)

- Data from prior studies (from NTS and worldwide) on radionuclide transport through the ecosystem:
 - transport of radionuclides through different media of the ecosystem,
 - transport/storage of radionuclides in different plant parts and animal tissues, and
 - seasonal effects of radionuclide transport/storage in plants and animals.
- Inventory of radionuclides found in the environment during previous studies of neighboring communities off the NTS.
- The pattern of fallout offsite from nuclear tests conducted on the NTS.
- List of offsite farms/dairies/ranches at which crops and livestock have been sampled and analyzed for radionuclides.

Sources of Environmental Input

- Previous radionuclide monitoring data for domestic livestock and crops offsite (EPA/DOE documents).
- Existing soils and surface water radionuclide inventories off NTS (EPA/DOE documents).
- Inventory of radionuclide concentrations in key game animals off NTS.
- Existing literature (NTS and worldwide) on dose/effects of radionuclides in crops, game, and livestock.
- Map of fallout pattern from historic atmospheric nuclear tests conducted on the NTS (from the ARL/SORD).

Basis for Establishing Contaminant-Specific Action Level(s)

The action level chosen for analysis of foodstuffs is chosen to be the most conservative possible and will be the analytical detection limit for each radionuclide measured.

Potential Sampling Approaches and Appropriate Analytical Methods

The approach will be to sample those crop and animal products with the highest probability of entering the food chain (pathway) to humans and which have been shown over the past five years to be found in mean concentrations that are greater than analytical detection limits. This will only include offsite milk samples from cows and/or goats grazing on pasture vegetation or locally grown hay. Past monitoring data indicate that washed crops and meat of sampled livestock are at or below detection limits, although occasional milk samples have shown ⁹⁰Sr levels above detection limits. A 4-L milk sample will be collected with the cooperation of the farm/dairy

owner/manager from a site downwind of the NTS (to the northeast and east) and a control sample upwind will be collected. The milk samples will be analyzed for gamma emitters and ^{90}Sr . ^{89}Sr will not be analyzed because of its short half-life.

Analytical methods appropriate for radionuclide detection in milk will follow the recommended laboratory procedures (e.g., sample ID, sample preservation and handling practices, analytical methods, equipment calibration, reference source practices, frequencies, and methods and other quality assurance procedures) of the Environmental Regulatory Guide (DOE/EH-0173T, 1991).

Milk samples will be taken during the season most favorable for forage plant species to contain ^{90}Sr .

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY

Geographic Areas of the Field Investigation

Sampling will focus on areas known to lie within the historic downwind fallout pattern from historic aboveground nuclear tests conducted on the NTS (i.e., within one of the isodose areas shown in Figure E-11). Control milk samples will be collected from an area outside of the isodose areas. The spatial sampling boundaries will therefore be the boundary of the fallout pattern (*Figure E-11*) which was developed by the ARL/SORD.

Temporal Boundaries of the Decision

Milk sampling will be conducted once every year from one upwind and one downwind site off the NTS. If concentration levels are above the action level at a site, then monitoring frequency at that site may be increased to confirm the source of the contamination.

Milk samples will be collected in years with sufficient precipitation, irrigation, or other conditions to allow the sampled dairy cow(s) or goats to be pasture-fed or fed locally grown hay within the previous week of sampling. Milk will be collected at the same time of year that onsite biota will be sampled to consolidate sample analysis efforts.

Practical Constraints on Data Collection

It is possible that during the sampling period, there are no cows or goats from neighboring farms/dairies that have been grazing on pasture vegetation or locally grown hay within the past week. The sampling period will be shifted within the year in order to meet this criterion.

Figure E-11 Cumulative Estimated Exposure (mR) from All NTS Tests Through 1985

STEP 5: DEVELOP A DECISION RULE

Parameter(s) that Characterize the Population of Interest

The variable of concern is ^{90}Sr that has been identified from previous sampling of offsite milk to be occasionally at levels above detection limits. ^{90}Sr readily enters the human food chain when in cow or goat milk. One additional analysis has been included which is a gamma scan to detect other gamma-generating radionuclides.

Action Level(s) for the Decision(s)

The action level for ^{90}Sr will be the analytical detection limit for a 4-L milk sample.

Decision Rule

If the mean concentration of ^{90}Sr or gamma scans for the downwind milk sample is below the detection limit, then:

- Values will be documented in the ASER, but no additional evaluations, assessments, or special studies will be implemented. Environmental surveillance measurements of offsite cow milk will continue annually.

If the mean concentration of ^{90}Sr or gamma scans for the downwind milk sample is above the detection limit, then:

- The potential EDE from consumption of milk containing equivalent measurable levels of ^{90}Sr as was found in the sample will be calculated. Management will be advised of the elevated levels and additional sampling and analyses will be performed. These may include additional validation of laboratory analysis results, further statistical sampling, further milk sampling to determine the spatial or temporal boundaries of the contaminated pasture or feed, or sampling of other related media to confirm source levels and document trends. Monitoring may continue on a more frequent schedule than once a year.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

Possible Range of the Parameter of Interest

Only one milk sample from a downwind and an upwind site will be analyzed each year. The downwind site selected will represent the worst-case site for expected contamination, based on monitoring data available from all neighboring communities. It is believed that milk from a single cow or goat, or from many cows or goats at the one downwind site sampled, will graze over the same large area that is contaminated with low levels of ^{90}Sr particulates on the forage plants. No difference among cows or goats is expected in the transfer of ^{90}Sr (which mimics calcium) from forage into milk. Therefore, the milk from one sample is believed to be representative of the ^{90}Sr exposure experienced by all animals from the same farm/dairy. Collecting more than one milk sample at each site was considered unnecessary and not cost-effective. The monitoring approach will be nonstatistical and monitoring efforts will not establish statistical limits, but may report the power or limitations of statistical tests based on the limited sampling.

The lower bounds of the variable of interest (^{90}Sr) is the natural background concentration for this radionuclide in cow milk. The mean background level and sampling variance will be established by documenting levels measured in milk from upwind control sites with no history of radionuclide contamination from historical fallout.

The upper bounds of this variable in milk will be determined from published literature of the offsite radiological milk surveillance program and from estimated values determined from outside literature, values reported for other DOE sites, or other media measured off the NTS (e.g., surface soils).

Potential Consequences of Type 1 and Type 2 Errors

The two types of errors are defined below for the null hypothesis that no ^{90}Sr from historic NTS fallout is present. The action level is that observed concentration of ^{90}Sr that will trigger an action, such as the decision to better define the extent of increased concentration. The alternative hypothesis is that ^{90}Sr is present at concentrations above the action level.

False negative errors: (alpha [α] or Type 1 error) would occur when acceptance of mean sampling values for ^{90}Sr in milk leads the decision maker to conclude that the population means of ^{90}Sr in milk is below the action level when they truly are not. This is the more severe error.

False positive errors: (beta [β] or Type 2 error) would occur when acceptance of mean sampling values for ^{90}Sr in milk leads the decision maker to conclude that the population means of ^{90}Sr in milk is above the action level when they truly are not. This is the less severe error.

Acceptable Probability of Type 1 and Type 2 Errors

Proposed error margins are:

- $\alpha = 10$ percent for false positive with a 90 percent confidence
- $\beta = 20$ percent for false negative with an 80 percent confidence

In practice, these error margins may have to be adjusted (e.g., $\alpha = 20$ percent), based on variability encountered during analysis, because the sampling numbers and associated costs required to satisfy these error margins may otherwise be cost-prohibitive.

STEP 7: OPTIMIZE THE STUDY DESIGN

General Sampling and Analysis Design

Preliminary Estimate of Variability

Variability for ^{90}Sr in cow or goat milk from neighboring communities will be determined from past data.

Sampling Strategy

Select Downwind Contamination Site: From past radiological monitoring reports and maps, representative farms/dairies off the NTS with high levels of radionuclides in crops, animal products, and/or soils measured within the past five years will be selected. Ranchers/farmers will be questioned to obtain their cooperation and ensure that dairy cows are fed locally grown hay or pasture vegetation. If multiple sites are available for sampling, that site with a history of the most contaminated foodstuffs will be sampled as a “worst-case” downwind site.

Select Upwind Control Site: From past radiological monitoring reports, possible control sites off NTS will be selected. These sites should represent good ecological “control” sites for establishing background levels of ^{90}Sr in milk. Vegetation, climate, and other ecological site conditions should be close to those at the selected downwind site. Similar cooperation must be obtained from ranchers/farmers and cows must be feeding on pasture vegetation or locally grown hay.

Prepare a Detailed Sampling and Analysis Plan: The plan will be prepared and reviewed prior to field sample collection and sample analysis. This plan is scheduled for completion by the fourth quarter of FY 1998.

Collect and Analyze Milk Samples: A composited sample from many cows or goats, or a single sample from one cow or goat will be collected.

Modify the Sampling Program Based on Recommendations and Decision Rules: When action levels are exceeded during monitoring, the monitoring program will be modified to ensure that DQOs are satisfied. One site will be sampled and results reported each year. Results will be reported in the ASER. Recommendations will be made to modify the sampling program when changes in site conditions, regulatory requirements, or DOE Orders no longer satisfy the DQOs.

Details and theoretical assumptions of the selected design will be developed as soon as the sampling design is finalized and results of initial sample screening are received.

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10.0 DATA QUALITY OBJECTIVES FOR DIRECT RADIATION MONITORING ON AND AROUND THE NTS

STEP 1: STATE THE PROBLEM

Known or Suspected Sources of Contamination/Radiation

- Large areas on the NTS have radiation levels elevated above natural background levels as a result of atmospheric and near-surface weapons testing, and ventings from underground weapons testing.
- Limited areas occupied by the public outside the NTS have elevated radiation levels because of contamination from previous activities on the NTS.
- RWMSs contain radioactive material that may cause elevated radiation levels outside the fences around the sites.
- Accidents involving radioactive material or radiation-generating devices may result in elevated radiation levels.

Regulation: DOE/EH-0173T	Media: Direct Radiation
Environmental Regulatory Guide for Radiological Effluent Monitoring and	
Environmental Surveillance	
Plan Element	Citation Location
Use an environmental monitoring program	Section 1.0
Verify compliance with applicable environmental laws and regulations	
Verify compliance with environmental commitments	
Characterize and define trends in the condition of environmental media	Section 5.5
Establish baselines of environmental quality	Section 5.5
Identify and quantify new or existing environmental quality problems	Section 5.5
Measure releases, migration, subsidence, and performance changes	Section 5.5
Perform exposure pathway analysis	Section 5.1
Perform critical pathway analysis and document in ASER	Section 5.1
Parameters to be monitored	Section 5.4
Frequency of monitoring	Section 5.5
Location of monitoring points	Section 5.5
Equipment, instrumentation, and facilities to be used for measurements	Section 5.5
Method to be used for obtaining environmental samples	Section 5.5
Analysis method	Section 5.6
Action levels	
Quality assurance plan required	Section 10
Rationale for monitoring required	Section 5.1

STEP 2: IDENTIFY THE DECISION

- The rate of change in radiation levels is/is not consistent with the predicted change due to radioactive decay. Further investigation will be needed to determine the cause if the rate of change in radiation levels is not consistent with the predicted change due to radioactive decay.
- Radiation levels are/are not in compliance with DOE Order 5400.5 requirements.
- Radiation levels around the perimeter of RWMS are/are not in compliance with DOE Order 5820.2A.
- Ambient radiation levels in the area affected by an accident did/did not change as a result of the accident.
- The readings from these TLDs may also be used by Environment, Safety, and Health (ES&H) to determine compliance with Title 10 CFR 835 requirements for monitoring personnel.

STEP 3: IDENTIFY THE INPUTS TO THE DECISION

- TLD readings from TLDs posted in and near areas of soil contamination. Comparison of these readings with other data, such as the predicted decrease due to radioactive decay, demarcation study data, and “flyover” data.
- TLD readings from TLDs posted on- and offsite, dose estimates to members of the public from other pathways, DOE Order 5400.5 requirements, survey data from pressurized ion chambers (PICs), or portable instruments.
- TLD readings from TLDs posted along the RWMS perimeter, operations log, readings from survey instruments.

STEP 4: DEFINE THE STUDY BOUNDARIES

- Gamma radiation above about 60 KeV in the environment, from contaminated soil, and waste management operations.
- NTS and the areas around the NTS which may be affected by past, present, or future activities on the NTS.

STEP 5: DEVELOP A DECISION RULE

- For Environmental, Background, and Historical Stations, when the rate of change in radiation levels is not consistent with the predicted rate of change, the cause for the change shall be investigated. To minimize false-positive or false-negative conclusions, experimental error and modeling error shall be considered when determining if a rate of change is consistent with the predicted rate of change. Analysis of results shall include evaluations of results for single posting locations, as well as evaluations of the complete network and appropriate groupings within the network. Inconsistencies between predictions and results are to be investigated to determine if the change is due to migration or covering of radioactive material by wind or water erosion, operational changes, accidents, TLD system errors, personnel errors, etc.
- When it is estimated that exposures may approach or exceed 10 percent of the DOE Order 5400.5 requirements, investigations and corrective actions shall be performed.
- Investigations and corrective actions will be taken and reported as required by DOE Order 5820.2A.
- Estimated or known exposures to unmonitored personnel exposed as the result of an accident shall be reported in accordance with applicable rules and regulations.

STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

- The decision for the need to investigate discrepancies shall be correct with 80 percent probability (i.e., no more than 10 percent false-positive decisions and no more than 10 percent false-negative decisions).
- The decision that a member of the public did or may have received an exposure in excess of 10 percent of DOE Order 5400.5 requirements shall be correct with 80 percent probability (i.e., no more than 10 percent false-positive decisions and no more than 10 percent false-negative decisions).
- One hundred percent of the investigations, corrective actions, reports, and records required by applicable rules and regulations will be performed.

STEP 7: OPTIMIZE THE STUDY DESIGN

Design Objective: Comply with American National Standards Institute (ANSI) N545-1975 and DOE/EH-0173T.

- The TLD system performance specifications should comply with paragraph 3 of ANSI N545-1975.
- The TLD system shall be tested in accordance with paragraph 4 of ANSI N545-1975. This testing may be performed by the user, manufacturer, or other reliable entity. Documentation of the testing shall be of sufficient quality to be technically defensible.
- Calibration procedures for the TLD system shall be equal to or better than the criteria in paragraph 5 of ANSI N545-1975.
- TLDs shall be packaged to meet the criteria in paragraph 6.2 of ANSI N545-1975.
- Administrative and engineering controls shall be used to limit to less than 1 mrem per quarter the “non-field” exposure the TLDs receive during a field cycle. A field cycle is the period between the last annealing before posting, and readout after posting. Examples of administrative and engineering controls that might accomplish this is to allow TLDs to be stored in a lead cave no more than a total of seven days during a field cycle, and be allowed out of the lead cave while not posted no more than 24 hours during a field cycle. While out of a lead storage cave, the TLDs are not to be exposed to radiation other than ambient environmental levels on the ground; i.e., no air shipment. If the TLDs are shipped by air or the 1 mrem per quarter requirement cannot be attained by administrative and engineering controls, control TLDs shall be used to isolate field exposure in a manner consistent with ANSI N545-1975, Appendix B.
- ANSI N545-1975, Appendix C, discusses several options for the interpretation of field exposures to isolate contributions attributable to man-made radiation sources. The option of Invariance of Background with Location as discussed in paragraph C1.2 can be applied at the NTS only after the elevation and local geologic features which affect terrestrial radiation at the sampling location have been matched with a background location. The option discussed in paragraph C1.3, Invariance of Background with Time, can be used for the NTS environmental TLD system. However, due to changes in dosimetry systems and system calibration errors, the reported background at historical locations has fluctuated significantly with time. Therefore, one or more PICs, with a calibration traceable to National Institute for Standards and Technology (NIST), should be continuously stationed at one or more historical TLD locations to provide an independent measurement of the background. The PIC measurements can be used to monitor the calibration of the TLD system, and TLD system readings can be normalized to the PIC readings.

Siting: TLD posting stations for five categories are discussed below. The five categories are Environmental stations, Waste Management Site stations, Boundary stations, Offsite stations, and Historical stations. The purpose of Environmental stations is to demonstrate compliance/noncompliance with DOE Order 5400.4 requirements and to monitor trends in direct radiation levels in areas of soil contamination and relate these trends to predictions, flyover data, and demarcation data. The data from environmental TLDs may also be used during future facility siting decisions and by ES&H to determine Title 10 CFR 835 compliance. Waste Management Site stations are to comply with DOE Order 5820.2A to monitor the effect of waste management operations on the radiation levels at and near the perimeter of waste management sites. Boundary stations are to measure the direct radiation going offsite in the event of an accident to demonstrate compliance/noncompliance with DOE Order 5400.5. Boundary locations at least 10 km (6 mi) from the nearest area with elevated radiations levels, based on flyover data, are also used as background stations. Offsite stations measure direct radiation levels at the selected offsite locations to demonstrate compliance/noncompliance with DOE Order 5400.5. Historical stations, where the environmental radiation levels have been monitored by TLDs for many years and where the radiation levels are expected to be constant with time, will be used to monitor the performance of the TLD system and can be used to compensate for calibration errors or system differences when the use of new readers and/or TLDs is implemented. The guidelines in DOE/EH-0173T, paragraph 5.5, should be observed when selecting TLD stations.

a. TLD Posting Station Selection Criteria

- (1) Environmental Stations: Environmental TLDs are to be posted in and around areas where the radiation levels are elevated due to soil contamination. Because of the access restrictions to soil contamination areas where the contamination is removable, the stations will be located only within soil contamination areas if the contamination is not removable. Five to seven soil contamination areas should be selected. Seven stations should be selected for each selected fixed soil contamination area. These stations should transect the contamination area, with one station at or near the highest radiation levels in the areas, two stations where the radiation levels are approximately 50 percent of the highest levels, two stations near the edge of the posted area, and two stations just outside of the posted area.
- (2) Waste Management Site Stations: DOE Order 5820.2A, "Radioactive Waste Management"; and DOE/LLW-13Tg, Low-Level Waste Management Handbook Series – "Environmental Monitoring for Low-Level Waste Disposal Sites," provide requirements and guidance for monitoring direct radiation around the perimeter of waste management sites. DOE/LLW-13Tg recommends six perimeter stations, with the stations being nearest to where people are located, and near roads and parking areas used by trucks that deliver waste.
- (3) Background Stations: Background stations should be selected in areas where the ambient radiation levels are consistent with the radiation levels from natural background at environmental and waste management site stations. Natural background radiation levels vary significantly on the NTS because of elevation

variations and geologic features; therefore, background radiation levels should be separated into at least four ranges (e.g., $< 6 \mu\text{R/hr}$ [$< 52 \text{ mR/yr}$], $6 \text{ to } 12 \mu\text{R/hr}$ [$52 \text{ to } 105 \text{ mR/yr}$], $12 \text{ to } 18 \mu\text{R/hr}$ [$106 \text{ to } 158 \text{ mR/yr}$], $18 \text{ to } 24 \mu\text{R/hr}$ [$159 \text{ to } 210 \text{ mR/yr}$]), and at least three background stations selected for each range. A map of the NTS showing terrestrial exposure rates should be used for preliminary site selection. Final site selection should be made using ground radiation surveys with a PIC or other suitable instrument in accordance with DOE/EH-0173T.

DOE/EH-0173T states “Background or control measurement stations *should* be a minimum of distance of 15 to 20 km from the larger sites and 10 to 15 km from the smaller sites in the least prevalent wind direction.” For the purpose of selecting control TLD stations, each contaminated soil area, as identified by the flyover data, and each RWMS will be considered a site. Therefore, background TLD stations can be on the NTS while meeting the distance criteria above.

- (4) Offsite Stations: The selection for siting offsite TLD stations is discussed in the offsite network design.
- (5) Historical Stations: TLDs have been posted for over ten years at nine stations in areas not affected by soil contamination or other man-made radiation. The radiation levels at these locations are believed to not have changed with time. The reported radiation levels for these locations have varied in unison with time, indicating the reported radiation level changes are a reflection of changes in the TLD system used and TLD system calibration, rather than in the actual radiation levels

b. Stations Selected or Proposed

- (1) Environmental Stations: Current stations that meet the selection criteria should be retained. Surveys of these stations consistent with DOE/EH-0173T, paragraph 5.5, should be performed. When demarcation study data is available, the data should be reviewed to select potential new environmental TLD stations and new sites selected consistent with the process described in DOE/EH-0173T.
- (2) Waste Management Site Stations: Select locations consistent with the guidance in DOE/LLW-13Tg. Use existing stations if they meet the criteria in DOE/LLW-13Tg. Delete existing stations which are within the site-controlled areas.
- (3) Background Stations: Current stations which meet the selection criteria should be retained. Surveys of these stations consistent with DOE/EH-0173T, paragraph 5.5, should be performed. Background stations should be characterized and correlated to environmental, waste management, and offsite stations with similar elevation and geologic features (with respect to radiation levels).

- (4) Offsite Stations have been selected as discussed in the offsite monitoring plan.
- (5) Historical Stations: YUCCA Oil Storage, B-650 Dosimetry, B-650 Roof, Post Office, Nuclear Rocket Development Stations (NRDS), Warehouse, CP-6, Well 5B, A-27 Cafeteria, and HENRE.

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Attachment E1

Tritium in Vegetation on the NTS

TRITIUM IN VEGETATION ON THE NEVADA TEST SITE

Richard B. Hunter

and

Robert R. Kinnison

**Prepared by:
Bechtel Nevada Corporation
P. O. Box 98521
Las Vegas, NV 89193-8521**

**Prepared for:
U.S. Department of Energy
Nevada Operations Office**

ACKNOWLEDGMENTS

A large number of people aided materially with this project, including collecting plant samples, analyzing the extracted water, helping with text and references, secretarial and supervisory tasks, mapping the results, and preparing and editing the manuscript. Among those who helped were C. Castaneda, W. Glines, L. Jaussi, G. Junius, D. Lantz, S. Livenick, Y. Lee, H. Lowery, M. Morris, D. Pernice, C. Slotemaker, M. Weaver, W. Wharton, D. Witham, S. Wolf, and M. Young. Funding was provided by the U.S. Department of Energy under contract DE-AC08--96NV11718.

ABSTRACT

Shrubs and trees were sampled throughout the 3,500 km² (1,350 square mile) Nevada Test Site (NTS) to monitor tritium in transpiration-stream water and to determine locations of tritium-contaminated surface soils. Sample densities varied from 0.2 to 2 per square minute, with higher densities in areas of known or suspected contamination. Most concentrated tritium (>10,000 Bq/l H₂O) was found around the SEDAN cratering test, but vegetation at several other sites contained more than 300 Bq/l, the drinking-water limits for tritium. Apparent mechanisms of contamination included fallout, entrainment in material thrown out from cratering tests, neutron activation in alluvium beneath above-ground tests, and soil contamination from either pumped water or natural drainage. Slight effects of different plant species' rooting or water-storage habits were evident. No clear evidence of escape of tritium from contained underground explosions was found. Tritium in the vegetation was a plausible explanation for elevated concentrations found in feral horse feces. Levels of tritium found were not hazardous, but might be useful in studies of water movement through the desert ecosystem.

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INTRODUCTION

The NTS encompasses an area of 3,500 km² located in the deserts of west-central Nevada east of Death Valley National Monument. It was the site of 938 nuclear weapons tests between 1951 and 1992, including 100 tests above ground and 838 beneath the surface. One radioactive byproduct of those tests was tritium, the isotope of hydrogen with one proton and two neutrons, which decays to ³He with a half-life of 12.4 years. In 1995 there were estimated to be more than 11×10^{18} Bq (300 million Curies) of tritium from underground tests, primarily deep below the surface of the NTS; and approximately 3.7×10^{17} Bq (10 million Curies) of tritiated low-level radioactive waste buried within 37 meters (120 feet) of the surface (U.S. Department of Energy 1996).

Tritium in air, drinking water, and groundwater has been monitored on the NTS for many years. Air monitoring sites are primarily at work locations, while water is sampled from wells and worker facilities and the rare springs and seeps. Groundwater is sampled under the U. S. Department of Energy's (DOE's) Hydrologic Resources Monitoring Program. Results for all these sampling programs are published annually (e.g. Black et al., 1995; Black and Townsend 1996). A hydrologic model of movement of tritium from buried wastes has been published by Smiles, Gardner, and Schulz (1995). One study looked at tritium contamination from rainfall in the near-surface environment (Hurst 1988).

Vegetation on the NTS has rarely been sampled for tritium. Koranda (1969) and Koranda and Martin (1969) documented tritium levels in vegetation and kangaroo rats (*Dipodomys merriami*) near the SEDAN cratering test, which deposited crushed rock/alluvium to a radius of about 762 m (2500 ft) (Martin 1963). Mason et al., (1969) documented levels of tritium in soils near SEDAN and in vegetables grown on that soil, and documented a four- to five-fold decrease in concentration between soil and plant tritium. R. K. Schulz et al., published results of monitoring near-surface buried tritium wastes at a low-level waste burial facility (Schulz et al., 1990; Schulz and Weaver 1993, 1995). They sampled water in plants growing over the buried wastes, then based estimates of loss to the atmosphere on modeled plant transpiration. Finally, Ruggieri et al., (1988) observed diurnal fluctuations in plant tritium content in reeds and trees growing in a ditch carrying tritiated water pumped away from the vicinity of the CAMBRIC underground test (Bryant 1992).

In 1993 and 1994, tritium was measured in fresh horse feces (~4 Bq/l) and a few grass samples from areas where feral horses grazed (Greger 1995). These observations were a major impetus for this study, as the source of tritium in the horse feces could not be determined from available monitoring data.

Three hypotheses were proposed to explain the tritium in grass and horse feces: (1) they could result from airborne tritium at higher concentrations than measured at the nearest air monitoring stations; (2) they could result from transpiration of rainwater which fell decades earlier, when atmospheric levels were considerably higher (Kinnison 1996; Weiss et al., 1979); (3) they could be the result of upwards movement of contamination from underground weapons tests. Available evidence was scanty for all three hypotheses, and none was well supported. For example, the air monitoring stations were at town sites or facilities some distance from the center of the highest known source at SEDAN crater. Vadose zone water was found by Hurst (1988) to contain

negligible tritium in the mid-1980's at the only sampled site in Yucca Flat. And the few studies of deep groundwater in the Yucca Flat area did not attempt to collect evidence of tritium migration to the surface (Borg et al., 1976; Buddemeier 1988).

METHODS

The goal of this study was to map the occurrence of tritium in NTS vegetation. The finding of unexplained tritium in grasses within the feral horse range indicated the presence of either unknown sources or unknown transport pathways from known sources; hence, we could not justify limiting the search area to known source regions. A twofold approach was therefore adopted in which known or suspected source regions were sampled at one or two locations in every adjacent square minute, and the rest of the area of the NTS was sampled at single locations in one of each five square minutes. (One square minute is slightly larger than a square mile, or 2.6 km².)

A map of the NTS, with grid lines at each minute of latitude and longitude, was used to select square minute areas. Each square minute containing a suspected or known source and the set of eight square minutes immediately adjacent to it, were selected for sampling at two locations each. Suspected sources included each of the Plowshare tests (designed to explore the use of nuclear explosions for surface excavation - SEDAN, DANNY BOY, BUGGY, CABRIOLET, PALANQUIN, and SCHOONER); the ponds holding drainage from tunnels into Rainier Mesa (known to be contaminated before drying up in 1993); the Cambic ditch and the pond it drained into on Frenchman Lake (tritiated water was pumped from 1978-1992); the low level Radioactive Waste Management Site in Frenchman Flat (shown by Schulz et al. (1993, 1995) to have elevated tritium in trenchcap vegetation); an area near the U3AH/AT waste burial site in Yucca Flat; the area around an air sampler at BJY in Yucca Flat which detected a slight tritium peak in summer of 1994 (Kinnison 1996); and the EPA Farm, because of low level tritium experiments performed there in the late 1960's (Black and Smith 1984). One location per square minute was sampled in an area of multiple underground tests on Pahute Mesa, in consideration of the finding of a tritium-contaminated well in the region (Well PM1; Davis et al. 1995, 1996a). Two squares in the general area of mildly contaminated grass samples (see Greger 1995) were sampled, at one location each. The total of the selected square minutes for two locations each was 81, of which 77 were sampled (at 149 locations). Two of the four unsampled squares were barricaded, and sampling was postponed but never completed. The other unsampled squares were too difficult to access, being in rough, isolated terrain. All 26 squares chosen for 1 sample location were sampled.

Of the remaining squares without suspected sources, one in five was randomly selected, totaling 201 squares. Of these only 146 were actually sampled, primarily due to time and access problems. Most randomly selected squares left unsampled were far from roads and therefore too time-consuming to sample. A total of 957 square minutes were not sampled, including those selected but not sampled. Overall, 629 samples were collected and analyzed from 341 sites. No samples were taken inside barricades or roped-off contaminated areas. Sample locations were determined with Global Positioning System units (Magellan 5000 Pro or Trimble Scout Master units). An average of 50 position determinations taken during sample collection was recorded for each sample. Samplers were generally unaware of the source locations and sampled at convenient locations within the selected squares, rather than at locations close to the suspected sources.

Samples were collected in late summer (July 15 - Sept. 26) to assure plants were drawing water from as deeply as possible in the soil, after rainfall had been depleted. There was little spring rainfall in 1996, and virtually none during the summer anywhere on the NTS. Sampling began during afternoons, but analyses of duplicate samples from CAMBRIC ditch showed no significant difference between morning and afternoon tritium concentrations. Sampling was subsequently conducted throughout the day.

During sampling most species were dormant. Samplers attempted to collect thicker stem tissue of deep-rooted drought-hardy shrubs or trees. In the lower elevations the primary species were *Larrea tridentata* (creosotebush) and *Ephedra nevadensis* (Nevada Ephedra), both long-lived large shrubs, and therefore thought to be deeply rooted. In areas where those species were absent, *Atriplex canescens* (Four-wing saltbush) was preferred. At middle elevations, where *Yucca brevifolia* (Joshua tree) was present, its leaves were collected, usually together with an adjacent shrub (the Joshua tree survives by storing water, rather than tolerating dessication). At higher elevations pinyon pine and juniper trees (*Pinus monophylla* and *Juniperus osteosperma*) were favored, though the shrubs *Ephedra viridis* (green ephedra) and *Artemisia tridentata* (Big Sage) were sampled in the absence of trees. Sampling of leaf or fine-stem tissue was usually avoided, to reduce the possibilities of water exchange between the plant and the atmosphere. Stems up to 1 cm thickness were cleaned of leaves and twigs, then cut into pieces and placed in 500 ml Nalgene® bottles. That same day the plastic lid was removed and the bottle was placed inside a two quart (1.8 L) glass jar sealed with a metal lid. After several days in the sun, water distilled out of the stems and condensed inside the jar; it was then poured into glass scintillation vials. Yields of water ranged from 1 to >50 grams and from 6 to >100 percent of the weight of remaining sample. Scintillation vials were stored at room temperature up to two weeks prior to analysis.

Samples were counted for 70 minutes on one of several scintillation counters, using 2.5 ml of the sample solution and 10 ml of Ultima Gold® scintillation cocktail. Background was counted for each batch of 10 to 18 samples, as was a reagent blank and spike (15.8 Bq/l). Background was averaged over 20 batches, and subtracted from total counts. Minimum measurable activity was generally 2.7 Bq/l, and the detection limit (2σ) was normally 1.7 Bq/l.

Mapping of the results was done with SURFER® (Golden Software), using kriging to develop isopleth lines.

RESULTS

The proportions of vegetation samples measuring more tritium than the detection limit of the assay were greater for suspected sources than at the random locations (Table 1) ($X^2 = 43.1$, $p < .001$).

The highest concentrations were in samples from the square minute containing SEDAN crater (Table 2). One sample location was estimated as 60 m outside the throw out mound surrounding the crater (186,000 and 135,000 Bq/l) and the other was about 200 m from the crater (64,000 Bq/l). This area was disturbed and occupied by scattered shrubs of *Hymenoclea salsola* (cheesebush) and *Atriplex canescens* (Fourwing saltbush), both invaders of disturbed areas. The two locations were about 0.5 miles apart.

The next highest values were two orders of magnitude lower, around 400 Bq/l. These levels occurred in CAMBRIC ditch (in *Tamarix* samples used to determine morning/afternoon fluctuations), in trees from the dried pond edges into which the CAMBRIC ditch flowed (one random sample), and in one sample (396 Bq/l) from the fallout pattern of the PALANQUIN test (Table 2) on Pahute Mesa.

Figure 1 shows the distribution of tritium with isometric lines created by an inverse distance squared algorithm. The clear high concentrations are in northern Yucca Flat around SEDAN crater; in central/western Frenchman Flat surrounding CAMBRIC ditch and pond, and extending northwards towards the low-level RWMS; north of PALANQUIN/CABRIOLET on Pahute Mesa; and on Rainier Mesa and its base. One central high area was found just west of Yucca Flat and East of Tippipah spring. It could not be associated with any known test.

Isolated instances of tritium concentrations greater than the detection limit occurred elsewhere. Two samples in undisturbed desert east and southeast of the RWMS (locations 36°51.19'N, 115°56.27'W and 36°50.46'N, 115°56.74'W) showed concentrations of 3.3 and 13.6 Bq/l, respectively. The two sites are both about 1.1 mile from the RWMS site, and 0.9 and 2.5 miles respectively from the nearest CAMBRIC ditch sample point. A sample taken a few meters N of the fenced waste burial trenches (trench 4) at RWMS (36°51.46'N, 115°57.31'W) showed 10.3 Bq/l. The relatively large distance of the contaminated sites from the two nearest sources suggested atmospheric transport, but the lack of a concentration gradient or a uniform pattern of elevated concentrations was puzzling.

Several locations with elevated HTO were sampled on large areas blasted free of vegetation by above-ground weapons tests conducted in the 1950's. These areas were not expected to have elevated tritium levels, hence were generally sampled only randomly. Most samples from blast areas were from the T3 blast area, which was sampled more densely because of some suspected sources (waste burial site U3AH/AT and BJY air monitor) on or near T3 ground zero.

Pairing the blast area samples with the closest undisturbed samples showed the set of samples from blast areas had significantly higher tritium concentration than the set of undisturbed samples (signed rank test). Ten of the 23 samples from blast areas were above the detection limit of 1.7 Bq/l, while none of the 23 matched samples was (Table 3). The ten elevated samples were from five locations. Distances between the blast area locations and the associated undisturbed sites ranged from approximately 0.37 to 2.24 minutes, and averaged 1.09 ± 0.12 minutes, i.e. they were about 1 mile apart.

Two sites on blast areas with elevated tritium had shrubs transplanted in 1979 (T1) and 1985 (T3) during revegetation trials. On the T1 site only one of the three plants sampled had detectable HTO, a *Tamarix ramosissima* (saltcedar). A transplanted *Ephedra nevadensis* and a natural *Hymenoclea salsola* (cheesebush) were below the detection limits. On the T3 revegetation site two *Larrea tridentata* (creosotebush) growing within one meter of each other differed 28 percent in HTO concentration, but an *Atriplex polycarpa* (saltbush, cattle spinach) about 15 meters away had 600 percent more (Table 3). Thus, at both revegetation sites, the HTO content was particularly variable, and the species which translocate sodium to the leaves (saltcedar, saltbush) had the higher concentrations.

One random sample south of T3 ground zero (36° 59.68' N; 116° 01.33' W) had the characteristics of a blast area - absence of most shrubs and vegetation mostly annual plants and grasses. In this unexplained cleared area, an isolated *Atriplex canescens* (Fourwing saltbush) had tritium concentration of 1.9 Bq/l, just above the detection limit. The nearest undisturbed sample point (36° 58.12' N; 115° 58.94' W) had three samples, all between 0.1 and 0.3 Bq/l.

Tunnel Containment Ponds

Elevated tritium was suspected in vegetation near the base of Rainier Mesa because ponds of drainage water from tunnels drilled into the mesa were contaminated. N Tunnel drainage ponds were empty through 1995 and 1996, but water percolating into the soil from previous years was suspected to still contaminate vegetation. However, elevated HTO in plants sampled within two miles of N Tunnel and E Tunnel and their drainage ponds was not correlated with distance from the ponds (Table 4). The closest samples to the ponds, 0.06 and 0.27 minutes distant, were below the detection limit. Two samples below the east scarp of Rainier Mesa were contaminated, an *Ephedra viridis* (green Mormon tea) and a *Pinus monophylla* (Pinyon pine) located 0.68 and 0.29 minutes from the nearest pond. Other elevated samples were between 1.34 and 1.78 minutes from the nearest pond, all on top of the mesa and west (upwind) of the ponds. Mean distance of the elevated samples from the ponds was 1.20 ± 0.24 minutes (sem), and mean distance of the non-elevated samples was 1.08 ± 0.14 minutes.

The maximum tritium concentration found near the tunnel ponds was 232 Bq/l. For comparison, the mean concentration of tritium in E Tunnel pond in 1995 was 2775 Bq/l (Davis et al., 1996b).

PALANQUIN, CABRIOLET, SCHOONER

In the northeast corner of the NTS sampling was at two locations per square minute because of three Plowshare program cratering tests, similar to the SEDAN test. The square minute containing the SCHOONER test was fenced off, and was therefore not sampled, but adjacent square minutes including the PALANQUIN fallout area were. Samples taken in the area north of the PALANQUIN test ranged from 3.7 to a maximum of 385 Bq/l. This area, along Trail Ridge Road (20-03 road), was denuded of shrubs and trees in 1965 by fallout from the PALANQUIN blast (Rhoads et al., 1969a). The highest tritium concentration was in the center of the area of killed shrubs and trees. Detectable tritium was found outside the killed area in decreasing concentrations with distance, indicating fallout from the PALANQUIN test was the source of the tritium. Tritium concentrations seemed to peak somewhat farther north than the vegetation damage (Figure 2).

The CABRIOLET test was 2500 feet (762 m) east of PALANQUIN, and fallout drifted to the northwest, across the PALANQUIN fallout pattern. There were no elevated tritium samples that could be associated specifically with CABRIOLET.

BUGGY and DANNY BOY

BUGGY and DANNY BOY were Plowshare tests conducted on the west side of the NTS. Samples were not collected in the immediate vicinity of either crater because they were marked-off with contaminated signs. Only one sampled location in the square minutes surrounding these

two tests gave detectable tritium. That location was 0.6 miles northeast of the BUGGY crater in the channel of a steep ravine (37° 00.77' N, 116° 21.93'W). A smaller ravine coming from the general direction of BUGGY joined it above the sample point. An *Ephedra viridis* contained 4.9 Bq/l, and a *Purshia tridentata* (bitterbrush) contained 19.7 Bq/l.

Underground Test Areas

One area of dense underground tests on Pahute Mesa was sampled at one location per square minute, while Areas 19 and most of Yucca Flat were sampled only at one random location per five square minutes. In addition, there were a number of underground tests within the densely sampled areas of T3 ground zero and BJY. A number of samples from those areas were slightly above the detection limits, but not consistently (Table 5). Comparing all the analyses from square minutes within or adjacent to underground tests (excluding those around SEDAN, PALANQUIN, and T3 GZ-BJY), the mean concentration of tritium in the vegetation was 1.72 ± 1.88 Bq/l (mean $\pm$ 95% confidence limit), barely above the detection limit of 1.67 Bq/l ($\pm$ 1.67, 2 σ , based on counting statistics). This value is significantly above the mean concentration of all 47 samples from Area 25 (-0.16 ± 0.16 Bq/l; t-test, unequal variances, one tailed, $p = 0.03$), which had no known tritium sources. However, all samples above the detection limit were sampled with adjacent plants which were below the detection limit (Table 5).

Tippipah Valley

Near where Tippipah Valley joins Yucca Flat two random locations were sampled. The first, at 37° 03.54'N, 116° 10.84' W, had an *Ephedra nevadensis* with 22 Bq/l and a *Yucca brevifolia* with 115 Bq/l. The second location, 37° 04.31'N x 116° 10.26' W, had a *Hymenoclea salsola* with 50 Bq/l, and another *Yucca brevifolia* with 0.9 Bq/l. There was no obvious tritium source or disturbance nearby.

Effects of Plant Species

There were significant differences between plant species sampled at the same locations, i.e., within a few meters of each other. For the 54 locations where two species were sampled and at least one of the two was above the detection limit, the mean ratio of the larger to the smaller tritium concentration was 12.5 ($\pm$ 34.5, 95% confidence limits). The median difference between two such plants was 6.8 Bq/l, well above the 1.7 Bq/l (2 σ) analytical error. The median, first and third quartiles, and maximum values were all considerably greater in the higher concentration samples. (There was only one location where tritium was detectable and two of the same species were sampled, those two tritium values were 10.6 and 14.8 Bq/l, Table 3). In the 162 pairs of plants where both were below the detection limits, the average ratio between the higher and lower concentrations was 5.63 ± 5.80 (95% cl) and the median difference was 0.6 Bq/l, well below the analytical error. This suggests that, where contamination exists, the variation between plants was much greater than the analytical error and, where absent, the analytical error predominated.

There was some evidence for species differences in tritium content. Concentration ranges were generally too great to show differences with standard statistics, but in pairs of samples from one location where one sample was above the detection limit and one plant was *Yucca brevifolia*, the

Yucca was normally the lower of the two values (14 of 17, significant at $p < .05$, sign test). Similarly 12 of 14 *Juniperus osteosperma* (Utah juniper) were lower than the matching plant ($p < 0.10$, sign test). Six of eight pine trees (*Pinus monophylla*) were higher than the matching plants (not significant), usually juniper trees. This suggests the juniper and *Yucca* are more shallow-rooted than the companion species, usually pinyon pine and mixed shrubs, respectively, assuming the tritium is from deep, long-lasting soil contamination.

Low Tritium Areas

Certain areas of the western parts of the NTS had average tritium values below zero (Figure 1). These areas are essentially uncontaminated and far from weapons testing activities. In the central part of Jackass Flats was an area below detection limits but above zero, which stood out from the surroundings. This may indicate slight contamination of that area. The three sample locations which defined it were all far from obvious structures or disturbances. Programs in Jackass Flats have included studies on nuclear rocket development and the MX rocket program, but sites disturbed by those programs were not near the elevated tritium locations. The surrounding area, statistically below zero, suggests the background value was too high, which might be corrected by adding approximately 0.25 Bq/l to each result.

An analysis of variance on the various valleys and mesas on the NTS showed no significant differences ($F_{7,594} = 1.03$, $P = 0.409$), although Yucca Flat averaged an order of magnitude higher (2423 Bq/l, $n = 159$) than any other major landform. Essentially the variability within landforms was greater than that between them, and the tritium activity was associated with point sources rather than broad regions.

DISCUSSION

Caveats

The above results should be considered approximate, for several reasons. First, sampling was at low density in both suspected contaminated areas and random samples. At low sample densities it would be easy to miss fairly large contaminated areas, and it is unlikely the maximum concentration would be sampled in any contaminated area. Second, although an attempt was made to select larger and presumably deeper-rooted plants, it appeared from paired samples that many uncontaminated plants occurred near contaminated ones, again suggesting some contaminated areas might have been missed. Third, recall the sampling was done at the time of seasonally peak atmospheric tritium levels, when soils were dry; hence, seasonal tritium contents in plants should have been at or near maximum. Finally, some evidence suggests the background value was somewhat high, hence reported values may be slightly low. However, the mapping (Figure 1) and interpretation of results were based on relative concentrations, and should not have been affected by the statistics.

With those caveats, an examination of mechanisms and probable mechanisms follows.

SEDAN - Throwout

The highest plant concentrations of tritium ($>37,000$ Bq/l) were those nearest SEDAN ground zero. In the SEDAN test, tritium contamination was associated with soil and fractured rock material thrown out of the crater. The radius of deposition of material from the “ground zero” was roughly 2,500 feet (762m) (Martin 1963). The samples were taken on areas where deposition of several inches to several feet of material occurred. After the July 1962 test, the depth to maximum tritium concentration increased to 6-8 feet below the surface by the late 1960's (Martin and Koranda 1971).

Koranda (1969) and Martin and Koranda (1971, 1972) studied vegetation and kangaroo rats near SEDAN crater and reported tritium concentrations on the order of 11,000,000 Bq/l, and a half-life in the SEDAN environment of about 13.2 months (Martin and Koranda 1971). If their half-life estimate (based on decreases in k-rat concentrations, which did not respond to rainfall) were correct, the concentrations after 26 years would be roughly 0.7 Bq/l, below our detection limit. This clearly was not the case, suggesting that tritium has continued to be supplied to the near-surface environment from deeper sources, or that the environmental half-life was inadequately determined, or loss of the tritium is more complex than presumed.

Air concentrations of tritium about 1,000 meters north of SEDAN were monitored starting in the latter half of 1995 (reported by Davis et al., 1996b). In the two-week periods before and after vegetation was sampled (September 9, 1996) the air concentration at that station was 6.3 and 4.7×10^{-5} Bq/l of air, or about 13.7 and 13.0 Bq/l of water contained in that air. Tritium in stem water was roughly 4,500 times more concentrated than the airborne water. Clearly the plants were obtaining water from a much more concentrated source and releasing it to the air, rather than vice-versa.

Vegetation samples in the square minute north of SEDAN ranged from 0.7 to 2.6 Bq/l, roughly one tenth the concentration in atmospheric water at the SEDAN air sampler. Those samples were collected somewhat closer to the EPA farm facility, where the tritium in atmospheric moisture was 9.6 and 10.4 Bq/l, also greater than the stem-water concentration. At those sample points, roughly a mile north and northeast of SEDAN crater, the vegetation may be equilibrating with atmospheric moisture, passing over SEDAN and/or the EPA farm. Ruggieri et al, (1988) during a wet period, found vegetation growing in the CAMBRIC ditch equilibrated at night with atmospheric moisture, to about 50 percent of the plant water composition. Theirs was probably an extreme measurement, as they were studying aquatic plants (reeds and Tamarix trees growing in water) during an unusually wet and humid period. Nevertheless, for water-stressed desert shrubs Babu and Went (1978) showed nighttime radiation to the sky could lead to water pickup into leaves at relatively large rates (e.g. 136 mg/gdw/hr) without condensation from air, at roughly 90 percent relative humidity.

Tritium in vegetation around SEDAN, therefore, seemed consistent with the known source being throwout from the crater at the time of the test (July 1962), with a relatively longer than expected residence time. Other Plowshare throwout mounds, such as those around SCHOONER,

PALANQUIN, CABRIOLET, BUGGY, and DANNY BOY, were not measured because access was limited. They might be expected to have elevated tritium levels similar to those at SEDAN.

PALANQUIN - Fallout

Tritium in vegetation along Trail Ridge Road north of PALANQUIN had the highest concentrations on Pahute Mesa (385 Bq/l). The distribution coincided with a pattern of fallout kill of vegetation along the same road, indicating the source was fallout from the PALANQUIN test in April 1965 (Rhoads et al., 1969a). However, the mechanism whereby tritium was deposited and stored for 30 years in order to be available to vegetation in 1996 is problematic.

Radiation kill of vegetation by fallout after the Plowshare tests PALANQUIN, CABRIOLET, and SCHOONER was relatively well studied (Rhoads et al., 1969a, 1969b; Wallace and Romney 1972). Vegetation died over a three to six month period due to beta radiation entrained in dust adhering to the leaves. Protection of plants from dust in the fallout by covering them with plastic for two weeks after the SCHOONER test (1968) prevented their death (Wallace and Romney 1972). There was no mention of rainfall in those reports, but weather records show April, July, and August 1965, just after the PALANQUIN test, were unusually wet months, with 1.62 inches (41 mm), 1.53 inches (39 mm), and 2.88 inches (73 mm) of rain respectively falling on Pahute Mesa. Vegetation damage was first noted in June of 1965 (Rhoads et al., 1969a). Essington (1987) discusses tritium found in soil samples at "nuclear sites 219, 221", which we presume to be PALANQUIN/CABRIOLET. He measured 0.3 to 2.6 Bq/g of soil in 1980. Assuming soil of about 5 percent water content (it was described as "very dry"), that would have been about 740 to 5180 Bq/l of soil water at the time of sampling, which was about tenfold higher than the random plant samples in 1996.

Although vegetation sampling was sparse, there seemed a significant correlation of tritium levels with the PALANQUIN fallout pattern, though the CABRIOLET fallout pattern crossed that of PALANQUIN (Rhoads et al., 1969b). Most plausibly, tritium may still linger because the heavy rainfall following PALANQUIN washed water past the root zones of the dying shrubs into the vadose zone. After most of the shrubs and trees died, there was no reestablishment for many years (Romney et al., 1980). Although grasses quickly invaded the kill area (Rhoads et al., 1969a), their relatively shallow root systems may have left the tritiated moisture from PALANQUIN fallout unavailable to plants long enough for it to diffuse downwards and still be available during dry seasons until 1996.

An alternative hypothesis, that tritium from the PALANQUIN crater is currently reaching the fallout zone with prevailing winds, is not as plausible. Recall that at SEDAN, plants a mile north of the crater had about 10^{-5} times the concentration of those within several hundred meters. Similar dilution at PALANQUIN would suggest that near its crater, concentrations should then have been 37,000,000 Bq/l. That is higher than the estimated concentrations of tritium in newly formed cavities, such as Cheshire (Buddemeir 1988), in the rubble chimney of Bilby crater (Borg et al., 1976, citing Beetem et al., 1965), and about equal to that reported for water in the CAMBRIC cavity (Bryant 1992). After nearly two half-lives and much weathering, those values seem unlikely for 1996.

BUGGY - Runoff

Only one location sampled in the nine square minutes surrounding BUGGY had tritium concentrations above the detection limit. Although no samples were taken near the crater itself, the throw out mounds on each side of the trench BUGGY created should be presumed to contain tritium at relatively high concentrations. The one positive sample was from the channel of a ravine downhill from the trench, below a junction with another ravine coming from the direction of BUGGY. It seems plausible that tritium at one time flowed either on the surface or in shallow groundwater to that ravine system and contaminated the bottom of the second ravine. There is almost no data available to confirm this, but a sample taken on the slope of the ravine somewhat further north and east (farther from BUGGY) had no detectable tritium.

CAMBRIC - Infiltration

The maximum concentration found in *Tamarix* trees growing in the CAMBRIC ditch was 796 Bq/l. A similar value (918 Bq/l) was found on Frenchman Lake in the runoff pond formed by the CAMBRIC experiment. Those samples span a distance of about 1.0 mile (Ruggieri et al., 1988). Some samples closer to the ditch, however, were below detection limits. For example, one sampled location 0.19 mile north of the northern end of the CAMBRIC ditch had stem water with 0.4 Bq/l. The contamination was thus closely associated with the drainage channel and ponds and was therefore the remains of water infiltrated into the soil during that radionuclide migration experiment. Although the pumped water was considered to be “released” into the environment, an unknown portion still remains in the soils under and immediately adjacent to the channels. After pumping ceased in 1991, much of the aquatic vegetation associated with the flowing water died, but *Tamarix* trees continued to mine the infiltrated water and release it to the atmosphere.

Bryant (1992) presented a graph of tritium concentration versus total volume pumped from the RNM2s well at CAMBRIC. Using that graph we estimate approximately 1.85×10^{15} Bq (50,000 Ci) were pumped from the vicinity of the CAMBRIC cavity. This is very close to tritium production in the CAMBRIC test estimated by Borg et al., (1976) of 2.22×10^{15} Bq (60,000 Ci). Bryant (1992) states that the peak concentration in the pumped stream was about 1,000 times less concentrated than the water in the cavity. It seems unlikely that the migration experiment removed 80 percent of the total tritium formed and therefore that the estimate by Borg was too low (“...the test is known to have deposited 6 ± 0.3 g of ^3H into the environment.”). Borg suggested estimates of tritium production during underground tests, which he did not detail, were “probably accurate to within a factor of 2 or 3 ...”. This may relate significantly to the estimate of total tritium contained on and beneath the surface of the NTS, which was >309 million Ci in 1995 (DOE 1996; Table 4-1).

RWMS - Upward Diffusion

Estimates of total tritium buried at the low-level waste management site in Frenchman Flat are 3.4×10^{17} Bq (9.3 million Ci) (DOE 1996). Various sources are buried at depths of 10 to 120 feet. No vegetation samples were collected within the fenced compound, but samples have been taken by other researchers (Schulz and Weaver 1995). The maximum concentration of a single plant sampled on a trenchcap above tritium waste buried about 12 feet deep was 10.4×10^6 dpm/ml, or

17.3 MBq/l in 1994 (Schulz and Weaver 1995). That particular plant decreased 75 percent in concentration in 1995, a year with more rain. Air samplers around the perimeter of the RWMS at that time (mid-summer 1994) measured a peak of about 45×10^6 pCi/ml air, which, assuming an average water content of 3 mg/L of air, is about 55.5 Bq/l of water. Thus in the approximate 200 m distance to the air samplers tritium from that one plant was diluted by at least 10^5 . Other plants nearby had much lower concentrations, suggesting the high plant had a root or roots near a concentrated source.

One vegetation sample was collected next to the northern fenceline of the RWMS. Its stem water contained 10.2 Bq/l. At that time (July 23, 1996) the air sampler with the highest tritium (RWMS No. 4) averaged 9.2 Bq/l of water in air. The approximate equivalence of air and plant water suggests perhaps a long term equilibration of the two, including equilibration with the soil water, but not a significant contamination of soil water outside the RWMS boundary. Similarly, other plant samples in the square minutes around the RWMS ranged from 0.4 to 14 Bq/l. The eight samples surrounding the RWMS averaged 4.1 Bq/l, while the eight nearest random samples averaged -0.1 Bq/l. The difference between the two averages is marginally significant (one-sided t-test, unequal variances, $t=2.31$, $p = 0.027$), suggesting that the vegetation near the RWMS was slightly elevated in tritium.

The data from near the RWMS suggest that the mechanism of spread is probably through the air from concentrated locations within the RWMS fenced area.

It should be noted that some of the buried tritium waste at the RWMS is known to be released to the atmosphere. Schulz and Weaver (1993) estimated one shrub plot released 2.1×10^{11} Bq (5.6 Ci) in 1990, the second year of a drought. In the summer of 1993, the GCDT waste burial test was releasing about 2.8 MBq/day ($75 \mu\text{Ci/day}$) $\sim 1\text{GBq/a}$ (0.027 Ci/year). In addition 2.2 million Ci of waste buried from 65 to 120 feet deep (GCD) was causing detectable tritium increases at 40-50 feet, eight years after burial (Weaver and Schulz 1995). The latter data contradict the implications of a model of diffusion of tritium through soils (Smiles et al., 1995), which suggested no tritium would ever reach the surface from the GCD burial.

Water potential measurements at another waste burial site in the Mojave Desert suggest that water is slowly moving upward at 10^{-8} to 10^{-10} cm/s (Andraski 1997). Because Frenchman Flat has a relatively steep temperature gradient (Sass and Lachenbruch 1982), we suspect a greater upward flux may be present, driving tritiated water back towards the surface from buried wastes. The best evidence for upward moisture flux, however, is the tritiated water in vegetation samples.

Blast Areas - Neutron Activation

There are two possible mechanisms for the contamination of the blast areas: One is contamination through atmospheric transport from other locations, with storage in the soil due to the absence of vegetation. The second is neutron activation by the atmospheric tests conducted above-ground on the sites during the 1950's. There is little information available to support either hypothesis.

Romney et al., (1981) showed that soil water built up on a site scraped for road fill in central Frenchman Flat, indicating that in the absence of vegetation, water is stored in the vadose zone. The same mechanism could be expected on other NTS disturbed areas, including the blast areas in

Yucca Flat. The question then arises, what would be the tritium content of such stored water? Hurst (1988) attempted to measure the depth of penetration of recent rainfall in western Yucca Flat in a wash and adjacent bajada. He found measurable tritium to 10.7 feet depth in the wash, with an activity of 0.3 Bq/l. Penetration on the bajada was less. In the wash, one might expect, when rainfall was rapid enough to produce runoff, that some water might penetrate past the root zone, even though the wash were vegetated. That situation is somewhat comparable to the blast areas. However, on the blast areas the details of the observations did not fit well with a stored-rainwater model.

First, concentrations on the blast areas varied from below detection limits to 96 Bq/l. One would expect the concentrations of tritium in rainfall events to be uniformly spread over large areas and to elevate vadose zone water concentrations on all the blast areas where shrubs were absent. In fact, although sampling was sparse, the highest concentrations found appeared to be towards the centers of the blast areas. The highest concentrations, moreover, were somewhat above what might be attained from atmospheric moisture. Reports of atmospheric tritium on the NTS from 1982 on were summarized in Kinnison (1996). Concentrations in the atmosphere in 1982, excluding those near laboratories, averaged 5×10^{-6} Bq/ml of air. This would be about 174 Bq/l of airborne water, almost 1,000 times greater than Hurst found. Maximum concentrations in air were about three times higher. However, during wet weather, when humidity increases, the concentration of tritium in the NTS atmosphere falls (unpublished data), and water is more likely to be stored from winter rainfall than summer rainfall, when evaporation is rapid. Furthermore, rain which fell on the blast areas is also likely to have mixed with and diluted the already present vadose zone water (about 10 percent of soil dry weight - McGrath 1987). Some will have been transpired by shrubs in the intervening dry years, and some will have been lost to radioactive decay. It seems implausible that concentrations as high as 96 Bq/l stored from prior rainfall would still occur and be found in random samples in 1996.

An alternative mechanism is neutron activation. Neutrons from above-ground tests would penetrate considerable distances into the soil, below the root zone, and at the same time the vegetation would be removed by the blast. Borg et al., (1976) briefly discussed tritium production by neutron activation due to tests below the water table, but did not give the basis of his estimates. Hence it is difficult to estimate the magnitude of production of below-ground tritium by above-ground tests. (Some soil samples were collected by researchers of the Nevada Applied Ecology Group down to about 45 cm depths. They reported primarily on transuranic elements, but some data may be available in their reports on other elements created by neutron activation, which might allow estimates of the depth and quantities of neutron penetration). Tritium production by neutron activation would presumably be centered under the test location (ground zero), and not extend to the edges of the vegetation-free areas, which are on the order of one mile (1.6 Km) in diameter. The concentration of tritium produced could also be expected to vary with distance from the ground zero. At least superficially therefore, the distribution of tritium in vegetation appeared more likely to be from neutron activation than from stored rainwater.

Supporting this possibility is the finding of tritium in shallow levels of a borehole drilled in a subsidence crater on the T3 ground zero area (Smith and Thompson 1996). A tritium peak was found between 10 and 50 m depth in a 62 m deep hole, considerably above the expected location surrounding the test at 216 m depth.

Rainier Mesa - Chimney Effect

Samples near the base and on top of Rainier Mesa had detectable tritium, but the concentrations were not correlated with distance from known sources, the tunnel-effluent evaporation ponds. The only reasonable mechanism for transport from the tunnel ponds is surface or subsurface flow of water downwards from the ponds. Plants along the drainage paths might be expected to be contaminated. Because the terrain is steep, these flow paths would be restricted to the low areas in ravines beneath the ponds, which were not purposely sampled.

Water in wind blowing over the evaporation ponds might be expected to be contaminated. In fact, both air and water were sampled in 1995 and 1996 next to E Tunnel pond, the last pond to continue receiving contaminated water. The air sampler was about 20 m from the pond. Ratios of tritium concentration in the pond (~400 Bq/l) to the airborne water at the same times (pond water was sampled in February, August, and October 1996) ranged from 209 to 474 (unpublished data). Thus in a distance of 20 meters the concentration decreased two to three orders of magnitude. If the average airborne concentration were to fall off with the square-root of distance, it would become undetectable (<0.4 Bq/l) easily by 100 meters. Thus our contaminated samples taken at distances of ≥ 0.3 miles (480 m), and generally at higher elevations, should not have been affected.

Cannon et al., (1975-76) reported contamination of plants on Rainier Mesa by radionuclides presumed to come from nuclear tests within the tunnels below. The proposed mechanism was migration of radionuclides through fractures in the mesa rocks. If such fractures are present, and the below-ground environment is significantly hotter than the surroundings, air and water from the vicinity of the tests might move as in a chimney towards the surface of Rainier Mesa. Similar flow might occur in tunnel ventilation shafts or vertical drill holes for sensor emplacement.

EPA Farm - Unknown

The highest tritium concentration in vegetation sampled within one mile of the EPA Farm (14 Bq/l), which is itself about two miles north of SEDAN crater, occurred about one half mile north of the farm. Another sample one quarter of a mile south of it was lower (1.6 Bq/l). In the square minute between the EPA farm and SEDAN, concentrations ranged from 0.8 to 2.6 Bq/l. Thus there was a slight increase in tritium north of the EPA Farm when one would expect an increase towards the south, towards SEDAN crater.

This would be relatively inconsequential considering the sparse vegetation sampling and the rather high variation among plants. However, at the EPA Farm and south of it there are two air sampling stations. Tritium concentrations at the SEDAN station average approximately the same as at the EPA station (Davis et al., 1996b). In addition, tritium-in-air values at EPA have recently been the highest measured in northern Yucca Flat, and failed to fall with the rest of the stations in Yucca Flat between the mid-80's and mid-90's (Kinnison 1996). It appears therefore that there may be a source other than SEDAN near the EPA Farm which has not been characterized.

Underground Test Areas - Unknown

Eight of 33 locations sampled near underground tests had one of two plants above the detection limit. None were well above the limit. Seven of the eight locations were on Pahute Mesa, and one was in Yucca Flat. None was disturbed, though the one in Yucca Flat was near several blast areas. The eight positive areas were not clustered. In contrast, in Jackass Flats 34 samples were all below the detection limit. The observations suggest, but not decisively, that there is some slight leakage from underground tests. The available data do not suggest a mechanism or mechanisms.

Tippipah Valley - Unknown

The spot in Tippipah Valley with three of four samples positive was nearest some tunnel tests in Area 16. They are several miles distant from them, and a closer sample (YUF0110) was negative. The cause of the contamination, which is unlikely to be in error, is a mystery.

Significance of the Observations

At the present time, there are no regulatory limits on tritium in natural vegetation. A number of desert animals get water from the vegetation they consume and thus are subject to contamination. Regulatory limits on tritium in drinking water are currently 296 Bq/l. Eleven of the 602 analyzed samples (1.8 percent) exceeded that value, seven from Tamarix trees near or in CAMBRIC ditch, three from SEDAN, and one from the PALANQUIN fallout area. Some plant samples from inside the RWMS area also exceeded 296 Bq/l (Schulz and Weaver 1995). Many more plants must exist above that limit, because the 1996 samples were randomly selected and therefore are unlikely to include the most concentrated samples.

Animal sampling has been much less extensive, but has occurred. A number of kangaroo rats trapped within the Area 5 RWMS had detectable tritium in blood (Hunter et al., 1995). Fifteen of the 21 rodents exceeded 296 Bq/l. A mountain lion in Area 12 killed in 1991 had 263 Bq/l in its blood. Horse feces sampled in 1994 ranged from 10 to 31 Bq/l (Greger 1995).

Horses in 1994 were not drinking from E Tunnel pond, and atmospheric tritium concentrations were inadequate to explain their contamination. However, if a portion of their diet were to come from some of the contaminated vegetation reported here, the levels of tritium in their feces could be readily explained. In fact, the horse grazing areas include several of the contaminated sites in Figure 1; and thus, the source of their contamination appears to be the local forage.

Research on health effects of tritium suggests that a threshold for observable minor effects occurs between 4 million and 40 million Bq/l (see e.g. Blaylock and Trabalka 1976; Dobson 1976; Cahill et al., 1976), some 100 times greater than the most concentrated plant sample. Thus, there appears to be no present, significant danger of affecting the NTS biological environment at the measured tritium concentrations.

The existence of elevated environmental tritium levels could be an advantage in several ways. There is currently very little information known about water movement within the desert environment. Recharge of groundwater is a significant problem, for example (see Smith et al., 1995; Andraski 1997). The above vegetation data suggest that, for example, water penetrated below the root zone on Pahute Mesa following the PALANQUIN test in 1965, over a relatively large area. They also show that around SEDAN, the vegetation was using water in 1996, which was present in 1962. The contamination of all four horse feces sampled by Greger (1995) shows there is considerable movement of tritium within the NTS environment. In contaminated areas the relative rooting depths of different species, or different sizes of plants within a species, might easily be studied. Thus, in a number of ways, the presence of tritium could enhance the value of the NTS for environmental or ecological research.

Table 1. Numbers of Samples Taken and Counts of Those at Different Concentrations of Tritium (HTO)							
Location type	Number of Samples	Number below 1.67 Bq L ⁻¹	Number 1.67 to 2.66 Bq L ⁻¹	Number >2.66 and <3.7 Bq L ⁻¹	Number >3.7 and <37 Bq L ⁻¹	Number >37 Bq L ⁻¹	Number not Analyzed
Suspected	327	230	13	7	42	25	10
Random	264	233	4	2	6	3	16
Accidental	38	36	1	0	0	0	1
Totals	629	499	18	9	48	28	27

Table 2. High, Median, and Low Concentrations (Bq L ⁻¹) of HTO in Stem Water of Random Plants in the Square Minutes Containing and Surrounding Suspected Tritium Sources						
	Minute Containing Source			Minutes Surrounding Source		
Source	High	Median	Low	High	Median	Low
SEDAN	185,740	135,050	64,010	38.1	3.1	-0.4
CAMBRIC	0.1		-0.3	918	0.4	-0.7
PALANQUIN	140	10.7	3.1	396	1.0	-0.3
Rainier Mesa	232	2.9	-1.2	209	0.4	-1.3
Tunnel Ponds	5.1	0.5	-0.3	209 ¹	0.5	-0.8
Mud Plant	31.9	25.5	0.2	79.2	0.3	-0.9
BUGGY	1.1	-0.2	-0.4	19.7	0.3	-0.9
RWMS	10.3		1.2	13.6	1.1	0.1
SCHOONER	(not sampled)			1.6		

¹ Tunnel Ponds are at the foot of Rainier Mesa, this value is the same sample as for Rainier Mesa.

Table 3. Locations, Species, and Tritium Concentrations (Bq L⁻¹) of Water Extracted from Plants on and next to Blast Areas from Above-ground Nuclear Weapons Tests (1951-1957). Asterisks Indicate Plants Transplanted onto Blast Areas. Location Codes Indicate Minutes N of 36° and W of 116°. Plant Abbreviations Are the First Three Letters of Genus and Species Combined.

Blast Site	Blast Area Location	Species	³ H	Control Location	Species	³ H
T1 GZ	0306a	EPHNEV*	-0.2	0406a	LARTRI	-0.2
	0306b	TAMRAM*	4.2	0205a	LARTRI	0.0
	0306c	HYMSAL	0.4	0205b	YUCBRE	-0.1
T2 GZ	0806a	HYMSAL	92.5	0908c	EPHVIR	-0.9
	0806b	CHRNAU	90.3	0908d	YUCBAC	-0.8
T3 GZ	0101a	ATRCAN	2.0	0100b	ATRCAN	-0.4
	0101b	CHRNAU	2.2	0100a	ATRCAN	0.2
	0101c	ATRCAN	0.3	0102b	EPHNEV	-0.8
	0101d	ATRCAN	0.4	0200c	EPHNEV	0.0
	0102a	ATRCAN	0.0	0102c	KRALAN	0.4
	0201a	SAL AUS	1.8	0200d	YUCBRE	0.9
	0201b	ATRCAN	25.5	0200a	ATRCAN	-0.4
	0201c	KRALAN	31.9	0200b	ATRCAN	0.1
	0202a	ATRCAN	-0.9	0303c	LARTRI	0.4
	0202b	CHRNAU	0.3	0303e	YUCBRE	0.4
	0202c	ATRCAN	-0.3	0303b	ATRCAN	0.0
	0300a	LARTRI*	10.6	0300e	LARTRI	0.2
	0300b	LARTRI*	14.8	0300f	YUCBRE	0.8
	0300c	ATRPOL*	79.2	0401a	EPHNEV	1.1
	0301a	ATRCAN	-0.7	0301c	ATRCAN	-0.1
	0301b	ATRCAN	0.9	0301d	YUCBRE	-0.8
	0302b	CHRNAU	0.0	0402b	ATRCAN	0.3
	0302c	EPHNEV	0.7	0303a	HYMSAL	0.5

Table 4. Concentrations (Bq L⁻¹) of Tritium in Water Extracted from Trees and Shrubs Within 2 Miles of the N Tunnel and E Tunnel Containment Ponds, and the Approximate Distances, in Miles, from Those Ponds. Two Samples of Different Species Were Taken at Each Location.

Elevated Samples			Samples below Detection Limit ($4.5 \times 10^{-7} \mu\text{Ci/ml}$)		
Location	Maximum concentration	Distance (minutes)	Location	Maximum concentration	Distance (minutes)
1111c,e	209	0.29	1111a,b	0.9	0.06
1110a,b	5.1	0.68	1110c,e	0.8	0.27
1112c,e	7.0	1.34	1210a,b	0.8	0.76
1212a,b	4.5	1.37	1211c,e	0.5	0.76
1212c,e	232	1.72	1211a,b	0.7	0.86
1212f,g	204	1.78	1210c,e	0.2	0.96
			1209a,b	1.0	1.11
			1109c,e	1.1	1.17
			1010a,b	0.5	1.21
			1112a,b	0.4	1.37
			1209c,e	0.8	1.40
			1011a	-0.5	1.61
			1109a,b	1.2	1.62
			1113a,b	0.6	1.98

Table 5. Sample Locations near Underground Test Sites in Which at Least One Plant Was above the Detection Limit of 1.67 Bq L⁻¹. Note at No Site Were Both Samples above the Detection Limit. There Were 25 Other Locations Where No Tritium Was Detected in Either of the Two Sampled Plants.

SAMPLE	Area	location	SPECIES	Bq L ⁻¹	SPECIES	Bq L ⁻¹
0602a,b	9	37° 06.56'N, 116° 02.67'W	EPHNEV	59.6	YUCBRE	1.5
1528a,b	20	37° 15.50'N, 116° 28.55'W	JUNOST	1.9	PURTRI	1.6
1429a,b	20	37° 14.74'N, 116° 29.88'W	ARTNOV	1.9	EPHVIR	0.8
1727a,b	20	37° 17.50'N, 116° 27.09'W	ARTTRI	2.0	ATRCAN	-0.2
1828a,b	20	37° 18.45'N, 116° 28.50'W	EPHVIR	22.2	JUNOST	0.6
1928a,b	20	37° 19.11'N, 116° 28.63'W	EPHVIR	2.1	JUNOST	1.6
1725a,b	20	37° 17.13'N, 116° 25.93'W	PINMON	3.8	JUNOST	0.4
2018c,e	19	37° 20.11'N, 116° 18.53'W	PINMON	5.2	JUNOST	0.7

Figure 1. NTS Tritium Levels in Plants

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APPENDIX F

VADOSE ZONE MONITORING PLAN CHECKLIST

VADOSE ZONE MONITORING PLAN CHECKLIST

Site Name: _____

Corrective Action Unit: _____

Corrective Action Site: _____

Location: _____

Historical Site Description: _____

Current Site Description: _____

Constituents of Concern (COCs):

- ☐ Radionuclides
 - ☐ Alpha
 - ☐ Beta
 - ☐ Gamma
 - ☐ Neutron
 - ☐ Non-specific
- ☐ Volatile/Semivolatile Organic Compounds
- ☐ Metals
- ☐ Polychlorinated Biphenyls
- ☐ Pesticides/Herbicides
- ☐ Other: _____

COC Source(s):

- ☐ Waste Disposal Area
 - ☐ Managed Facility
 - ☐ Historic Disposal Site
- ☐ Spill Site
- ☐ D&D Facility
- ☐ Septic Tank/Leachfield
- ☐ Injection Well/Sump
- ☐ Crater/Shaft/Tunnel
- ☐ Muckpile
- ☐ Lagoon
- ☐ Underground Storage Tank
- ☐ Aboveground Storage Tank
- ☐ Other: _____

Impacted Media:

- ☐ Soil
 - ☐ Porous media
 - ☐ Fractured media
- ☐ Air
- ☐ Plants
- ☐ Groundwater
- ☐ Surface water
- ☐ Other: _____

Exposure Pathways:

- ☐ External
- ☐ Internal
 - ☐ Absorption
 - ☐ Inhalation
 - ☐ Ingestion
- ☐ Other: _____

Migration Pathways:

- ☐ Contact
- ☐ Plants
- ☐ Air
- ☐ Water
- ☐ Animals
- ☐ Other: _____

Potential Receptors:

- ☐ Human
- ☐ Plant
- ☐ Animal
- ☐ Other: _____

Land use:

Current use _____ Future use _____

☐ Unrestricted☐ Restricted☐ Withdrawn☐ Institutional control☐ Unrestricted☐ Restricted☐ Withdrawn☐ Institutional control**Monitoring drivers** (check all that apply):☐ DOE Orders☐ Code of Federal Regulations☐ Nevada Administrative Codes☐ Facility Use Permits☐ Resource Conservation and Recovery Act (RCRA)☐ Clean Air Act (CAA)☐ Safe Drinking Water Act (SDWA)☐ Toxic Substance Control Act (TSCA)☐ National Environmental Policy Act (NEPA)☐ Other: _____

Transport Mechanism:☐ Liquid Phase☐ Colloidal☐ Solid Phase☐ Gas Phase**Monitoring Approach for Solute Transport:**☐ Direct☐ Indirect☐

Not Applicable

☐ **Direct:**

Sample Types:

☐ Soil Matrix☐ Soil Solution☐ In situ analysis

Sampling Methods: _____

Analysis Methods: _____

Measured Parameters: _____

Surrogates: _____

Monitoring Approach for Solute Transport (continued):

☐ *Indirect:*

Surrogates: _____

Measured Parameters: _____

Methodology: _____

Parameters:

☐ Water Content

☐ Chemical analysis

☐ Water Potential

☐ Other _____

☐ Radiological

Type of Instrumentation: _____

Method of Calibration (if applicable): _____

Monitoring Approach for Gas Transport:

☐ Direct

☐ Indirect

☐ Not Applicable

Sampling Methods:

☐ Soil gas

☐ In situ analysis

☐ Air sample

Sampling Methods: _____

Analysis Methods: _____

Measured Parameters: _____

Surrogates: _____

Monitoring Locations, Number, and Justification: _____

Monitoring Frequency:

- ☐ Daily
- ☐ Weekly
- ☐ Monthly
- ☐ Quarterly
- ☐ Bi-annually
- ☐ Annually
- ☐ Other _____

Monitoring Duration:

- ☐ 1-5 years
- ☐ 5-10 years
- ☐ 10-30 years
- ☐ Indefinite
- ☐ Other _____

Key Decision which Monitoring Supports: _____

Action to be Taken if Contaminant Migration Is Observed: _____

Action Level for Monitoring Parameters (if applicable): _____

Regulatory Point of Compliance: _____

Negotiated Point of Compliance (if applicable): _____

Basis for Action Level / Point of Compliance: _____