DOE/NV/25946--553

Closure Plan for the Area 5 Radioactive Waste Management Site at the Nevada Test Site

September 2008

Prepared for:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

under Contract Number
DE-AC52-06NA25946

Prepared by:

National Security Technologies LLC
Vision • Service • Partnership

DISCLAIMER

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EXECUTIVE SUMMARY

The Area 5 Radioactive Waste Management Site (RMWS) at the Nevada Test Site (NTS) is managed and operated by National Security Technologies, LLC (NSTec), for the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO). This document is the first update of the preliminary closure plan for the Area 5 RWMS at the NTS that was presented in the Integrated Closure and Monitoring Plan (DOE, 2005a). The major updates to the plan include a new closure schedule, updated closure inventory, updated site and facility characterization data, the Title II engineering cover design, and the closure process for the 92-Acre Area of the RWMS.

The format and content of this site-specific plan follows the *Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Closure Plans* (DOE, 1999a).

This interim closure plan meets closure and post-closure monitoring requirements of the order DOE O 435.1, manual DOE M 435.1-1, Title 40 Code of Federal Regulations (CFR) Part 191, 40 CFR 265, Nevada Administrative Code (NAC) 444.743, and Resource Conservation and Recovery Act (RCRA) requirements as incorporated into NAC 444.8632.

The Area 5 RWMS accepts primarily packaged low-level waste (LLW), low-level mixed waste (LLMW), and asbestiform low-level waste (ALLW) for disposal in excavated disposal cells.

The Area 5 RWMS covers 293 hectares (724 acres) and is bounded by a buffer zone 300 meters (1,000 feet) wide. The southeast and northeast quadrants of the RWMS are actively used for disposal of wastes, although many of the disposal units in the southeast quadrant, the 92-Acre Area, are operationally closed or nearing capacity. The northeast quadrant is being developed and is referred to as the “Expansion Area.”

NNSA/NSO is currently planning to close the 92-Acre Area in 2011. Closure planning for this site takes into account the regulatory requirements for a diversity of waste streams, disposal and storage configurations, disposal history, and site conditions. Activities associated with final closure of the 92-Acre Area are scheduled to be completed in fiscal year (FY) 2011. Activities associated with final closure of the Area 5 RWMS are scheduled to start in FY 2028 and be completed in FY 2029.

The 92-Acre Area contains 25 shallow excavated pits and trenches and 13 Greater Confinement Disposal (GCD) boreholes. The pits and trenches range in depth from approximately 4.6 to 14.6 m (15 to 48 ft). A small quantity of classified transuranic (TRU) materials was inadvertently buried in one trench in 1986. The GCD boreholes are intermediate-depth disposal units, 3 to 3.7 m (10 to 12 ft) in diameter and about 36 m (120 ft) deep. Unclassified GCD boreholes include high-specific-activity LLW, whereas the classified GCD boreholes include high-specific-activity low-level, TRU, and mixed TRU (MTRU) wastes.

With the exception of three disposal units, all of the pit and trench disposal/storage units within the 92-Acre Area are covered with operational covers made up of native soil approximately 2.4 m (8 ft) thick. Pits P03U, P06U, and P09U are active.

The Pit P03U Mixed Waste Disposal Unit (MWDU) operates under RCRA Interim Status. The Nevada Division of Environmental Protection (NDEP) will allow the NNSA/NSO to continue to operate Pit P03U under Interim Status for a period not to exceed five years and to accept up to 706,293 additional cubic feet of LLMW from onsite and offsite generators. The end of operation of the Pit P03U MWDU under Interim Status is anticipated to be before December 1, 2010. The

lowest tier of Pit P06U was used for disposal of thorium waste. Pit P06U currently accepts asbestiform waste under State of Nevada Solid Waste Disposal Site Permit SW 1300001 (NDEP, 2000). Minor changes to the permit application were approved by the NDEP in 2006. Because the volume of the forecasted asbestiform waste stream is low, Pit P06U is being reclassified to receive both LLW and ALLW. Pit P09U is a LLW disposal unit nearing capacity. Pits P06U and P09U are likely to be operationally closed before Pit P03U completes operations.

Seven of the 13 GCD boreholes (GCDT, GCD-01C, GCD-02C, GCD-03C, GCD-04C, GCD-05U, and GCD-10U) are full of waste to approximately 21.3 m (70 ft) depth and are operationally closed with 21.3 m (70 ft) of native soil cover to grade. Two of the boreholes (GCD-06U and GCD-07C) are partially filled with waste but are inactive. Four of the boreholes (GCD-08C, GCD-09U, GCD-11U, and GCD-12U) were not used and remain empty.

For closure planning, the following five closure units (each of the closure units contains one or more waste disposal units, also called waste disposal cells) have been defined by waste type, location, and similarity in regulatory requirements:

- Corrective Action Unit (CAU) 111
- Pit P03U MWDU
- Asbestiform LLW Unit
- LLW Unit
- TRU GCD Borehole Unit

Closure of all units within the 92-Acre Area must meet the requirements of DOE orders. Additional closure regulatory requirements for these units are summarized below.

CAU 111 is currently listed in the *Federal Facility Agreement and Consent Order* (FFACO, 1996 [as amended 2008]) and in RCRA Part B Permit NEV HW0021 (NDEP, 2005). CAU 111 consists of 10 pits and trenches within the 92-Acre Area; all of these pits and trenches are covered with operational soil covers. The disposal units in CAU 111 were in use prior to promulgation of the RCRA. Most of the pits and trenches are known or suspected to contain hazardous constituents. Closure of the CAU 111 pits and trenches must meet the requirements of the FFACO.

Closure of Pit P03U MWDU must meet the RCRA permit requirements. An interim closure and post-closure care plan was published in December 2005 (DOE, 2005b). ALLW units must be closed as a Class III Solid Waste Disposal Site according to the requirements of NAC 444.6891.

The closure of the TRU GCD Borehole Unit will also meet the 40 CFR 191 requirements. Because of the presence of hazardous constituents (known or suspected) in the TRU GCD boreholes, the requirements of 40 CFR 265, NAC 444.743, and RCRA requirements as incorporated into NAC 444.8632 must also be followed.

Area 5 RWMS will be closed in two phases: closure of the 92-Acre Area in 2011 and closure of the expansion area in 2029. In agreement with NDEP, a three-step closure process is being implemented to close the 92-Acre Area in 2011:

- Development of Data Quality Objectives (DQO) document
- Development of the Corrective Action Decision Document (CADD) and Corrective Action Plan (CAP)
- Development of a closure report

The DQO document is currently being developed, and a draft CADD/CAP will be submitted to NDEP by the end of FY08, with NDEP approval in FY09.

The closure cover for the 92-Acre Area consists of two monolayer-evapotranspiration (ET) covers. A Title II engineering design (90 percent complete) of the covers is presented in this plan.

Monitoring at the Area 5 RWMS is required under a variety of regulatory drivers, including federal regulations and DOE orders. Monitoring data, collected via sensors and analysis of samples, are needed to evaluate radiation doses to the general public; to confirm, validate, and maintain performance assessment; to demonstrate regulatory compliance; and to evaluate the actual performance of the RWMSs. Monitoring provides data to ensure the integrity and performance of waste disposal units. The monitoring program is designed to forewarn management and regulators of any failure and need for mitigating actions.

The plan describes the current program for monitoring direct radiation, air, vadose zone, biota, groundwater, meteorology, and subsidence at the Area 5 RWMS. The development of the interim monitoring plan is described. The final post-closure monitoring plan will be developed as part of the final closure plan.

Groundwater monitoring will continue at the Area 5 RWMS in accordance with RCRA permit requirements. However, NNSA/NSO may seek concurrence from NDEP to discontinue groundwater monitoring in the future. Discontinuation of groundwater monitoring is justified because there is no significant potential for migration of liquid from the Pit P03U MWDU to the uppermost aquifer during the active life of the facility or the 30-year post-closure care period under RCRA (Shott et al., 1998).

Active institutional controls, such as control of access, cover maintenance, and monitoring, will continue for 100 years after the facility closure in 2029. For wastes with hazardous constituents, institutional controls will be conducted according to the RCRA permit conditions negotiated with NDEP. Passive institutional controls, such as markers, records, or archives, and government ownership regulations regarding land and resource use, will continue thereafter. Management of the RWMS is planned to be transferred eventually to another agency or group within NNSA/NSO (Landlord) with long-term responsibilities at the NTS. Under this NTS Landlord, waste disposal operations may continue. The Landlord will also oversee and conduct institutional control activities.

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LIST OF ACRONYMS AND ABBREVIATIONS

3-D	three-dimensional
ac	acre(s)
ANSI	American National Standards Institute
ARL/SORD	Air Resources Laboratory, Special Operations Research Division
ASTM	American Society for Testing and Materials
$Bq/m^2/s$	Becquerel per square meter per second
BLM	Bureau of Land Management
BN	Bechtel Nevada
C	Celsius
CA	Composite Analysis
CADD	Corrective Action Decision Document
CAP	Corrective Action Plan
CAS	Corrective Action Site
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter(s)
CR	containment requirement
DAS	Disposal Authorization Statement
DASH	Deep Arid System Hydrodynamic
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy/Nevada Operations Office
DQO	Data Quality Objectives
DSA	Documented Safety Analysis
DVRFS	Death Valley Regional Flow System
ETLD	environmental thermoluminescent dosimeter
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
F	Fahrenheit
FACE	free air carbon dioxide enrichment
FFACO	*Federal Facility Agreement and Consent Order*
ft	feet
ft^3	cubic feet
FY	fiscal year
g	standard acceleration of gravity
gal	gallon(s)
GBM	generalized boosting model
GCD	Greater Confinement Disposal
ha	hectare(s)
HC	hazard category
HDP	heat dissipation probe
HGU	hydrogeologic unit

HQ	Headquarters
HSA	high-specific activity
HSU	hydrostratigraphic unit
HWSU	Hazardous Waste Storage Unit
ICMP	Integrated Closure and Monitoring Plan
IHI	inadvertent human intrusion
in.	inch(es)
IPR	individual protection requirement
IT	International Technology Corporation
km	kilometer(s)
km^2	square kilometer(s)
Ksat	saturated hydraulic conductivity
L	liter(s)
LANL	Los Alamos National Laboratory
LCA	Lower Carbonate Aquifer
LCCU	Lower Clastic Confining Unit
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	low-level waste
LLMW	low-level mixed waste
LWIS	Low-Level Waste Information System
m	meter(s)
m^3	cubic meter(s)
m/s	meters per second
Ma	million years ago
MFP	mixed fission product
mi	mile(s)
mi^2	square mile(s)
mm	millimeter(s)
mm/yr	millimeter(s)/year
MOP	member of the public
mph	miles per hour
mrem/yr	millirem(s) per year
mSv/yr	milliSievert(s) per year
MTRU	mixed transuranic
MWDU	Mixed Waste Disposal Unit
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NEC	Nevada Environmental Commission
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NFB	no-flux boundary
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NSTec	National Security Technologies, LLC
NTS	Nevada Test Site
NTSER	Nevada Test Site Environmental Report
NTSWAC	Nevada Test Site Waste Acceptance Criteria
NWAR	nuclear weapons accident residue

OI	Organization Instruction
PA	Performance Assessment
pCi/m^2/s	picocuries per square meter per second
pdf	probability density function
PE-g	plutonium equivalent gram
PET	potential evapotranspiration
QAASP	Quality Assurance, Analysis, and Sampling Plan
Rad/NucCTEC	Radiological/Nuclear Countermeasures Test and Evaluation Complex
RaDU	radium disposal unit
RCRA	Resource Conservation and Recovery Act
REECo	Reynolds Electrical and Engineering Company, Inc.
RREMP	Routine Radiological Environmental Monitoring Plan
RSN	Raytheon Services Nevada
RTG	radioisotope thermonuclear generator
RTR	Real-Time Radiography
RWM	Radioactive Waste Management
RWMS	Radioactive Waste Management Site
s	second
SA	Sensitivity Analysis
SI	sensitivity index
SLB	shallow land burial
SME	Subject Matter Expert
SND	State of Nevada Demographer
SNL	Sandia National Laboratories
TDR	time-domain reflectometry
TEDE	total effective dose equivalent
TFRG	TRU Waste Disposal Facility Federal Review Group
TLD	Thermoluminescent Dosimeter
TRU	transuranic
TSR	Technical Safety Requirement
UGTA	Underground Test Area
WEF	Waste Examination Facility
WIPP	Waste Isolation Pilot Plant
WMD	Waste Management Database
WMP	Waste Management Project (NNSA/NSO)
yr	year

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1.0 INTRODUCTION

The Area 5 Radioactive Waste Management Site (RMWS) at the Nevada Test Site (NTS) is managed and operated by National Security Technologies, LLC (NSTec), for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO). This document is the first update of the preliminary closure plan for the Area 5 RWMS at the NTS that was presented in the Integrated Closure and Monitoring Plan (ICMP) (U.S. Department of Energy [DOE], 2005a). The major updates to the plan include a new closure schedule, updated closure inventories of radionuclides and hazardous constituents, updated site and facility characterization data, the Title II engineering cover design, the closure process for the 92-Acre Area of the RWMS, and a preliminary post-closure monitoring plan.

The format and content of this site-specific plan follows the *Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Closure Plans* (DOE, 1999a).

This interim closure plan meets the closure and post-closure monitoring requirements of the order DOE O 435.1, “Radioactive Waste Management”; manual DOE M 435.1-1, “Radioactive Waste Management Manual”; Title 40 Code of Federal Regulations (CFR) Part 191, “Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes”; 40 CFR 265, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities”; Nevada Administrative Code (NAC) 444.743, “Final Cover or Closure; Postclosure”; and Resource Conservation and Recovery Act (RCRA) requirements as incorporated into NAC 444.8632, “Compliance with Federal Regulations Adopted by Reference.”

1.1 GENERAL FACILITY DESCRIPTION

1.1.1 Disposal Site Location

The Area 5 RWMS is a 296-hectare (ha) (732-acre [ac]) area in northern Frenchman Flat set aside for low-level waste (LLW) disposal at the NTS. Figure 1-1 shows the locations of the Area 5 RWMS with respect to the NTS administrative areas. The operationally active area encompasses approximately 58 ha (144 ac) in the southeast corner of the RWMS (Figure 1-2). The southeastern and northeastern quadrants of the RWMS are actively used for disposal or storage of wastes, although many of the disposal units in the southeastern quadrant (referred to as the 92-Acre Area) are operationally closed or nearing capacity. The northeast quadrant is being developed and is referred to as the “Expansion Area.”

1.1.2 Disposal Site Description

The Area 5 RWMS consists of five operational areas, the disposal units, the Real-Time Radiography (RTR) system, the Transuranic (TRU) Waste Storage Pad and TRU Pad Cover Building, the S02C classified area, and the Waste Examination Facility (WEF) (Figure 1-2, Figure 1-3). The RTR is used for verification of mixed waste generated off site.

The TRU Waste Storage Pad and Pad Cover Building are Hazard Category-2 (HC-2) facilities used for storage of TRU waste. The S02C classified area is a HC-2 facility consisting of seven cargo containers used for the storage of classified TRU waste. The WEF is a HC-2 facility used to examine and repackage TRU waste for shipment to the Waste Isolation Pilot Plant.

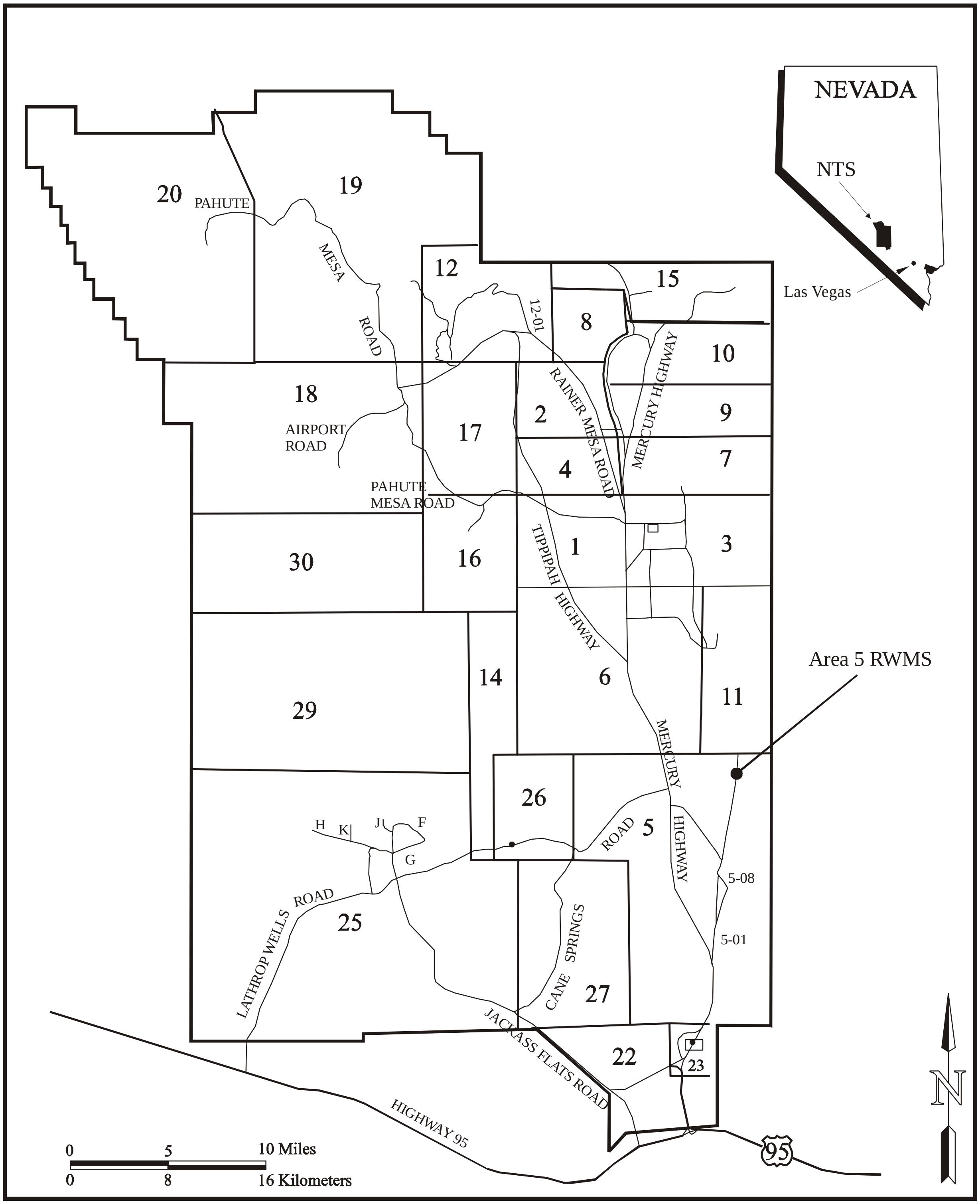

Figure 1-1. Location Map of the Area 5 Radioactive Waste Management Site within the Nevada Test Site in Southern Nevada.

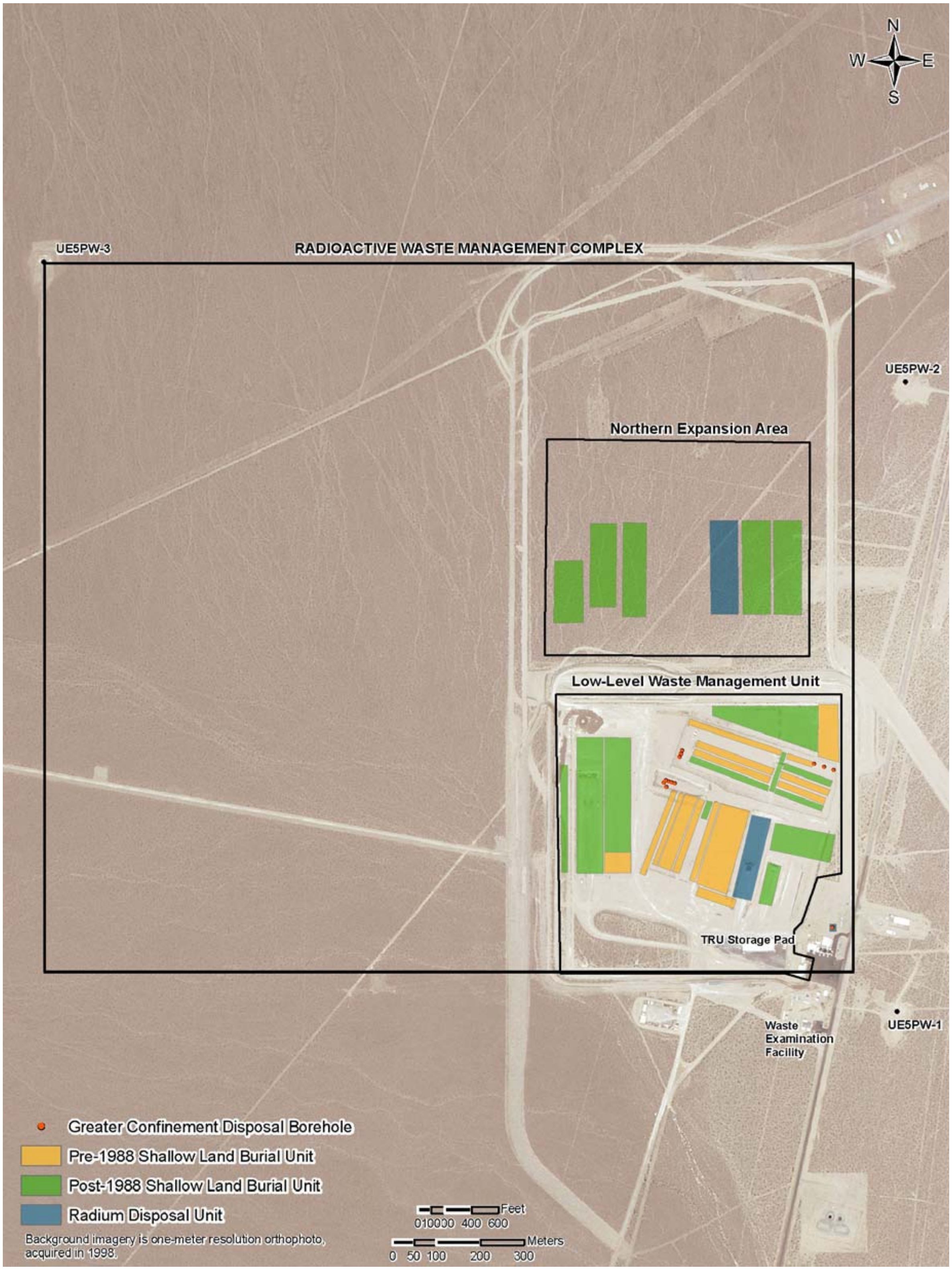

Figure 1-2. Features of the Area 5 RWMS.

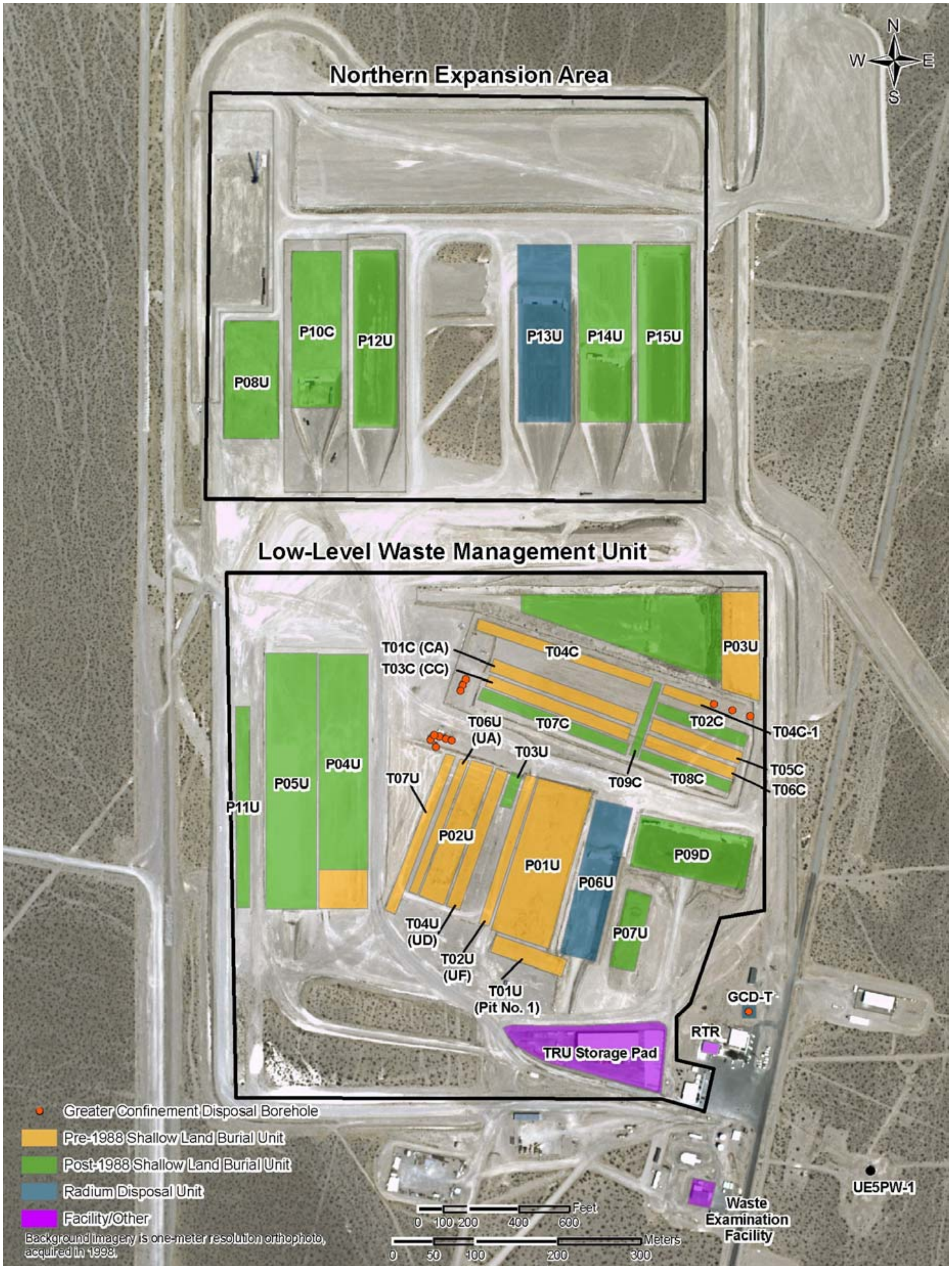

Figure 1-3. Area 5 Radioactive Waste Management Site.

The Area 5 RWMS is the operational active area used for radioactive waste disposal. The Area 5 RWMS accepts low-level waste (LLW) generated by DOE operations and classified LLW generated by U.S. government agencies. Categories of waste currently accepted include classified and unclassified LLW, mixed waste, and LLW containing friable asbestos.

Disposal of LLW by shallow land burial began at the Area 5 RWMS in 1961. The DOE implemented the NTS Waste Management Program and established the Area 5 RWMS in 1978. Prior to that, the Area 5 RWMS was known as the Sugar Bunker Waste Dump. All of the original Sugar Bunker Waste Dump waste disposal units are now part of Corrective Action Unit (CAU) 111. In 1978, disposal of waste from offsite generators began. From 1983 to 1991, TRU and high-specific activity wastes were disposed in 36-meter (m) (120-foot [ft]) deep Greater Confinement Disposal (GCD) boreholes. Waste disposed in GCD boreholes since September 26, 1988, does not include any TRU waste. Since 1987, mixed wastes have been disposed in Pit P03U under RCRA interim status. Changes to the Area 5 RWMS facility are noted under the Performance Assessment (PA) maintenance program in the annual summary reports submitted to DOE Headquarters (HQ) (NSTec, 2008a).

The active Area 5 RWMS is bounded on the north, west, and east by a flood protection system consisting of berms, levee extensions, and flood control channels. The flood protection system was designed to provide protection from a 25-year, 24-hour storm as required under RCRA. Three pilot wells (UE5PW-1, UE5PW-2, and UE5PW-3), located outside of the Area 5 RWMS, are used for groundwater monitoring.

1.1.3 Disposal Unit Description

The 92-Acre Area contains 25 shallow excavated pits and trenches and 13 GCD boreholes (Figure 1-3). The pits and trenches range in depth from approximately 4.6 to 14.6 m (15 to 48 ft), and have been used to dispose classified and unclassified LLW, low-level mixed waste (LLMW), and asbestiform waste. A small quantity of classified TRU waste was inadvertently buried in one trench in 1986 (Dickman, 1989). The GCD boreholes are intermediate-depth disposal and storage units, 3 to 3.7 m (10 to 12 ft) in diameter and about 36 m (120 ft) deep. Unclassified GCD boreholes include high-specific-activity LLW, whereas the classified GCD boreholes include high-specific-activity low-level, TRU, and mixed TRU (MTRU) waste. Classified materials storage units are designated with a "C" and unclassified waste disposal units are designated with a "U" at the end of the name. The classified units are primarily in the middle of the site, flanked to the north, south, and west by unclassified units.

CAU 111 includes the following waste units, which are all operationally closed: P01U, P02U, T01U, T02U, T04U, T06U, T01C, T03C, T05C, and T06C.

With the exception of three disposal units, all of the pit and trench disposal/storage units within the 92-Acre Area are covered with native soil approximately 2.4 m (8 ft) thick. Pits P03U, P06U, and P09U are active. The Pit P03U Mixed Waste Disposal Unit (MWDU) operates under RCRA Interim Status. The Nevada Division of Environmental Protection (NDEP) will allow the NNSA/NSO to continue to operate Pit P03U under Interim Status for a period not to exceed five years and to accept up to 706,293 additional cubic feet of LLMW from onsite and offsite generators. The end of operation of the Pit P03U MWDU under Interim Status is anticipated to be before December 1, 2010.

The lowest tier of Pit P06U was used for disposal of thorium waste. Pit P06U currently accepts asbestiform waste under State of Nevada Solid Waste Disposal Site Permit SW 1300001

(NDEP, 2000). Because the volume of the forecasted asbestiform waste stream is low, minor changes to the permit application were approved by NDEP in 2006 to allow Pit P06U to receive both LLW and asbestiform waste. Pit P09U is a LLW disposal unit nearing capacity. Pits P06U and P09U are likely to be operationally closed before Pit P03U completes operations. Seven of the 13 GCD boreholes (GCDT, GCD-01C, GCD-02C, GCD-03C, GCD-04C, GCD-05U, and GCD-10U) are full of waste or material to approximately 21.3 m (70 ft) depth and are operationally closed with 21.3 m (70 ft) of native soil cover to grade. Two of the boreholes (GCD-06U and GCD-07C) are partially filled with waste or material, but are inactive. Four of the boreholes (GCD-08C, GCD-09U, GCD-11U, and GCD-12U) were not used and remain empty.

Six disposal units have been developed in the northern expansion area. These include P08C, P10C, P12U, and three deeper units, P13U, P14U, and P15U. These deeper units have been excavated to a greater depth, 8 to 9 m (26 to 30 ft), to allow a thick cover for attenuation of ^{222}Rn flux density.

1.1.4 Waste Inventory

The current estimate of waste volume at the closure date of 2028 at the Area 5 RWMS, including the future forecasts, is 671,000 cubic meters (m^3) (approximately 23.7 million cubic feet [ft^3]). The radionuclide activity inventory at closure is 3.65 million curies (Ci). The current (2007 estimate) disposed waste volume accounts for 66 percent of the total closure waste volume (NSTec, 2008a).

The hazardous waste inventory has been compiled from the best available records for all units that contain hazardous materials. The Pit P03U MWDU and the Asbestiform Unit are permitted units with well-kept records. Waste in the CAU 111 Units and the GCD boreholes contain hazardous materials of uncertain quantities.

The CAU 111 disposal units were in operation prior to the implementation of a detailed recordkeeping system. Waste was typically disposed in bulk form or containerized in plastic bags, steel drums, and cardboard, plywood, or steel boxes. Waste stream descriptions are limited. Typical waste stream descriptions include laundry wastes, laboratory wastes, scrap metal, contaminated soil, personal protective equipment, and samples.

Material shipped to classified units was typically described only as “classified waste.” Other waste streams include farm wastes from the historic U.S. Environmental Protection Agency (EPA) Farm operations, which may have included animal wastes. Many records do not indicate the exact location where the waste was disposed. Analytical waste profiling focused primarily on radioactivity but typically only stated a total curie estimate without identifying specific radionuclides. From process knowledge and general waste descriptions, it can be inferred that some wastes contain hazardous constituents. Approximately 40 percent of available records indicate hazardous constituents may be present; however, the amount of hazardous constituents present in these wastes is unknown.

Past laboratory operations at the NTS have typically included the use of organic solvents. Waste streams denoting laboratory wastes are therefore assumed to contain an unknown amount of organic solvent. Solvents may include those typically found in laboratories (e.g., toluene, acetone, trichloroethylene, benzene, and carbon tetrachloride). Lead shielding, loose lead, and lead bricks have also been noted in disposal records. Lead shielding is assumed to be present from any record denoting the disposal of radioactive sources.

Known hazardous waste in the GCD boreholes includes an estimated 60.5 kilograms of lithium hydride in borehole 4 and 45.0 kilograms of lithium deuteride in borehole 1 (Chu and Bernard, 1991). These exhibit the hazardous characteristic of reactivity. Some of the classified nuclear weapons accident residue (NWAR) waste in boreholes 1, 2, and 3 may contain melted high explosives in the waste matrix. Lead and mercury are also believed to be present in the NWAR waste matrix, which exhibit characteristics of toxicity.

1.1.5 Land Use

The Area 5 RWMS is protected from public access and future development by government control of the NTS and the surrounding Nellis Air Force Range complex to the north, east, and west. Lands to the south and west of the NTS are administered by the Bureau of Land Management (BLM) and the National Park Service (Figure 2-1). This federal use and management of the land further buffer the NTS from external influence.

Historical and DOE uses of these lands were discussed in the 1998 PA. Current land uses at the NTS include hazardous chemical spill testing, emergency response training, nonnuclear weapons testing, radioactive waste management, and environmental technology studies. Land use in Frenchman Flat remains the same as described in the 1998 PA, except for the addition of two new facilities, the free air carbon dioxide enrichment (FACE) facility and the Radiological/Nuclear Countermeasures Test and Evaluation Complex (Rad/NucCTEC). The FACE facility is an outdoor environmental research experiment investigating the long-term effects of atmospheric carbon dioxide on desert ecosystems. FACE is located south of the Frenchman Flat playa. The Rad/NucCTEC is a research and testing facility for instrumentation for the detection of weapons of mass destruction located south of the Device Assembly Facility. Operation of the FACE and the Rad/NucCTEC facilities is not expected to have any impact on the performance of the Area 5 RWMS.

NNSA/NSO plans to restrict access to the NTS in perpetuity (Crowe et al., 2007). The NTS's primary national security mission requires restriction of public access. Residual radioactivity from past activities, including aboveground and underground nuclear testing, precludes release of large areas of the NTS until contamination is cleaned up to free release standards. Restoration of some areas contaminated by nuclear testing may not be economically or technically feasible. Such areas will be closed in place with permanent land-use restrictions. The NNSA/NSO land-use plans for the NTS include plans to prohibit construction and drilling within the Area 5 RWMS in perpetuity.

Ranching and mining remain important land uses in southern Nevada. More recently, recreational activities and irrigation-based agriculture have become important land uses in southern Nevada. Provided that the NTS remains withdrawn from all forms of appropriation, these activities likely will not have a significant impact on the NTS.

1.1.6 Related Documents

Federal Facility Agreement and Consent Order

The *Federal Facility Agreement and Consent Order* (FFACO, 1996 [as amended 2008]) is an agreement among the State of Nevada, the DOE, and the U.S. Department of Defense to identify DOE sites in the state of Nevada with historical contamination, initiate corrective action and final closure, and ensure that corrective actions consider public input. Site closure under the FFACO follows a RCRA-like process, beginning with identification of corrective action sites (CASs). CASs are categorized as industrial sites, Underground Test Areas (UGTAs), soil sites, and off-NTS sites. When necessary, corrective action investigations are conducted to identify hazardous constituents and characterize their migration. Corrective action plans for CAS closure reflecting agreed-upon closure standards are developed, implemented, and post-closure status documented. Closure of the 92-Acre Area will be subject to the FFACO process.

National Environmental Policy Act

The environmental impacts of waste management activities at the NTS have been evaluated and subjected to public comment through the National Environmental Policy Act (NEPA) process (DOE, 1996). The preferred alternative, the expanded use option, describes the impacts of LLW and mixed waste disposal, TRU and MTRU storage, certification and repackaging of TRU for offsite disposal, mixed waste accumulation and storage, polychlorinated biphenyl waste storage, and site closure. The DOE has also evaluated the environmental impacts of LLW and mixed waste treatment and disposal alternatives on a nationwide basis (DOE, 1997a). The preferred alternative for LLW disposal was disposal at a small number of regional disposal sites, including the NTS. Selection of the NTS as a regional DOE LLW disposal site has increased the number of DOE generators using the site, increased the annual waste volume disposed, and changed the radionuclide composition of disposed waste.

Documented Safety Analysis

A Documented Safety Analysis (DSA) has been prepared to support all nuclear operations at the Area 5 Radioactive Waste Management Complex, including the WEF, the TRU Storage Pad and TRU Pad Cover Building, the Classified TRU Materials Storage Area, and the disposal units of the Area 5 RWMS (DOE, 2004a). The Area 5 RWMS has been classified as a HC-2 facility. Unmitigated doses were calculated for workers and for the member of the public (MOP), assumed to be at the closest NTS boundary 2.1 kilometers (km) (1.3 miles [mi]) to the east. The primary hazard associated with operation of the Area 5 RWMS was a fire involving exposed waste packages. Technical Safety Requirements (TSRs) for the Area 5 RWMS consist of several Administrative Control Programs and Specific Administrative Controls (DOE, 2004b). Administrative Control Programs include a Radioactive Inventory Control Program, a Nuclear Criticality Control Program, a Radiation Protection Program, and a Fire Safety Program. Specific administrative controls for the Area 5 RWMS include:

- Materials at risk inventory limits for exposed waste of 2,000 plutonium equivalent grams (PE-g) per disposal unit and 300 PE-g per container
- A LLW 6-m (20-ft) controlled combustibles zone
- Nuclear criticality limits

Groundwater Protection Plan

The NTS mission in the past has included underground nuclear testing, and the NTS remains ready to resume testing if necessary. Past nuclear tests and possible future testing activities make complete protection of NTS groundwater resources impossible. Therefore, the NNSA/NSO groundwater protection policy is to minimize impacts of testing on groundwater resources (DOE, 1993). Specific groundwater protection objectives for the NTS include:

- Predict the effects of underground nuclear testing on the groundwater beneath the NTS
- Minimize the environmental effects of underground nuclear tests through criteria for location and depth of nuclear tests
- Characterize hydrogeologic conditions and ambient (background) water quality

- Characterize and monitor groundwater contamination
- Develop and implement an appropriate remedial strategy for groundwater protection, waste treatment, and waste disposal
- Characterize, monitor, and remediate contaminants in the unsaturated zone

1.2 GENERAL CLOSURE APPROACH

Closure of the Area 5 RWMS disposal cells will be in accordance with the requirements under which each disposal cell is regulated. For ease of discussion, six closure units (groups of cells) have been defined by waste type, location, and similarity in regulatory requirements:

- CAU 111
- Asbestiform LLW Unit
- Pit P03U MWDU
- LLW Unit
- TRU GCD Borehole Unit
- Expansion Area LLW Unit

The first five units, which are located in the 92-Acre Area, will be closed in 2011 when the Pit P03U MWDU is to be closed. The closure of the expansion area cells will occur in 2028 when the Area 5 RWMS closes. Since NDEP must approve the closure of the CAU 111, Asbestiform LLW Unit, and Pit P03U MWDU, the closure of these units must follow closure documentation as required under applicable state regulations.

Closure regulations applicable to all or selected closure units are presented in:

- DOE O 435.1 and DOE M 435.1-1
- 40 CFR 191
- 40 CFR 265
- NAC 444.743
- RCRA requirements as incorporated into NAC 444.8632
- FFACO

Monitoring regulations applicable to all or selected closure units are included in:

- DOE O 435.1 and DOE M 435.1-1
- 40 CFR 61
- 40 CFR 191
- 40 CFR 264
- 40 CFR 265

The closure of all units will meet closure and post-closure monitoring requirements of DOE O 435.1 and DOE M 435.1-1. Additional closure requirements for each unit are summarized below.

CAU 111 is currently listed in the FFACO (FFACO, 1996 [as amended 2008]) and in RCRA Part B Permit NEV HW0021 (NDEP, 2005). CAU 111 consists of 10 pits and trenches within the

92-Acre Area; all of these pit and trenches are covered with operational soil covers. The disposal units in CAU 111 were in use prior to promulgation of the RCRA. Most of the pits and trenches are known or suspected to contain hazardous constituents. Closure of the CAU 111 pits and trenches must also meet the FFACO requirements. The FFACO process provides a framework for documenting corrective actions.

The closure of Pit P03U MWDU must meet RCRA permit requirements. An interim Closure and Post-Closure Care Plan was published in December 2005 (DOE, 2005b). Asbestiform LLW unit will be closed as a Class III Solid Waste Disposal Site according to the requirements of the NAC 444.6891.

The closure of the TRU GCD Borehole Unit will meet the 40 CFR 191 requirements. Because of the presence of hazardous constituents (known or suspected) in the TRU GCD boreholes, the requirements of 40 CFR 265, NAC 444.743, and RCRA requirements as incorporated into NAC 444.8632 must also be followed.

In agreement with NDEP, a three-step FFACO closure process is being implemented to close the 92-Acre Area in 2011: (1) development of Data Quality Objectives (DQO) document, (2) development of Corrective Action Design Document (CADD) and Corrective Action Plan (CAP), and (3) development of a closure report. The DQO document is currently being developed, and a draft CADD/CAP will be submitted to NDEP by the end of 2008, with NDEP approval in FY 2009.

The closure cover for the 92-Acre Area consists of two monolayer-evapotranspiration (ET) closure covers. A Title II engineering design (90 percent complete) of the covers is presented in this plan.

Activities associated with final closure of the 92-Acre Area are scheduled to be completed in FY 2011. Activities associated with final closure of the Area 5 Expansion Area north of the 92-Acre Area are scheduled to start in FY 2028 and be completed in FY 2029.

The final closure cover for the expansion area will be essentially the same as the closure cover for the 92-Acre Area, for which a Title II engineering design (90 percent complete design) is included in this plan. An optimized cover thickness will be incorporated into the final design.

A monolayer-ET closure cover was selected as the preferred alternative design to a multilayered RCRA closure cover and other alternative designs only after a comprehensive evaluation of many alternatives. Multiple lines of evidence suggest that a monolayer-ET design will cost considerably less than a multilayer RCRA design, be much easier to install and maintain, and, in an arid environment, perform according to performance criteria over long periods of time, even under conditions of cover subsidence. The monolayer-ET cover and natural conditions at the NTS will integrate and operate as a system. Natural conditions that optimize the system are extremely low precipitation and high potential ET, great depth to groundwater, and negligible recharge to groundwater.

The final closure cover is also intended to attenuate radon flux, minimize release of radionuclides by plant and burrowing animal activities during the post-closure compliance period, and ensure long-term stability.

Monitoring at the Area 5 RWMS is required under a variety of regulatory drivers, including federal regulations and DOE orders. Monitoring data, collected via sensors and analysis of samples, are needed to evaluate radiation doses to the general public; to confirm, validate, and maintain PA performance; to demonstrate regulatory compliance; and to evaluate the actual performance of the RWMS. Monitoring provides data to ensure the integrity and performance of waste disposal units. The monitoring program is designed to forewarn management and regulators of any failure and need for mitigating actions.

Post-closure monitoring will be performed at the Area 5 RWMS during the 100-year institutional control period. The current monitoring activities that are regulatory driven in agreement with the State of Nevada will likely continue past the 2028 closure date of the Area 5 RWMS, such as the groundwater monitoring, which will continue at the Area 5 RWMS in accordance with RCRA permit requirements. However, NNSA/NSO may seek concurrence from NDEP to discontinue groundwater monitoring in the future. Discontinuation of groundwater monitoring is justified because there is no significant potential for migration of liquid from the Pit P03U MWDU to the uppermost aquifer during the active life of the facility or the 30-year post-closure care period under RCRA (Shott et al., 1998; Bechtel Nevada [BN], 2000).

NNSA/NSO will identify the elements of the final post-closure monitoring plan for the Area 5 RWMS, consistent with the following criteria in 40 CFR 194.42:

- Address significant disposal system parameters
- Address important disposal system concerns
- Obtain meaningful data in a short period of time
- Preserve disposal system integrity
- Be consistent and complementary with other monitoring programs

Monitoring activities during the post-closure period are expected to be reduced and limited to the following:

- Vadose zone monitoring at the lysimeter facility
- Biota monitoring
- Subsidence monitoring

Active institutional controls, such as control of access, cover maintenance, and monitoring, will start after final closure and continue for 100 years. For wastes with hazardous constituents, institutional controls will be conducted according to the RCRA permit conditions negotiated with NDEP. Passive institutional controls, such as markers, records, or archives, and government ownership regulations regarding land and resource use, will continue thereafter. Management of the RWMS will be transferred to another agency or group within NNSA/NSO (Landlord) with long-term responsibilities at the NTS. Under this NTS Landlord, waste disposal operations may continue. The Landlord will also oversee and conduct institutional control activities.

1.2.1 Closure Standards

The Area 5 RWMS is primarily a LLW disposal site. The Area 5 RWMS includes LLW and LLMW, small amounts of TRU waste, MTRU and asbestiform waste. Low-level and TRU/MTRU classified materials are also stored at the Area 5 RWMS. Waste with only a radioactive component is self-regulated by the DOE. The radioactive component of mixed waste is self-regulated by the DOE, whereas the hazardous component of mixed waste is regulated by the RCRA under the authority of the EPA. The NDEP has been granted the authority by the EPA to administer the RCRA in Nevada. NAC 444.8632 incorporates the federal RCRA requirements by reference (Nevada Environmental Commission [NEC], 1987). The following excerpts from DOE orders and other regulations provide the basis for this closure plan.

1.2.1.1 DOE O 435.1

The DOE order governing management of radioactive waste is DOE O 435.1. Associated with the order are a manual (DOE M 435.1-1) and a guide (DOE G 435.1-1, "General Responsibilities and Requirements"). The DOE manual provides the requirements, roles, and responsibilities to establish the NNSA/NSO Radioactive Waste Management Program according to the order. The DOE manual and guidance list the following requirements, among others, related to closure of LLW disposal cells.

- *Chapter IV, Q (Closure) (1). A preliminary closure plan shall be developed and submitted to DOE/HQ for review with the Performance Assessment and Composite Analysis. The closure plan shall be updated within one year following issuance of the Disposal Authorization Statement to incorporate conditions specified in the Disposal Authorization Statement.*
- *Q (1)(a). Closure plans shall be updated as required during the operational life of the facility.*
- *Q (1)(b). Closure plans shall include a description of how the disposal facility will be closed to achieve long-term stability and minimize the need for active maintenance following closure and to ensure compliance with the requirements of DOE O 5400.5, "Radiation Protection of the Public and the Environment" (or 10 CFR 834, when promulgated).*
- *Q (1)(c). Closure plans shall include the total expected inventory of wastes to be disposed of at the facility over the operational life of the facility.*
- *Q (2). Closure of a disposal facility shall occur within a five-year period after it is filled to capacity, or after the facility is otherwise determined to be no longer needed.*
- *Q (2)(a). Prior to facility closure, the final inventory of the low-level waste disposed in the facility shall be prepared and incorporated into the PA and CA which shall be updated to support closure of the facility.*
- *Q (2)(b). A final closure plan shall be prepared based on the inventory of waste disposed in the facility and the updated PA and CA prepared in support of the facility closure.*
- *Q (2)(c). Institutional control shall continue until the facility can be released pursuant to DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (or 10 CFR 834, when promulgated).*
- *Q (2)(d). The location and use of the facility shall be filed with the local authorities responsible for land use and zoning*.

1.2.1.2 40 CFR 265

Performance objectives related to closure of a waste disposal unit containing only LLW are similar in principle to those specified in the RCRA Subpart N, 40 CFR 265.310(a) for waste disposal cells containing LLMW:

At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:

- *Provide long-term minimization of migration of liquids through the closed landfill*
- *Function with minimum maintenance*

- *Promote drainage and minimize erosion or abrasion of the cover*
- *Accommodate settling and subsidence so that the cover's integrity is maintained*
- *Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present*

In addition to the above requirements, 40 CFR 265.310(b) specifies that:

After final closure, the owner or operator must comply with all post-closure requirements contained in 265.117 through 265.120, including maintenance and monitoring throughout the post-closure care period. The owner or operator must:

- *Maintain the integrity and effectiveness of the final cover, including making repairs to the cover as necessary to correct the effects of settling, subsidence, erosion, or other events*
- *Maintain and monitor the leak detection system according to Title 40 CFR 264.301(c)(3)(iv) and (4) of this Chapter and 265.304(b), and comply with all other applicable leak detection system requirements of this part*
- *Maintain and monitor the groundwater monitoring system and comply with all other applicable requirements of Subpart F of this part*
- *Prevent run-on and runoff from eroding or otherwise damaging the final cover*
- *Protect and maintain surveyed benchmarks used in complying with Title 40 CFR 265.309*

1.2.1.3 40 CFR 191

Small amounts of TRU and MTRU classified materials are disposed in GCD boreholes and one shallow-land disposal unit at the Area 5 RWMS. According to DOE M 435.1-1, TRU waste is to be disposed according to 40 CFR 191.

A compliance assessment document for TRU classified materials disposed in GCD boreholes, including a PA with respect to the requirements of 40 CFR 191, was completed by Sandia National Laboratories (SNL) (Cochran et al., 2001). Title 40 CFR 191 includes both quantitative requirements and qualitative "assurance" requirements that must be met to demonstrate adequate protection of human health and the environment. The three quantitative requirements pertain to containment, individual protection, and groundwater protection. The six assurance requirements are imposed to provide additional confidence that the containment requirements will be met: (1) active institutional controls, (2) passive institutional controls, (3) monitoring, (4) engineered and natural barriers, (5) siting to avoid resources, and (6) future removal of waste.

An assessment of the assurance requirements for TRU materials in the classified GCD boreholes is included in the appendix to this plan.

1.2.1.4 NAC 444.743

Pits P06U and P07U are permitted Class III asbestiform low-level solid waste disposal units at the Area 5 RWMS and must meet the following requirements:

- *NAC 444.743. Final cover or closure; post-closure. A Class III site must comply with requirements set forth in NAC 444.6891 to 444.6894, inclusive, concerning closure and post-closure.*

- *NAC 444.6891. Requirements for design and construction of system for final cover. 1. the owner or operator of a Class I site shall install a system for a final cover which is designed to minimize infiltration and erosion. Except as otherwise provided in Subsection 2, the system must be designed and constructed to:*
    - *(a) Have a permeability that is less than or equal to the permeability of any system for a bottom liner or natural subsoils present, or have a permeability no greater than 1×10^{-5} centimeters per second, whichever is less;*
    - *(b) Minimize infiltration through the closed municipal solid waste landfill unit by the use of an infiltration layer which contains at least 18 inches of earthen material; and*
    - *(c) Minimize erosion of the final cover by the use of an erosion layer which contains at least 6 inches of earthen material which is capable of sustaining the growth of native plants*.

1.2.2 Monitoring Standards

The following excerpts from the DOE orders and other regulations for monitoring provide the basis for the monitoring program.

1.2.2.1 DOE O 435.1

The DOE M 435.1-1 and DOE G 435.1-1 associated with DOE O 435.1 provide requirements and implementation guidance for air monitoring (including radon), vadose zone, meteorology, biota, direct radiation monitoring, and subsidence monitoring.

- *Chapter IV, P (1) (a). Dose to representative members of the public shall not exceed 25 millirem (mrem) (0.25 mSv) in a year total effective dose equivalent from all exposure pathways, excluding the dose from radon and its progeny in air.*
- *P (1) (b). Dose to representative members of the public via the air pathway shall not exceed 10 mrem (0.10 mSv) in a year total effective dose equivalent, excluding the dose from radon and its progeny.*
- *P (1) (c). Release of radon shall be less than an average flux of 20 pCi/m^2/s (0.74 Bq/m^2/s) at the surface of the disposal facility. Alternatively, a limit of 0.5 pCi/l (0.0185 Bq/l) of air may be applied at the boundary of the facility.*
- *R (3) (a). The site-specific performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.*
- *R (3) (b). The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance*.
- *R (3) (c). The environmental monitoring programs shall be capable of detecting changing trends in performance to allow application of any necessary corrective action prior to exceeding the performance objectives in this Chapter.*

1.2.2.2 DOE O 450.1

DOE O 450.1 (which replaced DOE O 5400.1) and Guidance Document DOE/EH-0173T (DOE, 1991) provide requirements for air monitoring (including radon), groundwater, vadose zone, meteorology, biota, and direct radiation monitoring.

- *Chapter IV, 5b. (1). Environmental surveillance shall be designed to satisfy one or more of the following program objectives:*
- *5b (1)(a) Verify compliance with applicable environmental laws and regulations*
- *5b (1)(b) Verify compliance with environmental commitments made in Environmental Impact Statements, Environmental Assessments, Safety Analysis Reports, or other official DOE documents*
- *5b (1)(c) Characterize and define trends in the physical, chemical and biological condition of environmental media*
- *5b (1)(d) Establish baselines of environmental quality*
- *5b (1)(e) Provide a continuing assessment of pollution abatement programs*
- *5b (1)(f) Identify and quantify new or existing environmental quality problems*

1.2.2.3 40 CFR 61

Title 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," provides requirements for radiological air monitoring (including radon) and direct radiation monitoring.

- *Subpart H, National Emission Standards for Emission of Radionuclides Other Than Radon from Department of Energy Facilities, Section 61.92 Standard. Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year.*

- *Subpart Q, National Emission Standards for Radon Emissions from Department of Energy Facilities, Section 61.192 Standards. No source at a Department of Energy facility shall emit more than 20 pCi/m^2/s of radon-222 as an average for the entire source, into the air. This requirement will be part of any Federal Facilities Agreement reached between Environmental Protection Agency and Department of Energy.*

1.2.2.4 40 CFR 264

The Pit P03U MWDU groundwater monitoring program is guided in part by the following sections of 40 CFR 264, Subpart F, "Releases from Solid Waste Management Units," unless as specified in the "Outline of a Comprehensive Groundwater Monitoring Program" (BN, 1998a) in agreement between NNSA/NSO and NDEP:

- 264.97, General groundwater monitoring requirements
- 264.98, Detection monitoring program
- 264.99, Compliance monitoring program
- 264.100, Corrective action program
- 264.101, Corrective action for solid waste management units

1.2.2.5 40 CFR 265

The Pit P03U MWDU groundwater monitoring program is driven in part by the following sections of 40 CFR 265, Subpart F, unless as specified in the "Outline of a Comprehensive Groundwater Monitoring Program" (BN, 1998b) in agreement between NNSA/NSO and NDEP:

- 265.90, Applicability
- 265.91, Groundwater monitoring system
- 265.92, Sampling and analysis
- 265.93, Preparation, evaluation, and response
- 265.94, Recordkeeping and reporting

1.2.2.6 40 CFR 191

Title 40 CFR 191 provides the following general monitoring requirement:

> Section 191.14 Assurance Requirements, (b). *Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.*

1.3 CLOSURE SCHEDULE

Activities associated with the final closure of the 92-Acre Area are scheduled to be completed in FY 2011. Activities associated with final closure of the Area 5 Expansion Area north of the 92-Acre Area are scheduled to start in FY 2028 and be completed in FY 2029. The major activities scheduled for the closure of the 92-acre area are as the following:

- 92-Acre Area DQO document submittal and approval by the NDEP by the end of 2008
- Draft 92-Acre Area CADD/CAP document submittal to NDEP by the end of 2008
- Development of the final CADD/CAP and approval by NDEP in March 2009
- Completion of the final closure cover design, issued for construction in February 2009
- Construction of the closure cover starting in February 2011
- Completion of the closure report (certification of closure) in July 2011

Near-term actions that will support the closure of the 92-Acre Area include the following:

- Optimizations of the final closure cover thickness, to be incorporated into the final closure cover design
- Acceptance by the TRU Waste Disposal Facility Federal Review Group (TRFG) of the measures implemented in this plan to meet the GCD assurance requirements under 40 CFR 191
- Placements of soil to improve performance of interim soil covers and ensure appropriate site drainage
- Filling the neutron probes and the GCD boreholes
- Removing the GCD trailer

Major activities that would be undertaken prior to the closure of the Area 5 RWMS in FY 2028 and those immediately after the final cover construction over the expansion area disposal cells include the following:

- Preparation and approval of the final PA document by Low-Level Waste Disposal Facility Federal Review Group (LFRG)
- Preparation and approval of the final Composite Analysis (CA) document by LFRG
- Preparation of the final closure and post-closure care plan
- Design and implementation of the assurance requirements for the GCD boreholes
- Final design of the closure cover over the disposal cells in the Expansion Area
- Construction of the closure cover over the disposal cells in the Expansion Area
- Initiation of the post-closure monitoring

1.4 RELATED ACTIVITIES

1.4.1 PA Maintenance Activities

The PA Maintenance Program (NSTec, 2007) has been tracking and resolving minor and secondary issues identified in the Disposal Authorization Statement (DAS) for the Area 5 RWMS (DOE, 2002a). These issues include the inconsistencies in conceptual models and models implemented in the PAs/CAs of the Area 5 RWMS and the Area 3 RWMS, conducting site monitoring and characterization to increase confidence in the results of the PAs, periodic assessment of changes in potentially interactive sources impacting the CA results, and periodic assessment of land-use restrictions and associated impacts on the CA results. The Area 5 RWMS DAS also calls for a future revision of the CA that incorporates the dose from the UGTAs within Frenchman Flat.

The resolutions of these issues are reported in the PA/CA annual summary reports (NSTec, 2008c). NNSA/NSO developed probabilistic PA/CA models using the GoldSim® platform to address these issues and evaluate their impacts on the PAs/CAs.

The PA Maintenance Program's long-term goal is to continuously reduce uncertainty of the scenarios, models, and model parameter values used in the PA and CA through field investigations and research. Sensitivity analyses are performed to identify sensitive model parameters and assumptions. Sensitive model parameters that are also uncertain will be the basis of the design of a post-closure monitoring program for the facility.

1.4.2 Environmental Restoration Activities

Environmental restoration activities associated with two categories of CAUs, the Soil Sites and the UGTA sites, in Frenchman Flat, are in progress. The results of these activities directly impact the assumptions of the Area 5 RWMS CA. The MOP dose in the CA incorporated the dose due to releases from soil sites within Frenchman Flat. It was assumed that residual radioactivity at theses soil sites will not need further cleanup. Groundwater dose from the UGTA sources will be incorporated into the CA when the UGTA groundwater modeling in Frenchman Flat is complete. As reported in the 2006 Annual Summary Report, the results of the flow and transport model that will aid in determining the 1,000-year groundwater contaminant boundaries for Frenchman Flat are not expected until FY 2009 (NSTec, 2008a).

1.4.3 Empty and Inactive GCD Boreholes

The four empty GCD boreholes (GCD-08C, GCD-09U, GCD-11U, and GCD-12U) will need to be filled with soil or waste and soil prior to or concurrent with construction of the final cover. Also, GCD-06U and GCD-07C, two inactive boreholes containing waste, will have to be filled with soil prior to or concurrent with construction of the final cover. The other GCD boreholes were previously filled to ground surface with clean native soil. The fill method should minimize voids and bridging to minimize potential future settling of the final cover.

1.4.4 Classified Material

NNSA/NSO historically considered classified material in the Area 5 RWMS trenches to be indefinitely stored. However, in June 2007 the Classified Material Disposition Task Group was jointly established by the DOE Deputy Assistant Secretary for Regulatory Compliance (EM-10) and the NNSA Office of Environmental Projects and Operations (NA-56) to develop a coordinated corporate process to address classified material disposition at the NTS. The initiative, expected to be complete by January 2009, will designate the Area 5 RWMS a classified waste disposal facility under DOE O 435.1 and the classified material in the trenches permanently buried as classified waste under DOE O 470.4-4, “Information Security.” For simplicity in this plan, classified material will be addressed as waste.

Ten trenches and five GCD boreholes within the 92-Acre Area contain classified waste (T01C, T02C, T03C, T04C, T04C-1, T05C, T06C, T07C, T08C, T09C, GCD-01C, GCD-02C, GCD-03C, GCD-04C, and GCD-07C). All of these classified material storage units have been covered or filled with soil. A sixth GCD borehole, GCD-08C, was designated for classified waste but never used.

The strategy for closure assumes that:

- The classified material will not be declassified.
- Security with respect to the closure-planning process will be limited to the same considerations as the unclassified waste cells for protection from inadvertent intruders.
- The TFRG will accept the position of the NNSA/NSO that classified TRU waste in GCD boreholes and the T04C trench will be closed in place, but subject to potential retrieval in accordance with a retrieval plan.

1.4.5 TRU and MTRU Waste in GCD Boreholes

Chu and Bernard (1991) reviewed records and prepared an inventory and preliminary source term model for materials regulated by 40 CFR 191 in the GCD boreholes. Boreholes GCD-01C, GCD-02C, and GCD-03C contain TRU nuclear weapon accident residues, and GCD-04C includes TRU waste from the DOE Rocky Flats Plant.

The GCD-01C inventory includes two containers that reportedly contain lithium deuteride and the GCD-04C inventory includes one container with lithium hydride. Both substances are reactive with water. The GCD-03C inventory includes melted high explosives, but the current hazard characteristics are unknown. Based on the findings of Chu and Bernard (1991), GCD-01C and GCD-04C contain MTRU and GCD-03C may contain MTRU. Borehole GCD-02C is suspected to contain MTRU because the inventory is similar to that in GCD-03C; however, this cannot be confirmed. The assumption is that these four GCD boreholes will have to meet both RCRA and 40 CFR 191 requirements in accordance with DOE M 435.1-1. The hazardous constituents will be treated as if regulated under RCRA.

The TRU waste in GCD boreholes 1 through 4 was evaluated to demonstrate compliance with the requirements of 40 CFR 191. Relevant standards for TRU waste disposal are found in 40 CFR 191 Subpart B, “Environmental Standards for Disposal,” and Subpart C, “Environmental

Standards for Groundwater Protection." Subpart B standards include containment requirements (CRs), assurance requirements, and individual protection requirements (IPRs). The CRs are probabilistic limits for the normalized cumulative radionuclide release to the accessible environment for 10,000 years. The CR is normalized to release limits scaled to the total TRU inventory disposed. The CRs limit the probability of exceeding the release limit to 1 chance in 10, and the probability of exceeding 10 times the release limit to 1 chance in 1,000. The assurance requirements specify institutional controls and disposal system features to increase confidence in the long-term compliance with the CRs. The required controls and features are active and passive institutional controls, monitoring, natural and engineered barriers, lack of attractive natural resources, and ability to retrieve wastes for a reasonable time period. The IPRs limit the committed effective dose to a MOP through all pathways for 10,000 years to 0.15 milliSievert per year (mSv/yr). Subpart C requires that sources of underground drinking water in the accessible environment comply with the limits in 40 CFR 141, "National Primary Drinking Water Regulations," for a period of 10,000 years.

SNL prepared a PA for the TRU GCD boreholes in 2001 (Cochran et al., 2001). In 2002, DOE determined that the PA met all requirements with the exception of the 40 CFR 191.14 assurance requirements for institutional controls; a monitoring program; markers, records, and other passive institutional controls; an engineered barrier system; information to support the claim that there are no economically useful minerals in the area; and removal of waste. NNSA/NSO committed to resolve these issues during the closure planning process for the Area 5 RWMS (Colarusso et al., 2003) and that the TFRG would review closure and post-closure documents to determine compliance with the 1993 version of 40 CFR 191 (Fiore and Berube, 2002). Assurance requirements will be resolved as part of the closure planning activities before the facility closes in 2029.

1.4.6 TRU Waste in Trench T04C

In 1986, 102 containers of classified TRU waste (about 2.6 pounds and 157 Ci of activity) from Rocky Flats Plant were disposed inadvertently in Trench T04C. The original T04C trench was later bisected by Trench T09C and the east side of Trench T04C was eventually redesignated Trench T04C-1. Although disposal of the TRU waste precedes the current surveyed grid system for container locations within waste cells, photographs indicate that the drums are in the west half of the original trench.

The Area 5 RWMS CA (BN, 2000) takes into account the contribution of this TRU inventory. For further assurance that, if left in place, the TRU in T04C does not pose a long-term risk to public and the environment, a special analysis was performed to determine the likelihood that TRU in T04C meets the requirements of 40 CFR 191 (Shott et al., 2008). The special analysis, which has been approved by TRFG, concludes that there is a reasonable expectation that all 40 CFR 191 disposal performance requirements are met. The special analysis evaluated the performance for a period of 10,000 years under climate change.

1.4.7 Corrective Action Unit 111

CAU 111 consists of 10 pits and trenches within the 92-Acre Area; all of these pits and trenches are covered with soil. The disposal units in CAU 111 were in use prior to promulgation of the RCRA. Most of the pits and trenches are known or suspected to contain hazardous constituents; however, based on waste receipt records, none of the pits and trenches received TRU waste. Closure of the CAU 111 pits and trenches must meet the requirements of DOE orders and the FFACO.

Characterization of the Area 5 RWMS was conducted over several decades to fulfill multiple management and compliance objectives. Although some of the site characterization work predates the FFACO and was not tailored to those processes, the characterization is thorough, and the results fulfill the purpose (if not the precise format) of the FFACO document process.

The FFACO process provides a framework for documenting corrective actions. For CAU 111, the corrective actions include the closure in place of the landfill waste, which was profiled and disposed in accordance with the pertinent regulations of the time. The existing interim soil covers are approximately 2.4 m (8 ft) thick. Although this thickness of soil provides adequate containment of the radioactive constituents based on the Area 5 RWMS PA (Shott et al., 1998), a greater thickness of soil will preclude migration of moisture to the waste zone prior to placement and vegetation of the final closure cover. Further, integration of the soil covers on the disposal/storage units will provide appropriate drainage of the site. The final closure cover will be filled, graded, and vegetated (as needed) to achieve the performance objectives. The closure cover and post-closure management of the CAU 111 landfill cells must continue to demonstrate compliance with RCRA and DOE post-closure performance requirements.

1.5 SUMMARY OF KEY ASSUMPTIONS

Assumptions related to closure and monitoring of the Area 5 RWMS is given in the life-cycle baseline of the NNSA/NSO Waste Management Project (WMP). Pertinent programmatic, scheduling, and funding assumptions from the Waste Management baseline are reproduced below, in addition to assumptions that relate more to the approach and responsibility for closure and monitoring described herein.

1.5.1 Assumptions Related to Closure

- Funding will be available to complete closure-related activities at the scheduled times.
- Closure of all disposal units within the Area 5 RWMS, regardless of waste type, will be included in the NNSA/NSO WMP baseline.
- Activities related to final closure of the Area 5 RWMS will be under the management and technical direction of the NNSA/NSO WMP.
- The plan will address closure of all disposal units at the Area 5 RWMS, including disposed LLW (asbestos, hydrocarbon-impacted, and regular LLW), and disposed LLMW.
- A single CADD/CAP will be issued for approval by NDEP, which will encompass the closure of the Pit P03U MWDU, CAU 111, the asbestiform waste pits, the LLW units, and the TRU and MTRU waste units within the 92-Acre Area of the Area 5 RWMS.
- CADD/CAP will incorporate conditions of 40 CFR 265.310, RCRA Permit NEV HW009, DOE O 435.1, the Area 5 RWMS DAS, 40 CFR 191, and other applicable regulations as appropriate.
- Soil backfill will be the engineered barrier for the GCD boreholes that contain waste.
- NDEP and NNSA/NSO will approve all documents required for final closure of regulated disposal units at the Area 5 RWMS.
- Activities related to final closure of the Area 5 RWMS 92-Acre Area will occur from FY 2009 through FY 2011.

- Closure cover construction at the Area 5 RWMS 92-Acre Area will be completed in FY 2011.
- Final closure activities for the Area 5 RWMS Expansion Area will occur between FY 2028 and FY 2029.
- Closure cover construction at the Area 5 RWMS Expansion Area will be completed in FY 2029.
- No waste will be accepted in the current disposal areas after FY 2028.

1.5.2 Assumptions Related to Monitoring

- Environmental monitoring will continue through FY 2028; after FY 2028, environmental monitoring will continue under long-term surveillance and maintenance.
- RCRA groundwater monitoring will not continue beyond the post-closure care period of 30 years at the Pit P03U MWDU.

1.5.3 Assumptions Related to Long-Term Surveillance and Maintenance

- Surveillance and maintenance during the active institutional control of the Area 5 RWMS will start after final closure in FY 2028 and continue for a period of 100 years (through FY 2128).
- An exemption from RCRA groundwater monitoring requirements will be obtained after final closure of the Pit P03U MWDU within the Area 5 RWMS 92-Acre Area.

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2.0 DISPOSAL FACILITY CHARACTERISTICS

This section provides information and data for the Area 5 RWMS and surrounding environment, disposal facility, and waste characteristics. The information provided emphasizes characteristics that are important to implementation of closure activities and the long-term performance of the disposal system.

The geography, demographics, and other physical characteristics of the NTS, Frenchman Flat, and surrounding areas are collectively important to the RWMS, in terms of meeting the performance objectives defined in DOE M 435.1-1 and other applicable regulations.

2.1 DISPOSAL SITE LOCATION

The NTS, located in Nye County, Nevada, 104 km (65 mi) northwest of Las Vegas, comprises approximately 3,561 square km (km^2) (1,375 square mi [mi^2]) of land reserved to the jurisdiction of the DOE under four land withdrawals (DOE, 1996). The primary use of the NTS between 1951 and 1992 was testing of nuclear weapons. Since 1992, subcritical experiments and other defense-related and nondefense-related activities have been and continue to be conducted at the NTS. Mercury, in the southeast corner of the NTS, is the primary support facility for the NTS. Other, smaller communities, including Amargosa Valley, Lathrop Wells, and Indian Springs, are also present within a few tens of km (tens of mi) of the NTS, along the U.S. Highway 95 corridor (Figure 2-1). The primary valleys on the NTS are Yucca Flat, Frenchman Flat, and Jackass Flats. Yucca Flat is in the northeast part of the NTS, Frenchman Flat is in the southeast part of the NTS, and Jackass Flats is in the southwest part of the NTS.

Frenchman Flat is a roughly circular basin bounded by the Massachusetts Mountains on the north, the Buried Hills and Ranger Mountains on the east and southeast, Mount Salyer on the west, and Mercury Ridge and Red Mountain on the south. Elevations range between 1,600 m (5,249 ft) in the surrounding mountains to 939 m (3,081 ft) at Frenchman Playa in the center of the basin. Frenchman Flat was one of several primary nuclear test areas. Atmospheric tests were conducted on the playa, and a limited number of underground tests were conducted in the northern part of the basin (Figure 2-2).

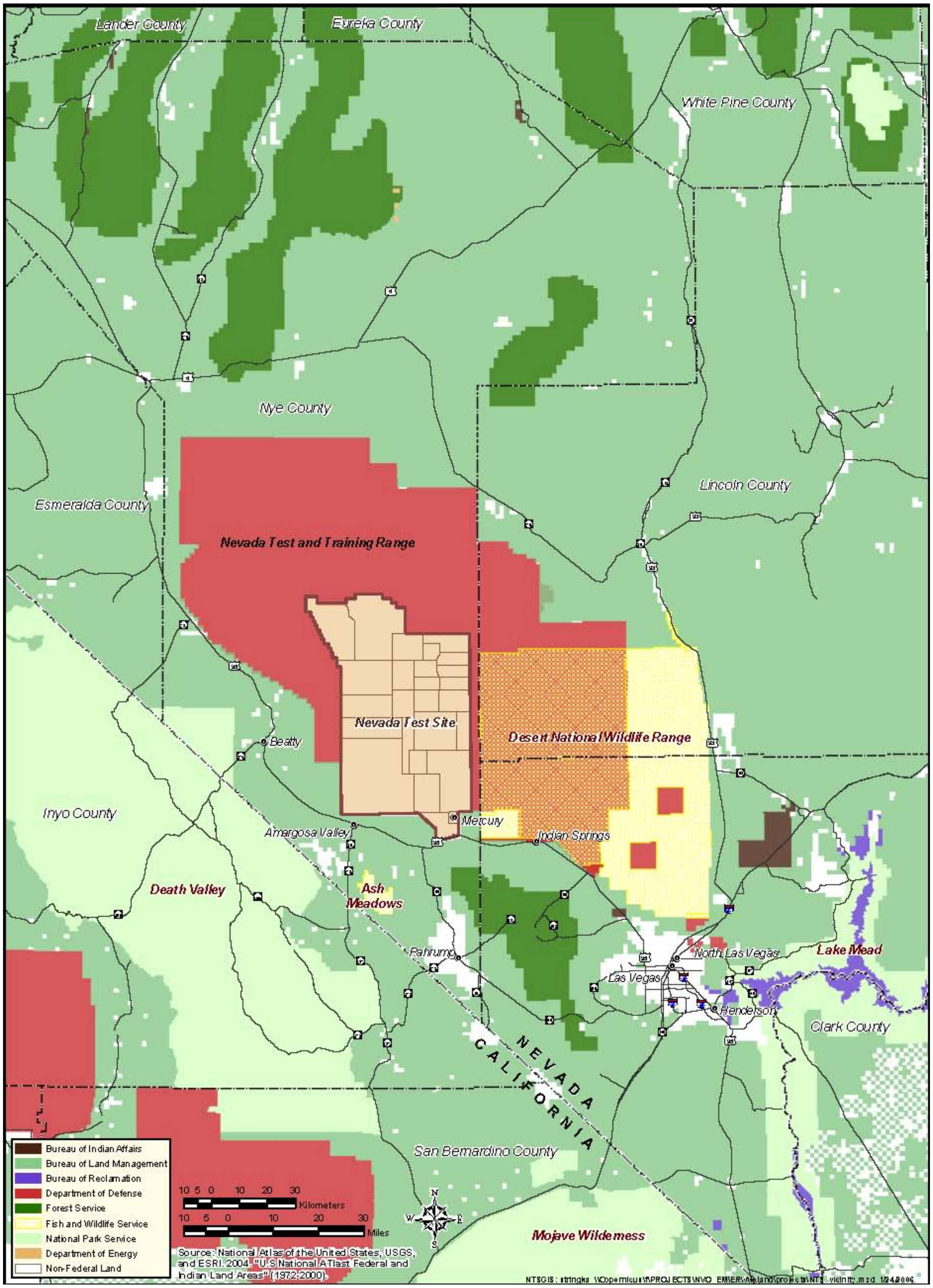


Figure 2-1. Nevada Test Site Location and Federal Land Management Areas.

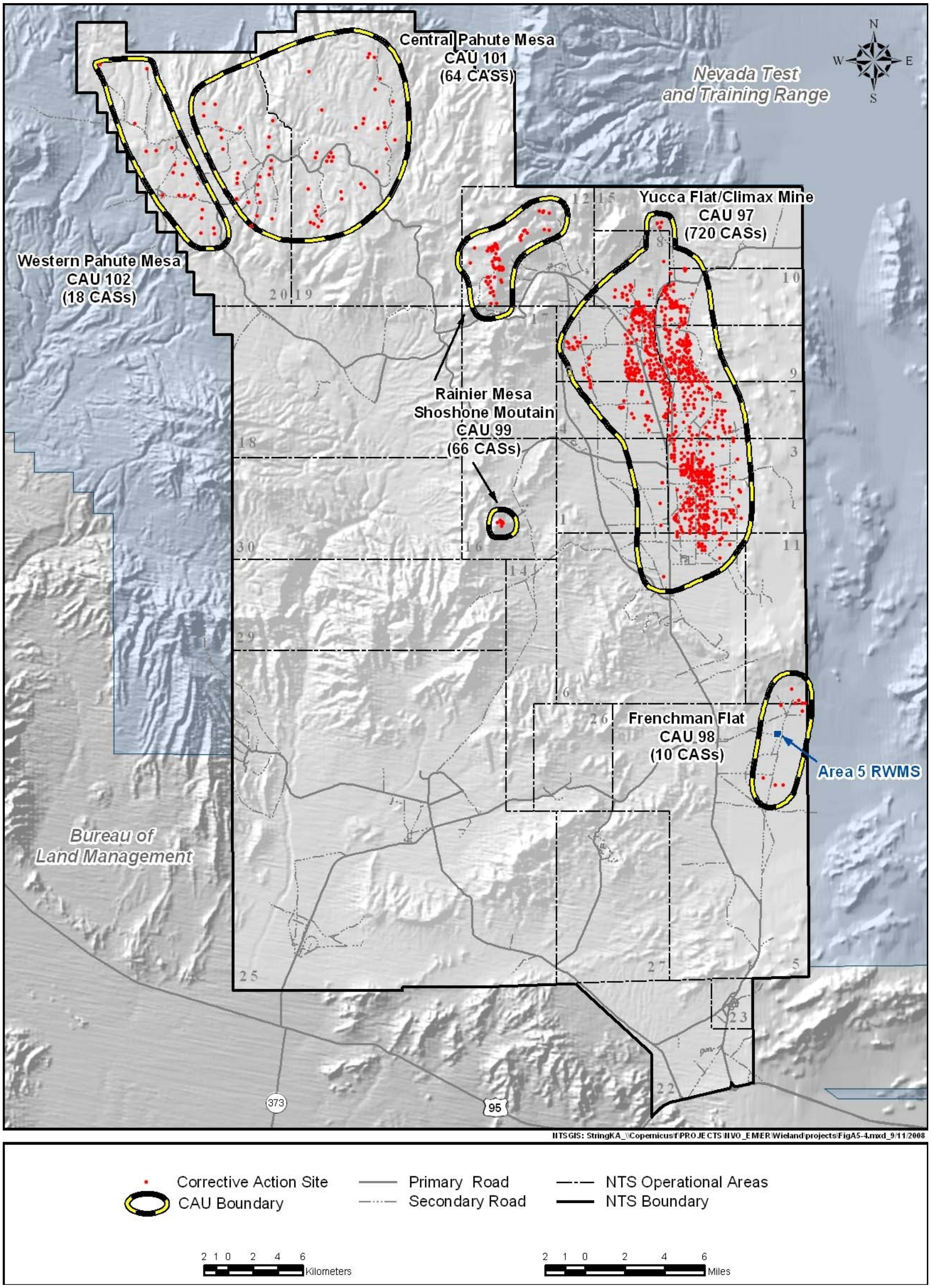


Figure 2-2. Underground Test Area Corrective Action Units.

2.2 DISPOSAL SITE DESCRIPTION

Disposal of radioactive waste at the Sugar Bunker Dump started in 1961. Between 1961 and 1978, eight trenches (T01U, T02U, T04U, T06U, T01C, T03C, T05C, and T06C) were filled primarily with NTS-onsite-generated waste and operationally closed. The Area 5 RWMS was established in 1978 and the facility began receiving greater amounts of waste from offsite generators in 1978. Between 1978 and September 26, 1988 (the latter date being when DOE O 5820.2A, "Radioactive Waste Management" [now replaced with DOE O 435.1] was promulgated), two pits (P01U and P02U) and one trench (T07U) were filled and operationally closed. Fourteen pits (P03U, P04U, P05U, P06U, P07U, P08U, P09U, P11U, P12U, P13U, P14U, P15U, P10C, and P16C) and seven trenches (T03U, T02C, T04C, T04C-1, T07C, T08C, and T09C) have been active since promulgation of DOE O 5820.2A; four of these pits (P04U, P05U, P07U, and P11U) and all seven trenches (T03U, T02C, T04C, T04C-1, T07C, T08C, and T09C) are now operationally closed, leaving ten currently active pits (P03U, P06U, P08U, P09U, P13U, P14U, P15U, P10C, P12C, and P16C) (Figure 2-3). Most of the LLMW at the Area 5 RWMS was disposed before 1992; however, Pit P03U has accepted small amounts of LLMW generated on site since that time.

The GCD concept was conceived in 1980 when ". . . the National Low-Level Waste Management Program began to review alternatives to the shallow land burial of high specific-activity (HSA) low-level radioactive Wastes" (Dickman et al., 1984).

Between 1983 and 1989, 9 of 13 GCD boreholes were used for disposal of HSA LLW (classified waste or waste similar to Greater-than-Class C) and TRU and MTRU classified materials or wastes. Seven boreholes have been filled and operationally closed with backfill of native soil, two boreholes have received waste and remain open, and four boreholes are empty. Waste was placed remotely in the GCD boreholes from the bottom to a depth of 21 m (69 ft) below surface and backfilled with native soil. Two GCD boreholes were active after promulgation of DOE O 5820.2A.

TRU waste previously stored at the Area 5 RWMS on a concrete pad has been disposed at the Waste Isolation Pilot Plant (WIPP) in New Mexico. Shipments of TRU waste to WIPP were started in 2004 and completed in FY 2006.

2.2.1 Disposal Operations

Waste to be disposed at the Area 5 RWMS is transported there on trucks. On arrival, shipping paperwork is checked and trucks are inspected both visually and with instrumentation to ensure that there is no leakage of contaminated materials from the containers. When cleared, the containers are off-loaded and disposed in the appropriate active pit or trench, depending on waste type, classification, or both. Trucks are released only after being surveyed for contamination. Once disposed, waste is covered with approximately 2.4 m (8 ft) of screened native alluvium. Seven unclassified pits (P03U, P06U, P08U, P09U, P13U, P14U, and P15U), and three classified waste pits (P10C, P12C, and P16C) currently are open for receipt of waste.

Pit P09U is used for drums of LLW. Pit P03U is designated for disposal of LLMW under RCRA interim status; however, only a small amount of NTS-generated mixed waste has been disposed there since 1992. Pit P06U has been deepened for disposal of thorium. The upper portion of P06U is permitted to accept asbestiform waste. Pits P08U, P13U, P14U, and P15U in the Expansion Area are open for disposal of LLW. GCD is not anticipated to be used as a waste disposal option in the future.

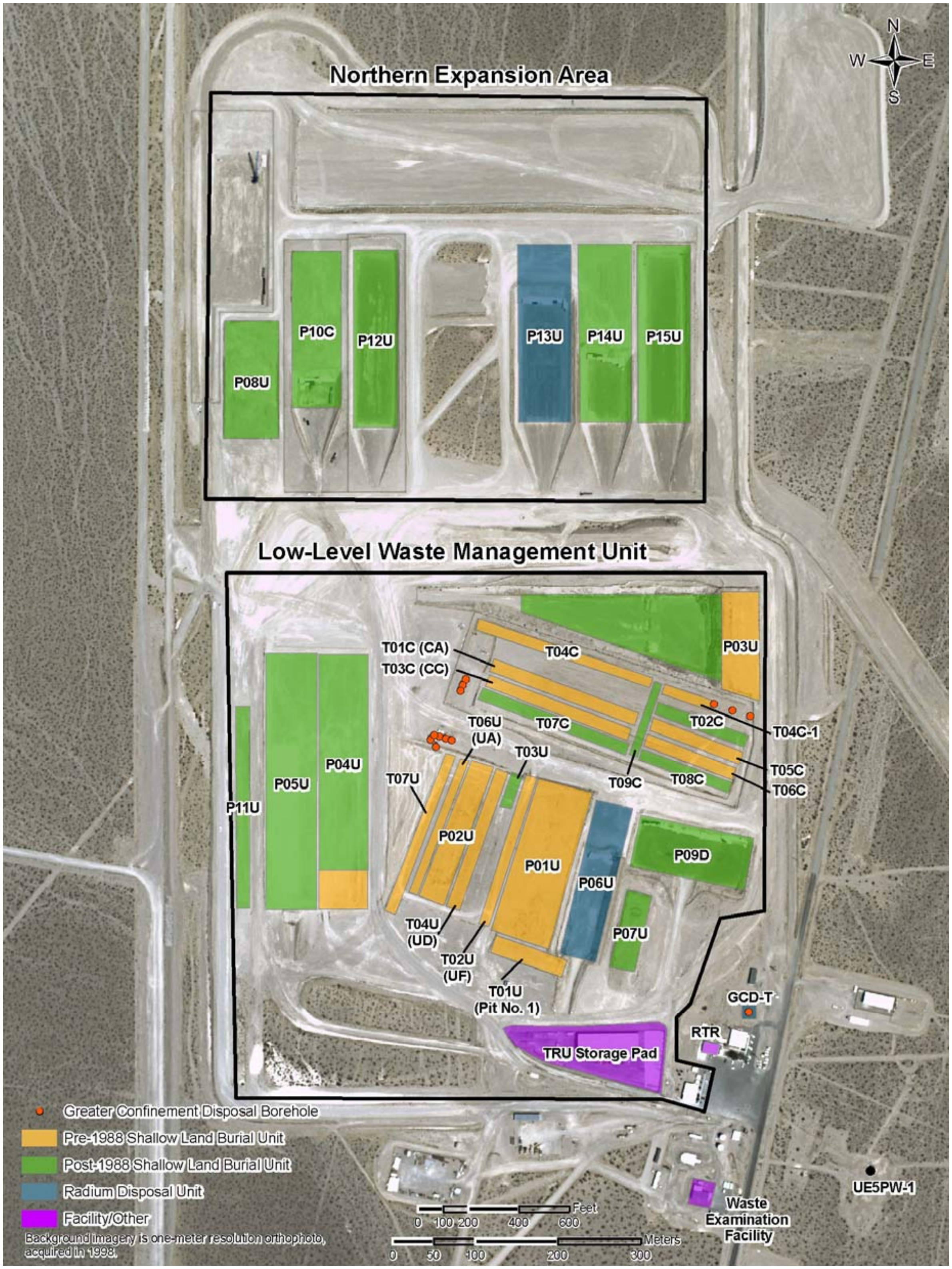


Figure 2-3. Disposal Units at the Area 5 Radioactive Waste Management Site.

2.2.2 Ancillary Facilities

The Area 5 RWMS includes several equipment storage yards and five permanent and nine semi-permanent structures that are used for offices, laboratories, storage, utilities, and routine operations. Ancillary to the Area 5 RWMS are a WEF and several support structures. The WEF exists to characterize TRU waste stored at the Area 5 RWMS. Neighboring the RWMS are a Hazardous Waste Storage Unit (HWSU) and several administrative support structures. Hazardous wastes are managed at the HWSU until they are shipped off site for disposal.

2.3 POPULATION DISTRIBUTION

No new population centers have been established near the Area 5 RWMS since the 1998 PA. Existing local communities continue to grow, with large urban centers experiencing the most rapid and consistent increases. The Las Vegas metropolitan area (composed of Las Vegas, North Las Vegas, Henderson, Boulder City, and Mesquite) is one of the fastest-growing metropolitan areas in the U.S., increasing from 4 to 8 percent per year. In 2004, the population of the Las Vegas metropolitan area was estimated to be more than 1.7 million (State of Nevada Demographer [SND], 2005a). Pahrump, a rural community in Nye County approximately 80 km (51 mi) southwest of the Area 5 RWMS, also continues to grow rapidly with a 2004 population estimated to be 30,465 (SND, 2005a). Long-term population trends for smaller rural communities near the NTS such as Amargosa (50 km [31 mi] southwest of the RWMS), with a 2004 population of 1,211, and Indian Springs (42 km [26 mi] to the southeast), with a 2004 population of 1,661, indicate slower, less consistent increases, with small decreases occurring in some individual years. By 2024, the approximate time of site closure, the population of Clark County is expected to increase to 2.7 million and Nye County to 57,665 (SND, 2005b).

2.3.1 Use of Adjacent Lands

The Area 5 RWMS is protected from public access and future development by government control of the NTS and the surrounding Nellis Air Force Range complex (Figure 2-1). Historical and DOE uses of these lands were discussed in the 1998 PA. Current land uses at the NTS include hazardous chemical spill testing, emergency response training, nonnuclear weapons testing, radioactive waste management, and environmental technology studies. Land use in Frenchman Flat remains the same as described in the 1998 PA, except for the addition of two new facilities, the FACE facility and the Rad/NucCTEC. The FACE facility, located south of the Frenchman Flat playa, is an outdoor environmental research experiment investigating the long-term effects of atmospheric carbon dioxide on desert ecosystems. Rad/NucCTEC, located south of the DAF, is a research and testing facility for instrumentation for the detection of weapons of mass destruction. Operation of the FACE and the Rad/NucCTEC facilities is not expected to have any impact on the performance of the Area 5 RWMS.

NNSA/NSO plans to restrict access to the NTS in perpetuity (DOE, 2000). The NTS's primary national security mission requires restriction of public access. Residual radioactivity from past activities, including aboveground and underground nuclear testing, precludes release of large areas of the NTS until contamination is cleaned up to free release standards. Restoration of some areas contaminated by nuclear testing may not be economically or technically feasible. Such areas will be closed in place with permanent land-use restrictions. The NNSA/NSO land-use plans for the NTS includes plan to prohibit construction and drilling within the Area 5 RWMS in perpetuity.

Ranching and mining remain important land uses in southern Nevada. More recently, recreational activities and irrigation-based agriculture have become important land uses in southern Nevada. Provided that the NTS remains withdrawn from all forms of appropriation, these activities likely will not have a significant impact on the NTS. The federal use and management of the adjacent land further buffer the NTS from external influence.

2.4 METEOROLOGY AND CLIMATOLOGY

Meteorology and climatology specific to the Area 5 RWMS is presented in detail in the PA (Shott et al., 1998) and the annual Waste Management Monitoring Report (NSTec, 2008b).

2.4.1 Precipitation

Most precipitation in the Transitional Desert occurs in winter and summer. Winter precipitation is generally associated with transitory low-pressure systems originating from the west and occurring as uniform storms over large areas. Summer precipitation is generally associated with convective storms originating from the south or southwest and occurring as intense local events.

The average annual precipitation based on a 44-year record (1963–2006) at a location 6.4 km (4 mi) south of the Area 5 RWMS is 124.9 millimeters (mm) (4.92 inches [in.]) (Air Resources Laboratory, Special Operations and Research Division [ARL/SORD, 2007). The average annual precipitation based on the 12-year record (1995–2006) collected at the Area 5 RWMS is 131.3 mm (5.17 in.). Annual precipitation is highly variable at the Area 5 RWMS. The standard deviation of the 12-year record of annual precipitation is 64.0 mm (2.52 in.). The maximum annual precipitation was 258.9 mm (10.19 in.) in 1998 and the minimum was 37.7 mm (1.48 in.) in 2002 (NSTec, 2008b). Figure 2-4 depicts the precipitation record for Area Well 5B and Area 5 RWMS monitoring stations.

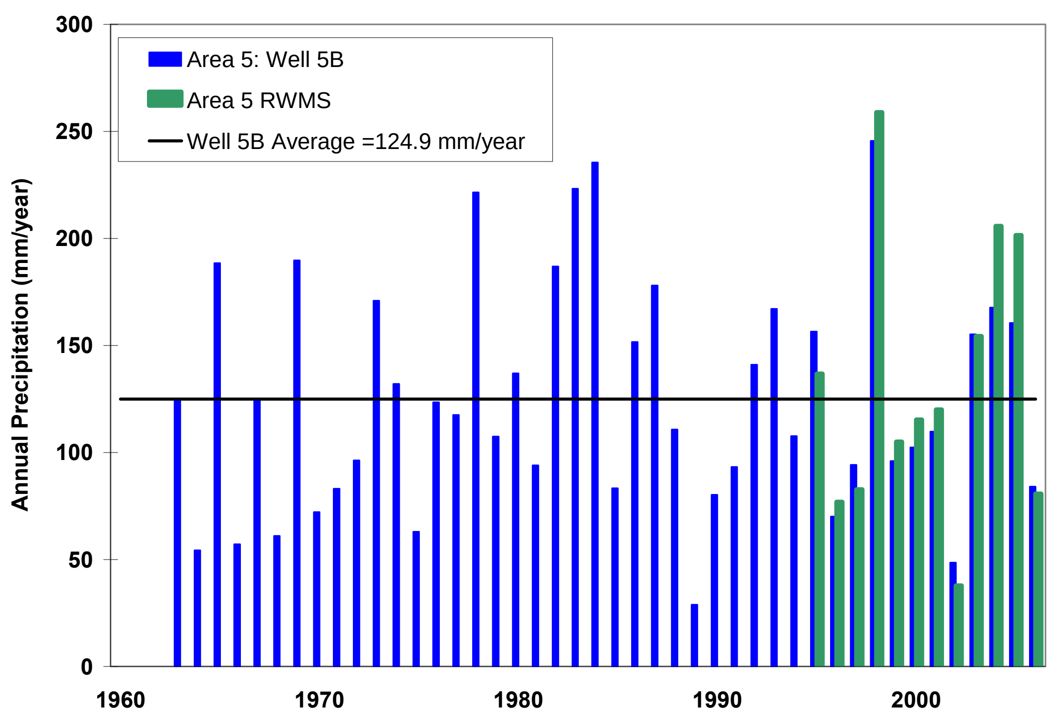


Figure 2-4. Historical Precipitation Record for Area Well 5B and Area 5 RWMS.

2.4.2 Temperature

Average daily temperatures at the NTS range between 2 degrees Celsius (°C) (35 degrees Fahrenheit [°F]) in January to 24°C (75°F) in August. Large daily fluctuations are common on the valley floors. The daily minimum air temperatures ranged from -15°C (5°F) in winter to 25°C (77°F) in summer.

At the Area 5 RWMS, the daily maximum temperature ranged from 12°C (54°F) in winter to 36°C (97°F) in summer. The daily minimum air temperatures ranged from -12°C (10°F) in winter to 17°C (63°F) in summer.

2.4.3 Potential Evapotranspiration

Potential evapotranspiration (PET) represents the environmental potential to evaporate and transpire water. PET is high at the Area 5 RWMS due to the high incident solar radiation, low relative humidity, and high average wind speeds. Using the radiation-based equation from Doorenbos and Pruitt (1977), the average annual PET at the Area 5 RWMS is approximately 12 times the annual average precipitation (Desotell et al., 2006).

2.4.4 Wind

Wind speed and direction have been recorded at the Area 5 RWMS meteorology station since 1994. During 2006, the average wind speed at the Area 5 RWMS was 2.6 meters per second (m/s) (5.8 miles per hour [mph]), and the maximum gust was 18.5 m/s (41.4 mph) (NSTec, 2008b). A wind rose diagram for 2006 is shown as Figure 2-5. Wind rose diagrams illustrate the frequency of wind velocities with respect to wind-source direction over a period of record, using hourly wind data measured at a height of 3.0 m (10 ft) above the ground surface. Generally, more wind comes from the north and higher wind speeds come from the south. The one-year wind rose diagram presented here is very similar to multi-year wind rose diagrams.

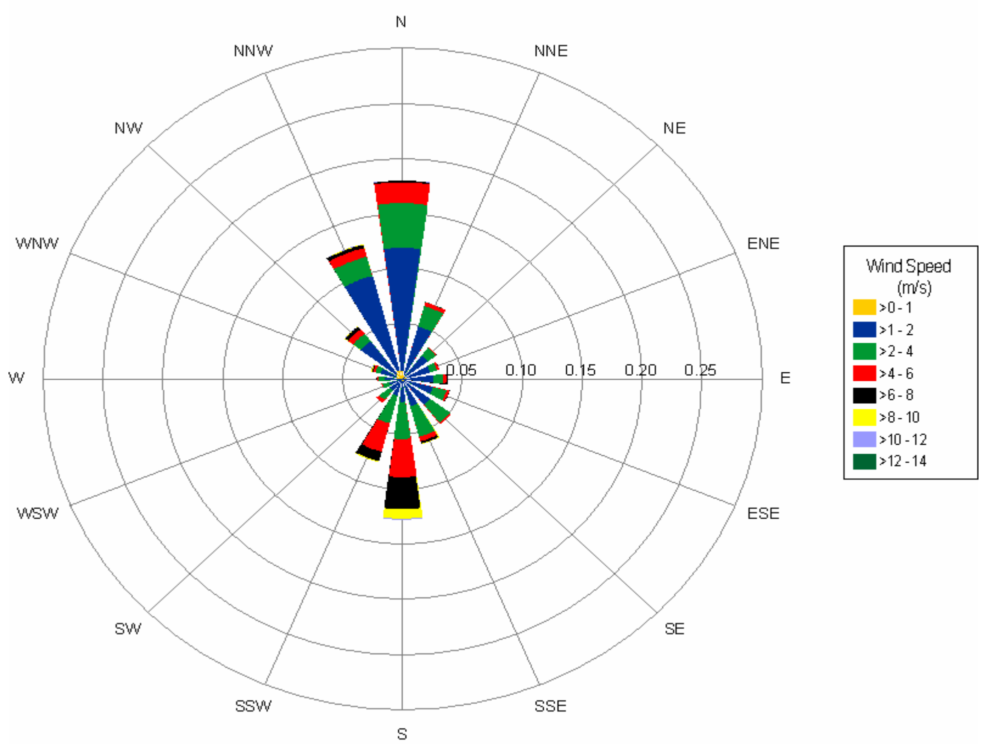


Figure 2-5. Wind Rose Diagram for the Area 5 RWMS Meteorology Station

2.5 ECOLOGY

The biotic processes that influence the pedoturbation of soils at the NTS have been investigated from the fall of 2000 to the present time. These investigations have included literature reviews of pedoturbation processes in arid lands (Hooten et al., 2001; Hansen and Ostler, 2003) and field investigations of organisms that contribute or are suspected to contribute to pedoturbation of soils at the NTS. These data were used to update model structure and input parameter distributions as documented within the model itself and in documentation distributed with the model.

2.5.1 Field Characterization of Plant Communities

Initially, all botanical fieldwork on the NTS was organized by plant association as outlined by Ostler et al. (2000). Plant communities for field investigations were chosen based on professional opinion as the plant associations were most likely to occur at the Area 3 RWMS or Area 5 RWMS over the next 1,000 years. These assemblages are broadly representative of the Mojave Desert flora, the Great Basin Desert flora, and the flora of the transition zone (ecotone) that lies at their interface. Given this basis, eight associations were chosen for the establishment of permanent, 1-ha (2.5-ac) plots (quadrats) that were located to provide coverage of the "most likely" plant communities (Table 2-1).

Table 2-1. Plant Associations of the NTS Investigated for Biotic Conditions of Pedoturbation.

Quadrat (plot) #	Plant Association	Desert Region
Quadrats 1 and 6	*Larrea tridentata-Ambrosia dumosa* shrubland	Mojave Desert
Quadrat 2	*Atriplex confertifolia-Ambrosia dumosa* shrubland	Mojave Desert
Quadrat 3	*Krascheninnikovia Lanata-Ephedra Nevadensis* shrubland	transition zone
Quadrat 4	*Lycium andersonii-Hymenoclea salsola* shrubland	transition zone
Quadrat 5	*Atriplex canescens-Krascheninnikovia lanata* shrubland	Great Basin Desert
Quadrat 6	*Artemisia tridentata-Chrysothamnus viscidiflorus* shrubland	Great Basin Desert
Quadrat 7	*Atriplex confertifolia-Kochia americana* shrubland	Great Basin Desert
Quadrat 8	*Artemisia nova-Artemisia tridentata* shrubland	Great Basin Desert

Of all NTS plant associations, the only one not investigated was the *Coleogyne ramosissima-Ephedra nevadensis* shrubland of the transition zone. There is, however, significant overlap of this community type among the plant associations chosen from the transition zone and Great Basin Desert.

To date, information gathered on plants from each of the quadrats has included perennial shrub density and percent composition. In addition to those values provided in Ostler et al. (2000), this information has supplied the PA model a range of data from which to estimate parameters relevant to plant community composition.

Additionally, perennial grass rooting depths and belowground spreads have been gathered (by means of hand excavation) for two dominant grass species (across all quadrats), including *Achnatherum hymenoides* (Indian ricegrass) and *A. speciosum* (desert needlegrass). Each of these species is considered "relatively deeply rooting" and has a potential bearing on the movement of contaminants from below the ground surface to the surface.

Investigations of perennial grass productivity of deeply rooting grasses on each quadrat have been conducted. Estimates of productivity are yet forthcoming from these investigations, but will provide enough information to derive distributions of perennial grass productivity for *A. hymenoides* and *A. speciosum* in all areas of the NTS, most importantly the RWMSs.

2.5.2 Field Characterization of Mammal Burrowing

Mammals are one of the better understood animal groups on the NTS from a taxonomic and biogeographic point of view. Investigations have therefore been primarily concerned with their overall contribution to the movement of soils from below to above the ground surface. Contribution of mammals to the movement of soils has been measured for each of the plant communities investigated.

Measurement of mammal mounding (spoils) for each of the plant communities was considered a coarse, but reasonable indicator of the current standing spoils of soil that had been moved from below to above the ground surface. Literature regarding the quantity and vigor of mammalian digging and soil movement appeared to support this contention concerning spoils. Thus, mammal mounding was first measured for the sake of correlating aboveground conical volume with actual mound volume over a range of mound sizes, from the smallest to the largest observed. Second, each quadrat was measured for estimating the standing volume of mammal spoils aboveground. This information was used to develop distributions of mammalian contribution of moving soils from belowground to aboveground, based also on literature values for estimating the percent mammal burrows in discrete soil layers.

2.5.2.1 Field Characterization of Ant Burrowing

Prior to field investigations, the association of ants with specific plant association and desert biome types was poorly understood for the region of the NTS. Investigations have provided significant information on the species' biogeographic distributions, as well as confirmation of species occurrence in the areas of each of the quadrats investigated. Additionally, the relative densities of ants in each of the associations have been well established in the context of nests per hectare. Moreover, estimates of ant nest densities per hectare have been supplemented by information on replacement rates of nests per year. Estimates of nest replacement have been in accord with literature estimates. This information has been critical in the estimation of soil movement by ants over time.

Five species of primary concern for soil movement were identified from literature and field studies on the NTS. Each of these species, along with their desert biomes of association, is listed in Table 2-2. Plant associations are too narrow a biotic community-organizational focus for the occurrence of the five species of concern, as they occur in areas of broader biotic affiliation than associations. Thus, desert biomes appear to be more functionally accurate for predicting the occurrence of species. These assertions are based primarily on observation, and not on specific analyses of ant-plant community types.

Table 2-2. Ant Species of Primary Concern for Maximum Nest Depths and Soil Movements at the NTS.

Ant Species	Desert Biome of Occurrence
Pogonomyrmex rugosus	Mojave Desert/transition zone
P. occidentalis	Great Basin Desert
P. salinus	Great Basin Desert
Messor pergandei	Mojave Desert
Myrmecocystus mexicanus	transition zone and possibly the Great Basin Desert

Ant nest depth information had previously been limited to literature that reported maximum burrowing (nest) depth values from areas outside of Nevada. Even more occlusive, nest geometry and volume by depth were completely lacking for all species of concern for significant pedoturbation. Field campaigns were therefore launched to discover the maximum burrowing depth, volume, and three-dimensional (3-D) character/distribution of chambers and galleries of each nest. This information was intended to improve modeling of ant pedoturbation by providing modelers with accurate, site-specific information on the potential for soil movement by ants on a per-depth basis to the maximum depth observed for each species.

Species investigated included *P. rugosus* (occurred in Areas 3 and 5), *Messor pergandei* (occurred in Area 5 only), and *Myrmecocystus mexicanus* (occurred in Area 3 only). Other *Pogonomyrmex* species were not investigated primarily because of budgetary and time constraints. However, literature information on excavations of *P. salinus* and *P. occidentalis* indicate that nests are geometrically similar to, but not as deep as, those of *P. rugosus*. Additionally, field investigations indicated that *P. occidentalis* is a low-elevation Great Basin Desert ecological analog of *P. rugosus*, while *P. salinus* appears to be a high-elevational analog. For the time being, this information of analogous ecological function is sufficient for current PA modeling efforts.

Three field trips of a total duration of five weeks were conducted to excavate the entirety of 19 *P. rugosus* nests (10 in Area 5 and 9 in Area 3), 13 *M. pergandei* nests, and 8 *M. mexicanus* nests. Excavations were initially exploratory in technique, but ultimately yielded the desired information and vastly improved understanding of the nesting/burrowing behavior of each of the species. Refinements that followed in PA modeling indicated vastly improved estimates of soil movement from belowground to above the ground surface. Estimates indicated that considerably less material was moved from the deepest reaches of the nests than had been previously suspected.

2.5.2.2 Field Characterization of Termite Burrowing

Termites are historically a perplexing taxonomic group for considering pedoturbation in the desert environs of the NTS. Literature and expert opinion in 2000 implied that southwestern U.S. desert termites may move soil from remarkable depths (>10 m [33 ft]) and bring it to the ground surface. Investigations into the biology and behavior of termites of the NTS have provided a very different view of their pedoturbation activities than previously suggested.

The nesting behavior of three genera of termites was investigated for each of the major desert areas covered by permanent quadrats. Genera investigated included *Reticulitermes, Gnathamitermes,* and *Amitermes.* Various techniques were used for considering their depths of burrowing, their rates of consumption of belowground cellulosic resources, and their proclivity to move belowground soil particulates to the ground surface, as well as the origin of such particulates.

The conclusion of the investigation is that there is fairly strong resource partitioning among the genera (perhaps five species). This would allow for the co-occurrence of more than one species in any given habitat, which was confirmed by observation and collection. All species consume belowground and aboveground woody resources, and may attack any exposed woody debris over time. This includes anthropogenic woody debris, including cardboard and paper.

Although termites will access and consume any available woody debris, only one species at the NTS was observed to excavate soil from below to above the ground surface. *Gnathamitermes sp.* 1 (an undescribed species) moves fine soil particles from below ground to coat dead portions of perennial grasses (preferentially *Achnatherum sp.*) and, to a limited degree, some perennial shrubs and harvest sun-bleached fibers from the surface layers of the plants. Excavations of ant nests were very informative for discerning the origin of the excavated fines, and show that most of the fine soil particulates originated from within 30 centimeters (cm) (1 ft) of the ground surface.

Indeed, excavations of ants provided great insight to termite activities belowground. Most termite activities were found to be limited to roots of 3 mm (0.1 in.) and greater diameter, with maximum depths of root excavations observed at nearly 1.5 m (4.9 ft). It is likely that termites of several species at the NTS can routinely excavate roots to nearly the maximum root depth in any given plant community. Their redistribution of contaminants will then be limited to ingestion of contaminants in roots and the haphazard redistribution that follows. However, most activity of termites was observed well above 1 m (3.3 ft) depth, and limited to roots and some soil rearrangement due to nesting activities or, in the case of *Gnathamitermes sp.* 1, due to some redistribution of near-surface fines. The sum of these observations implies that termites contribute somewhat to the accelerated collapse of belowground voids because of root intrusion or the presence of anthropogenic or other buried woody materials, but little to the movement of soils from depth to the ground surface.

2.6 GEOLOGY

Detailed descriptions of the geology of Frenchman Flat are in the Area 5 RWMS PA (Shott et al., 1998).

2.6.1 Regional Geology

In general, the sequence of rocks (from oldest to youngest) at the NTS is composed of Proterozoic and Paleozoic, primarily marine, sedimentary rocks; locally intrusive Cretaceous granitic rocks; Miocene volcanic rocks; and post-volcanic sand and gravel. These layers total approximately 10,500 m (35,000 ft) thick, if stacked at one location according to age (Frizzell and Shulters, 1990). The volcanic rocks of generally rhyolitic composition erupted a relatively large volcanic complex (referred to as the Southwestern Nevada Volcanic Field [Warren et al., 2003]) consisting of multiple nested and coalesced calderas located 40 km (25 mi) northwest of Frenchman Flat. These rocks dominate the highlands north and northwest of Frenchman Flat. The highlands bounding Frenchman Flat on the west are composed of intermediate composition tuffs, lavas, and debris flows from the Wahmonie volcanic center located west of Frenchman Flat.

2.6.2 Frenchman Flat Geology

Formation of the basin appears to be related to the termination of the left-lateral Rock Valley fault system. Northeast-striking faults of the Rock Valley system in the southern portion of Frenchman Flat turn north and then northwest as the faults of the system flare out into an extensional imbricate fan along the eastern and northern margins of the basin (Figure 2-6). This has resulted in the basin being dropped down on the south, east, and north, and filled with more than 2,740 m of mostly Tertiary volcanic rocks and alluvium. The main period of basin development appears to have begun between 11.45 and 9.14 million years ago (Ma), and may continue into the present.

The mountain ranges surrounding Frenchman Flat consist primarily of Tertiary volcanic rocks and underlying Paleozoic sedimentary rocks (Figure 2-6). Erosion of the mountain ranges has resulted in deposition of a significant thickness of alluvium. The stratigraphy of rocks within Frenchman Flat has been established from mapping and boreholes drilled for water wells, underground nuclear testing (Drellack, 1997), and most recently groundwater characterization wells for the UGTA Sub-Project (DOE, 2005c; 2005d). The thickness of alluvium in Frenchman Flat ranges between 0 and 1,500 m (0 and 4,900 ft), based on recent drillhole and 3-D seismic reflection data. The alluvium directly below the Area 5 RWMS is approximately 914 m (3,000 ft) thick (BN, 2005a).

The alluvium is underlain by interbedded Tertiary ash-flow and ash-fall tuff estimated to be over 1,190 m (3,900 ft) thick directly below the Area 5 RWMS. On the basis of 3-D seismic reflection data (BN, 2005a), the upper surface of the underlying carbonate rocks is about 2,100 m (6,900 ft) below the surface at the Area 5 RWMS, and perhaps as deep as 2,740 m (9,000 ft) near the center of the basin. A well recently drilled in northern Frenchman Flat showed the top of the carbonate rocks to be 1,426 m (4,678 ft) below surface (DOE, 2005c), approximately 3.2 km (2 mi) northeast of the RWMS.

Principal faults in Frenchman Flat are the Cane Spring Fault and the Rock Valley Fault zone (Figure 2-6). The Cane Spring Fault is a left-lateral, strike-slip fault that strikes southwest to northeast in the northern part of Frenchman Flat, 6.4 km (4 mi) northwest of the RWMS. The Rock Valley Fault zone is also a left-lateral, strike-slip fault zone with a minor dip-slip component (down to the north) that strikes southwest to northeast in the southern part of Frenchman Flat, about 8.8 km (5.5 mi) south of the RWMS.

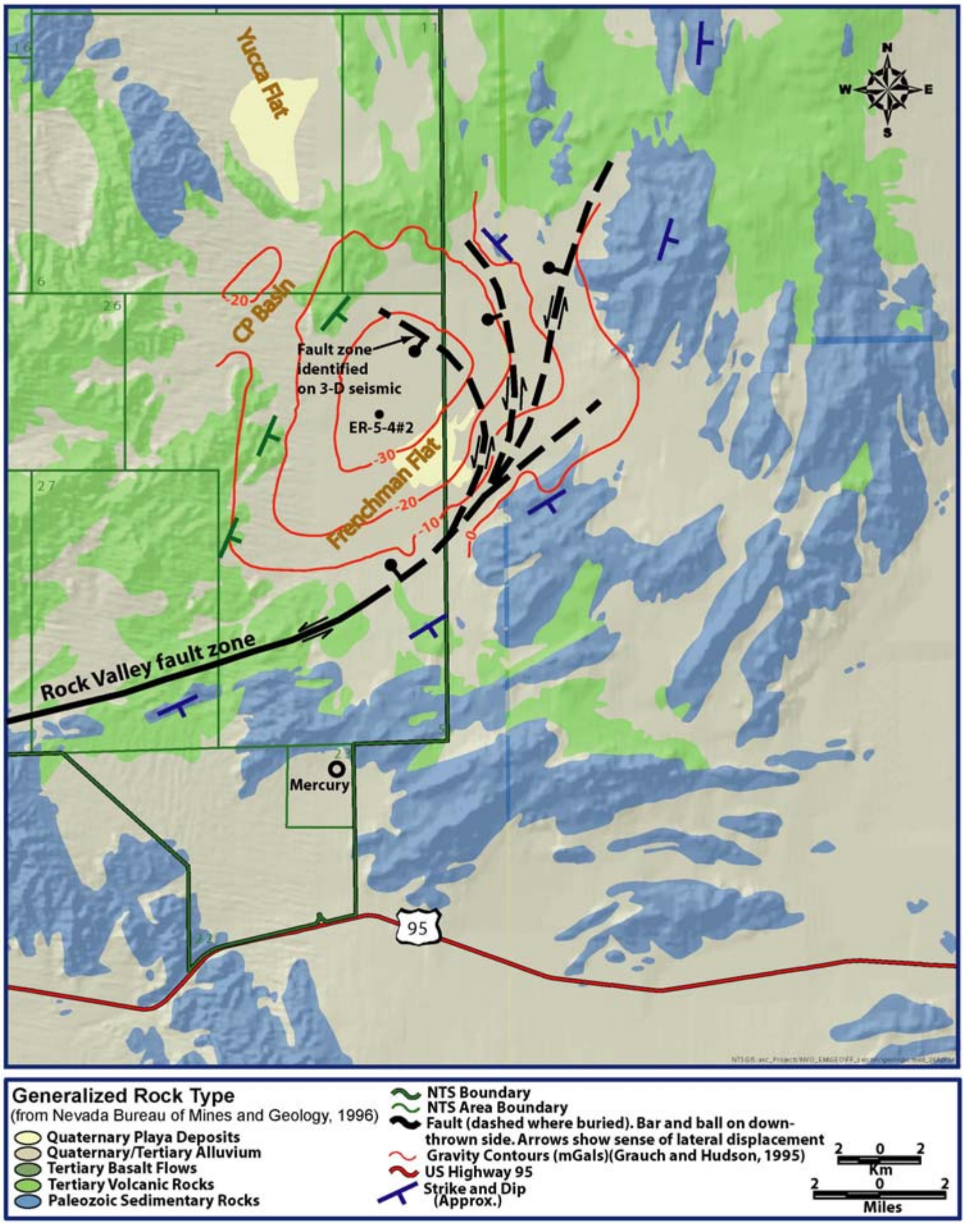


Figure 2-6. Simplified Geologic Map.

2.7 SEISMOLOGY

2.7.1 Potential for Seismic Activity

The 1998 PA concluded that seismic activity was not a significant concern for the Area 5 RWMS (Shott et al., 1998). This judgment was based on multiple lines of evidence including:

- Maximum predicted magnitudes and peak accelerations for seismicity are not significant concerns for the engineered structures (unlined pits and trenches in alluvium with a monolayer soil cover) used for shallow-land disposal of LLW.
- The return periods for large-magnitude earthquakes (>5.8 magnitude) are long and exceed 10,000 years (infrequent events relative to 1,000-year compliance period).
- There is no surface evidence of recent faulting in the vicinity of the Area 5 RWMS.
- There is a low likelihood of a future seismic event centered at the facility.
- It is unlikely that the facility will be compromised by future seismic activity.

Significant new information since revised tectonic studies of the Rock Valley fault zone (O'Leary, 1996) includes:

- A magnitude 4.7 earthquake in Frenchman Flat on January 27, 1999.
- Exploratory drilling and geophysical studies in Frenchman Flat for the UGTA Sub-project. These studies have led to a revised conceptual model for the Frenchman Flat basin.
- Continued seismic monitoring of the NTS region by the Nevada Seismological Laboratory of the University of Nevada-Reno for the Yucca Mountain Project (Brune et al., 2003). This monitoring has led to the recognition of increased seismicity in aftershock zones associated with the magnitude 5.6 Little Skull Mountain earthquake (June 29, 1992) and the Frenchman Flat earthquake of 1999.

2.7.2 January 1999 Frenchman Flat Earthquake

A magnitude 4.7 earthquake on January 27, 1999 (2:44 a.m. PST), in Frenchman Flat was the largest main shock in a foreshock sequence that included a magnitude 4.2 quake two days earlier. The event was the largest recorded earthquake on the NTS since the magnitude 5.6 Little Skull Mountain earthquake in 1992. The Frenchman Flat event occurred slightly off strike of the Rock Valley fault zone in southwest Frenchman Flat (latitude 36.81 north, longitude 115.98 west [Brune et al., 2003]). Aftershocks occurred along a northeast-trending zone and ranged in depth from 5 to 10 km (3 to 6 mi). First motion results are consistent with normal faulting, but strike-slip cannot be ruled out (Brune et al., 2003). There was no surface ground breakage associated with the earthquake and there were no observed seismic effects at the Area 5 RWMS.

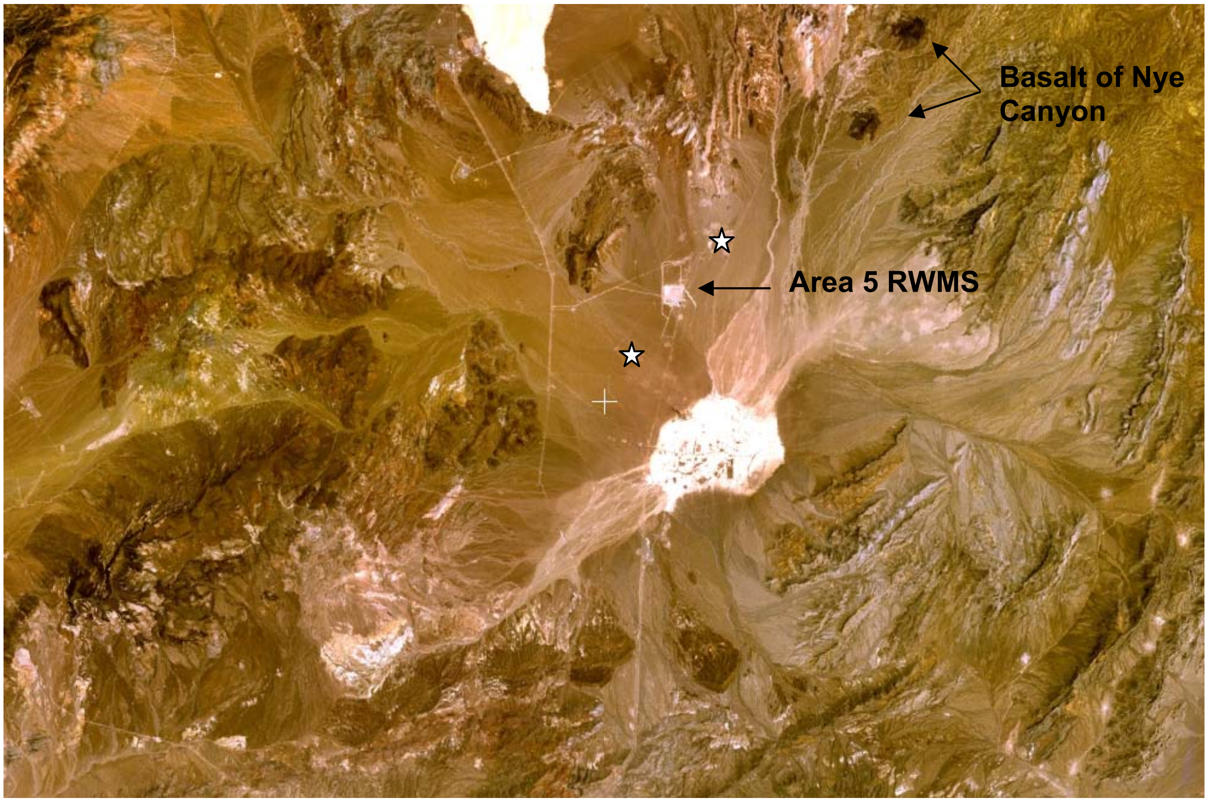


Figure 2-7. Satellite Photograph of the Frenchman Flat Basin of the Southeast Nevada Test Site.

The star symbols mark the location of the exploratory UGTA drillhole clusters. The white cross-hairs mark the location of the 1999 Frenchman Flat earthquake. Photograph adapted from the National Aeronautics and Space Administration World Wide imagery.

2.7.3 Structural Model of Frenchman Flat

A revised hydrostratigraphic model of Frenchman Flat has been developed for the basin and incorporates newly obtained information from the UGTA Sub-project. These data consist of five new exploratory drillholes, including a cluster of wells located several kilometers northeast of the Area 5 RWMS and a second cluster of wells located near the basin center, south-southwest of the RWMS (Figure 2-7 [BN, 2005a]). A 3-D seismic reflection survey was conducted in Frenchman Flat in 2001 that supplements and extends the data obtained from the exploratory drilling (BN, 2005a).

The structural model of Frenchman Flat basin used in the 1998 PA (Shott et al., 1998) is based largely on the interpretations of Carr et al. (1975) and Hudson (1997). The basin was interpreted as a predominantly extensional feature controlled by inferred north-south trending, down-to-the-west normal faults that merge to the south into the left-slip Rock Valley fault system. The basin lies between two northeast-trending left-slip faults, the Cane Spring fault on the northwest and the Rock Valley fault on the south. Strike-slip motion on these faults contributed to basin development, but the basin was viewed as a predominantly extensional basin defined by a series of north-south trending, east-tilted half-grabens extending beneath the central part of Frenchman Flat.

Based on the new drillhole and geophysical data, the revised structural model of the basin interprets basin-forming faults to be confined mostly to the east-northeast part of Frenchman

Flat. Northeast-trending faults at the eastern end of the Rock Valley fault system in southern Frenchman Flat are inferred to rotate north and northwest into an extensional imbricate fan structure on the eastern and northern margins of the basin (BN, 2005a). The resulting structure is a single, deep, and east-tilted half-graben structure beneath the central part of the basin.

A significant insight from the revised structural model is the identification of a major and previously unrecognized northwest-trending, down-to-the-southwest zone of faulting beneath the north part of Frenchman Flat near the Area 5 RWMS (BN, 2005a). This fault zone has as much as 600 m (2,000 ft) of displacement. The absence of surface offsets in the alluvial deposits and the northwest orientation of the zone suggest the fault zone beneath the facility is not a seismogenic structure. However, the fault is inferred to be related to curving north and northeast-trending faults southeast of the buried fault. These faults merge with the Rock Valley fault zone and are inferred to be associated with development of the Frenchman Flat basin. The presence of Quaternary scarps on the Rock Valley fault zone and the instrumentally located seismicity, including the 1999 Frenchman Flat earthquake, suggest basin formation is continuing.

2.7.4 Seismological Monitoring of the Nevada Test Site

The Nevada Seismological Laboratory maintains a seismic network in the vicinity of Yucca Mountain under a DOE-University and College System in Nevada cooperative agreement. Recorded seismicity during a five-year period (1997–2002) shows two zones of clustered seismic events. The first is an aftershock zone from the 1992 Little Skull Mountain earthquake; the second is an aftershock zone from 1999 Frenchman Flat earthquake (Brune et al., 2003).

2.7.5 Rock Valley Fault Zone

Tectonic studies of the Rock Valley fault zone are discussed in O’Leary (1996). The fault zone consists of multiple east-northeast striking, left-slip faults within Rock Valley at the south part of the NTS (Figure 2-6). These faults extend for more than 18 km (11 mi) from southern Jackass Flats on the west to southern Frenchman Flat on the east where the fault zone merges with a zone of north- and northeast-trending faults. The Rock Valley fault is grouped with two other northeast-trending left-slip faults, the Mine Mountain and Cane Spring faults; this group of faults forms the Spotted Range-Mine Mountain structural zone described by Carr (1984). These faults are listed in the Quaternary fault database of the United States, a compiled list of faults that are assumed to be sources of greater than magnitude 6.0 earthquake activity during the Quaternary (Anderson, 1998). Repeated clusters of generally lower-magnitude earthquakes within and adjacent to Rock Valley demonstrate that the Rock Valley fault zone is presently active (O’Leary, 1996). Trenching and paleoseismic studies of the Rock Valley fault system give slip rates of 0.002 to 0.05 millimeters per year (mm yr^{-1}) and recurrence intervals of 5,000 to 10,000 years (Coe et al., 1996). Studies associated with the Yucca Mountain Project conclude that the Rock Valley fault system could generate earthquakes of magnitude 7.0 or larger (O’Leary, 1996).

2.7.6 Seismic Effects

There is significant potential for seismic activity in the NTS area including Frenchman Flat during the next 1,000 years (Shott et al., 1998). The revised conceptual model of Frenchman Flat relates the origin of the Frenchman Flat basin to strike-slip along the Rock Valley fault system that terminates in an extensional imbricate fan structure in the eastern margin of the basin. Observational data suggest that this structure is still active. Relatively large-magnitude earthquakes (> magnitude 5.0) are expected events in the NTS region over time frames of 10,000 to 15,000 years.

A formal seismic risk assessment has not been conducted for the Area 5 RWMS. However, multiple lines of evidence support the conclusion that future seismic activity is unlikely to significantly degrade the isolation capability of LLW disposed in shallow land pits and trenches.

There are no observed offsets in alluvial deposits within the vicinity of the Area 5 RWMS. The active parts of the Rock Valley fault system and related imbricate fault systems are >5 km (3 mi) from the facility. The buried fault beneath the facility strikes northwest, a fault orientation that is not seismogenic in the current stress field (Carr, 1984). Future ground ruptures from earthquake activity are not expected to disrupt the facility.

The recurrence time or time between major earthquake events is relatively long (10,000 to 15,000 years) compared to the compliance period for waste isolation (1,000 years).

The most likely future effect of seismic activity is ground shaking associated with a distant earthquake event. The primary concern associated with the effects of seismic activity on closure covers is ground shaking and disruption of engineered components (geomembrane barriers, leachate collection system) that can lead to increased infiltration and/or enhanced vapor-phase transport. Closure plans for the Area 5 RWMS include construction of a thick (>3-m [9.8-ft]) monolayer-ET closure cover composed of alluvial soil. This closure cover does not contain engineered components that could fail or be disrupted by seismic events. The only anticipated effect of ground shaking is enhanced and/or accelerated compaction/subsidence. The important infiltration, water storage, and water removal characteristics of a monolayer-ET cover are not expected to be adversely affected by minor compaction. Kemnitz (1999) completed a seismic hazard assessment for the U-3ax/bl monolayer closure cover at the Area 3 RWMS. Model parameters and site response assessments were performed for a bounding analysis to assess damage to a monolayer closure cover at the U-3ax/bl disposal cell. The controlling earthquake for the analysis is an earthquake event on the Yucca fault with a peak horizontal acceleration of 0.79 g, where g is the acceleration of gravity. The maximum predicted deformation of the closure cover is between 2 and 8 cm (0.8 and 3 in.) (lateral and differential deformation). These deformations are insignificant compared to the expected subsidence in the closure cover (Kemnitz, 1999). The effects of future seismic events are not significant for the Area 5 RWMS.

2.8 VOLCANISM

The volcanic record of the NTS was summarized in the 1998 PA (Shott et al., 1998). Silicic volcanism in the region ceased following eruptions associated with the Black Mountain caldera about 8.5 Ma (Sawyer et al., 1994). Small-volume basaltic volcanism persisted in the region following cessation of silicic volcanism. All Quaternary basaltic volcanic activity in the NTS region is confined to the western and southwest parts of the the region, including the basalt of Sleeping Butte, the Quaternary basalt of Crater Flat, and the Lathrop Wells volcanic center (Crowe, 1990; Fleck et al., 1996; Heizler et al., 1999). Basaltic volcanism in the Frenchman Flat basin includes buried basalt encountered in the alluvial section in multiple drillholes, including the UGTA northern drillhole cluster (Carr, 1974; BN, 2005a). The age of these buried basalt lavas is about 8.5 Ma (Raytheon Services Nevada [RSN], 1994). Local vents for the buried basalt are present in Scarp Canyon, immediately north of Frenchman Flat (Crowe, 1990). The youngest basalt centers in the basin vicinity are the basalt of Nye Canyon. This volcanic unit consists of three basalt centers aligned along a north-northeast trend dated at about 7.3 Ma (RSN, 1994).

The absence of nearby Pliocene or Quaternary basaltic volcanism in the Frenchman Flat area is the primary basis for an assessment of minimal risk to the Area 5 RWMS from the recurrence of future volcanism. The nearest site of Quaternary basaltic volcanism is the Lathrop Wells center, over 50 km (31 mi) from the Area 5 RWMS. The absence of young volcanic centers in the area classifies the facility as removed from zones of active volcanism and in a setting of background volcanic rates for the southern Great Basin. Background volcanic rates for the southern Great Basin region have been estimated by multiple researchers. Crowe et al. (1998a) calculated a Quaternary recurrence rate of 3.7×10^{-6} events/yr^{-1} for post-caldera basaltic volcanism within an area emcompassing the NTS region and including Frenchman Flat. The likelihood of magmatic disruption of a 2.5-km^2 (1-mi^2) area equivalent to the dimensions of the Area 5 RWMS using this recurrence rate is 2×10^{-9} events/yr^{-1}. Connor et al. (2000) calculated an event rate of 1.3×10^{-9} events/yr^{-1} per km^2 for the last 2.0 Ma for the western Great Basin. Application of this rate to a 2.5-km^2 (1-mi^2) facility area gives a volcanic disruption probability of 3.2×10^{-9} events/yr^{-1}. These event rates are equal to a disruption probability of about 1 in 300 million per year, a sufficiently low probability to dismiss volcanism as a concern for the Area 5 RWMS.

2.9 HYDROLOGY

2.9.1 Surface Water

No permanent surface water is present within Frenchman Flat, with the exception of small artificial impoundments and Cane Spring, which issue from a perched aquifer recharged from infiltration through fractures in the nearby mountains. Cane Spring is approximately 14.4 km (9 mi) southwest of the Area 5 RWMS. Alluvial fans within Frenchman Flat are cut by numerous arroyos that drain storm runoff to the playa. Water that accumulates on the playa evaporates or infiltrates within a short period of time. Frenchman Playa is about 6.4 km (4 mi) southeast of the Area 5 RWMS.

Schmeltzer et al. (1993) identified three watersheds that could contribute water to the Area 5 RWMS: Barren Wash, Massachusetts Mountains–Halfpint Range, and Scarp Canyon. The total area of these watersheds is approximately 360 km^2 (140 mi^2). A flood hazard assessment for the Area 5 RWMS based on these watersheds shows that only the southwest corner of the Area 5 RWMS is within a 100-year flood hazard zone. This zone is defined by the Federal Emergency Management Agency to have a 0.01 (1 percent) probability that a flood with a depth of flow greater than 0.3 m (1 ft) could occur within any given year. The southwest corner of the RWMS has the potential for flooding from both alluvial-fan flow on the Barren Wash fan and shallow concentrated flow on the Massachusetts Mountains–Halfpint Range fan. Other parts of the Area 5 RWMS are within an area referred to as Zone X, where sheetflow resulting from a 100-year, 6-hour precipitation event is anticipated to be less than 0.3 m (1 ft) deep. Recent studies, and a documented 25-year, 24-hour precipitation event at the NTS, suggest that actual depths of flow and flow velocities may be considerably less than modeled because of water lost into the ground during transmission (French and Curtis, 1999). The currently active part of the Area 5 RWMS is now protected from a 25-year, 24-hour flood event via a channel and dike system.

2.9.2 Groundwater

2.9.2.1 Unsaturated Zone

Many studies and models have been completed that contribute to our understanding of the stratigraphy and physical properties of the unsaturated zone in Area 5, the physical properties of the existing operational covers, and the potential for movement of water through the vadose zone. In the early 1990s, several studies were conducted that characterized the unsaturated alluvium in the vicinity of the Area 5 RWMS. The studies provided physical property data useful for further evaluation of hydrogeologic processes; the potential for contaminant transport, erosion, and subsidence; and other factors that must be considered in planning for closure of Area 5 RWMS disposal cells.

2.9.2.1.1 Physical and Hydrologic Properties

Particle size analysis has been conducted for over 2,000 samples of Area 5 alluvium. Results indicate the alluvium composition is approximately 20% gravel, 70% sand, and 10% silt/clay using the Unified Classification System (Shott et al., 1998). Using this system, the soil is classified as a well-graded sand with silt and gravel.

Bulk density measurements have been conducted for over 400 samples of the Area 5 alluvium. Analysis of the results indicate bulk density is normally distributed with a mean of 1.58 grams per square centimeter and standard deviation of 0.13 (Neptune, 2006).

The average calculated porosity from 43 samples collected from the pilot wells (Figure 3-6) is 37.9% (BN, 2005c). Similar values were obtained from the Science Trench Boreholes where the geometric mean of calculated porosity for 18 samples collected is 36.1% (Reynolds Electrical and Engineering Company, Inc. [REECo], 1993).

Nearly 200 saturated hydraulic conductivity (Ksat) tests have been conducted for samples taken from the pilot wells and the Science Trench Boreholes. Analysis of the data indicated Ksat is lognormally distributed with a geometric mean of 2.69 x 10^{-3} centimeters per second and exhibits little spatial variability.

2.9.2.1.2 Unsaturated Hydraulic Parameters

Table 2-3 presents summary statistics for unsaturated hydraulic parameters fit to the van Genuchten water retention model (van Genuchten, 1980) for samples collected from the Science Trench Boreholes.

Table 2-3. Unsaturated Hydraulic parameters from the Science Trench Boreholes.

Statistic	α (cm^{-1})	N	Θ_r (cm^3/cm^3)
Min	0.008	1.30	0.00
Max	0.03	3.12	0.10
Geometric mean	0.019	1.831	0.075
Std deviation (arithmetic)	5.71e-3	0.529	0.024
No. samples	18	18	18

2.9.2.1.3 Vadose Zone Water Balance Monitoring

Water balance studies using two precision weighing lysimeters have been conducted at the Area 5 RWMS since 1994. The lysimeters are located approximately 400 m from the southwest corner of the RWMS. Each lysimeter consists of a 2 m x 4 m x 2 m deep steel tank filled with native alluvium, supported on a sensitive scale. One lysimeter is vegetated with creosote bush, fourwing salt bush, and annual grasses at the approximate density of the surrounding landscape, while the other lysimeter is maintained as bare soil. The total daily storage data for the lysimeters through 2006 is presented as Figure 2-8. One dimensional unsaturated zone flow model simulations were calibrated using the lysimeter data set. The 30-year model simulations calibrated to the lysimeter data indicate a 2 m thick soil cover with native vegetation essentially eliminates drainage (Desotell et al., 2006). This modeling study supports the conclusion that there is no groundwater pathway for contaminants.

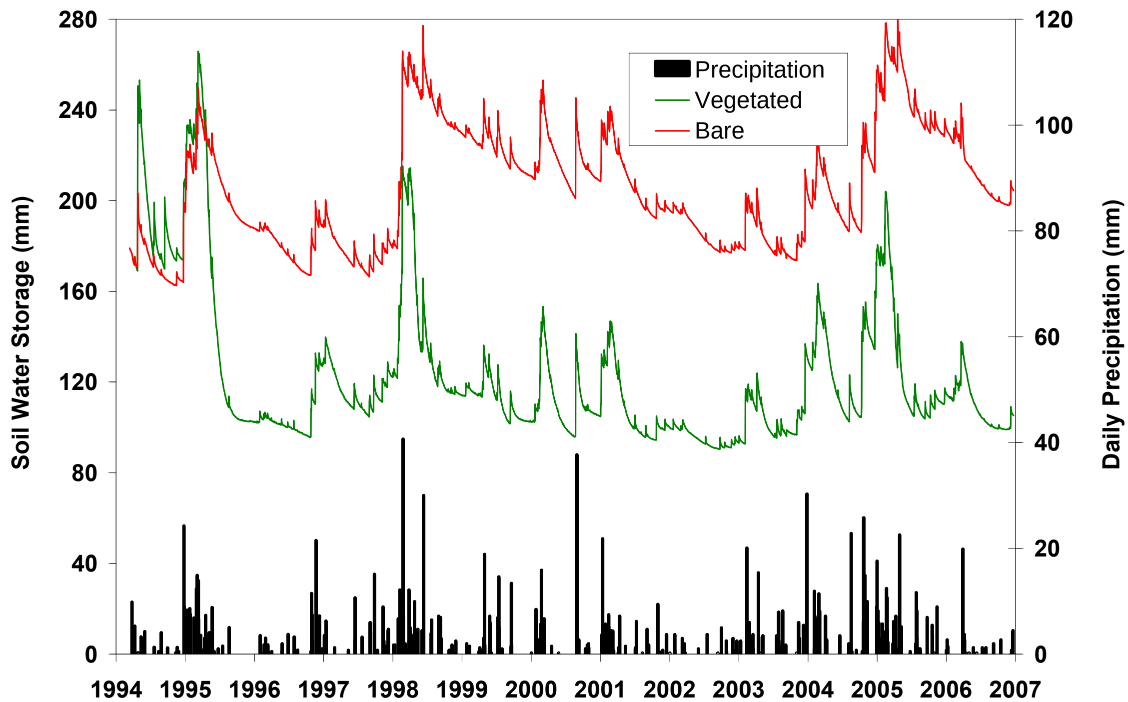


Figure 2-8. Soil Water Storage and Precipitation over Time, March 1994 through 2006.

2.9.2.1.4 Key Findings

Climate and vegetation strongly influence the movement of water in the near-surface alluvium (upper 2.0 m [6.5 ft]). Except for periods following precipitation events, water content in the near-surface region is low. Below this region is a zone where steady upward movement of water is occurring (Tyler et al., 1996). This zone extends to depths as great as 3 to 40 m (10 to 131 ft) in Area 5. Below this zone, water potential measurements indicate the existence of a static zone between approximately 40 to 90 m (131 to 295 ft) below the ground surface in Area 5 (Shott et al., 1998). In this static zone, essentially no vertical liquid flow is currently occurring. Below this static zone, flow is downward due to gravity. Stable isotope compositions of pore water indicate that infiltration into the static region must have occurred under cooler climate conditions in the past (Tyler et al., 1996)

Based on the results of extensive research, field studies, modeling data, and monitoring data, which are summarized in the Area 5 RWMS PAs (Shott et al., 1998), the alluvium within Area 5 exhibits little spatial variability, and there is no aerially distributed groundwater recharge under current climatic conditions.

2.9.2.2 Saturated Zone

2.9.2.2.1 Regional System

The NTS is located within the Death Valley Regional Flow System (DVRFS), one of the major hydrologic subdivisions of the southern Great Basin. The DVRFS covers an area of about 100,000 km^2 (38,600 mi^2) in Nevada and California (Belcher, 2004). The regional flow system consists primarily of volcanic rock in the west and carbonate rock in the east, and is estimated to transmit more than 86 million m^3 (70,000 ac ft) of groundwater annually. Most of this flow moves through a thick sequence of Paleozoic carbonate rock extending throughout the subsurface of central and southeastern Nevada and is sometimes referred to as the "central carbonate corridor." The three principal groundwater subbasins identified within the NTS region are Ash Meadows, Oasis Valley, and Alkali Flat-Furnace Creek Ranch subbasins. Yucca Flat and Frenchman Flat lie within the Ash Meadows subbasin (Laczniak et al., 1996). Figure 2-9 shows the NTS with respect to these subbasins and general groundwater flow directions.

The Ash Meadows subbasin covers an area of about 10,360 km^2 (4,000 mi^2). Precipitation is believed to recharge the subbasin along its northern boundary at the Belted, Reveille, Timpahute, and Pahranagat Ranges; along its eastern boundary at the Sheep Range; and along its southern boundary at the Spring Mountains. Recharge is also suspected to occur within the subbasin at higher elevations of the Spotted, Pintwater, and Desert Ranges. Groundwater primarily flows through the lower carbonate-rock aquifer and discharges along a line of springs in Ash Meadows. Groundwater flow rates through the different lithologic units of the Ash Meadows subbasin are highly variable. Estimates range from less than 0.3 to more than 300 m per day (1 to 1,000 ft per day), depending on the unit. In general, the regional carbonate-rock aquifer is believed to transmit water at the fastest rate; whereas, the basement and Eleana confining units transmit water at the slowest rate, and volcanic and valley-fill aquifers and confining units transmit water at intermediate rates (Laczniak et al., 1996).

The lower carbonate-rock aquifer within the Ash Meadows subbasin is the only subsurface pathway by which groundwater leaves Yucca Flat and Frenchman Flat basins. Groundwater flows south from Yucca Flat into Frenchman Flat and then southwest toward down-gradient areas (primarily Ash Meadows). Water levels within the lower carbonate-rock aquifer indicate that the gradient is nearly flat (less than 0.3 m/km [1.6 ft/mi]) between Yucca Flat and Frenchman Flat and down to the discharge Area at Ash Meadows. This flat gradient is an indication of a high degree of hydraulic continuity within the aquifer, which is probably a result of a high fracture (secondary) permeability (Laczniak et al., 1996).

Based on the existing data, and as interpreted from a regional groundwater flow model (DOE, 1997b), the overall groundwater flow direction in Yucca Flat and Frenchman Flat is to the south-southwest. Groundwater ultimately discharges at Ash Meadows and Franklin Lake Playa to the south and Death Valley to the southwest.

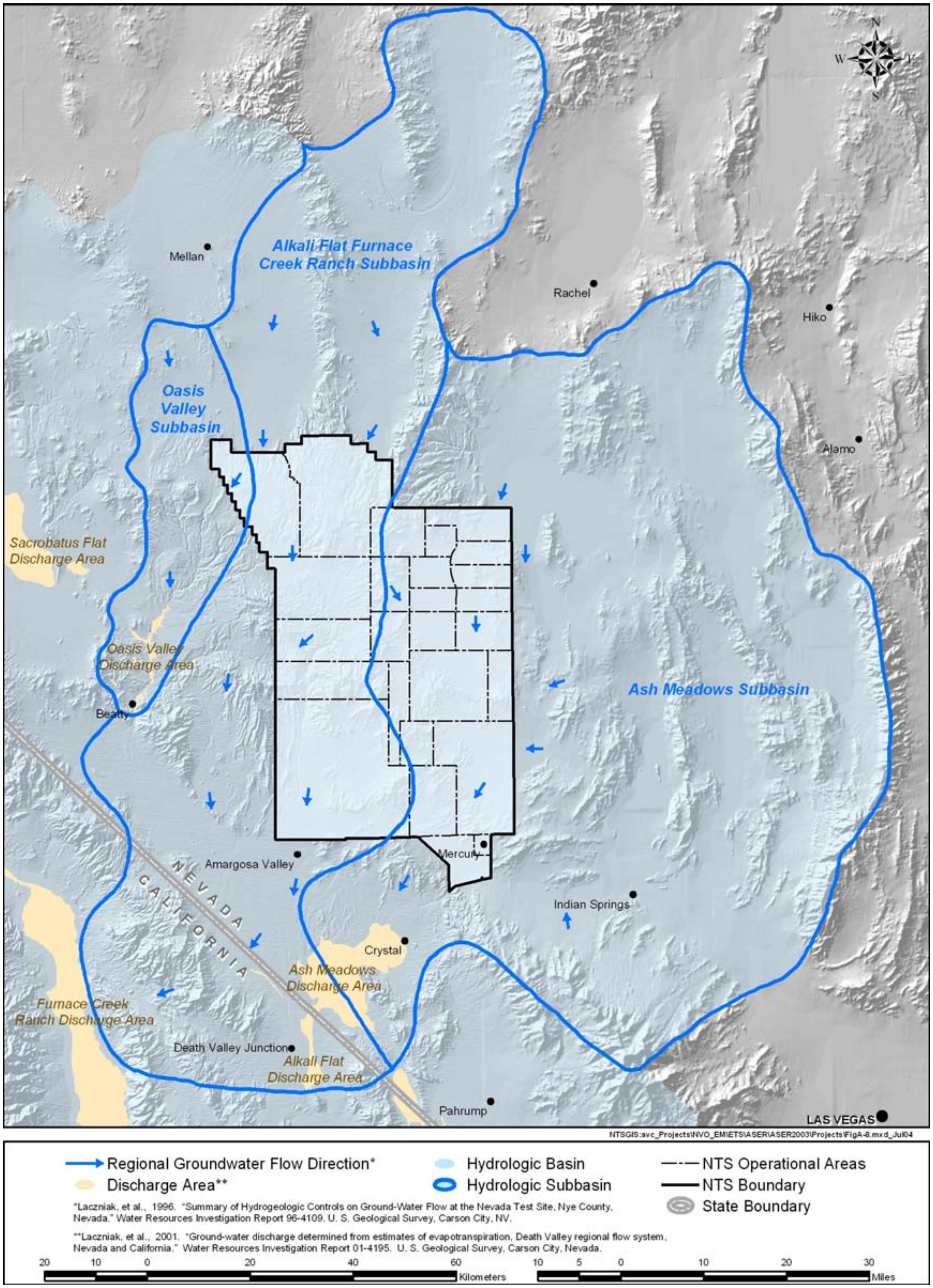


Figure 2-9. Hydrologic Subbasins.

2.9.2.2.2 Local Groundwater System

In the area of Frenchman Flat there is essentially a three aquifer system: alluvial aquifer, volcanic aquifer (welded and vitric tuff aquifers that are particularly important at the northern part of the basin) and the regional lower carbonate aquifer (LCA). Alluvium overlies the interconnected alluvial aquifer and volcanic aquifers, which are separated from the deeper LCA by low permeability confining units. Figure 2-10 presents a schematic regional cross-section, of the west-east profile through the location of Well ER-5-3#2, which is about 2,500 m (8,200 ft) northeast of the Area 5 RWMS. The profile was generated from a hydrostratigraphic model of the region (BN, 2005a).

The depth to the static water level in Frenchman Flat ranges from 210 m (690 ft) near the central playa to more than 350 m (1,150 ft) at the northern end of the valley. In the deeper, central portions of the basin, more than half of the alluvium section is saturated. From March 1993 through 1997, groundwater levels were measured frequently and on an irregular schedule at the three pilot wells surrounding the Area 5 RWMS. Since 1998, groundwater levels have been measured quarterly. Groundwater elevation measurements indicate the water table is essentially flat with a calculated groundwater velocity of less than 10 cm/yr (NSTec, 2008b). Sampling data from the pilot wells indicate the groundwater is sodium bicarbonate type water and has not been impacted from Area 5 RWMS disposal operations.

Water-level data for the LCA in the southern part of the NTS are limited, but indicate a fairly low gradient in the Yucca Flat, Frenchman Flat, and Jackass Flats area. This gentle gradient implies a high degree of hydraulic continuity within the aquifer, presumably due to high fracture permeability (Laczniak et al., 1996). Furthermore, the similarity of the water levels measured in Paleozoic rocks (LCA) in Yucca Flat, Frenchman Flat, and Mercury Valley implies that, at least for deep interbasin flow, there is no groundwater barrier among the three basins. Inferred regional groundwater flow through Frenchman Flat is to the south, turning southwest in Mercury Valley toward discharge areas in Ash Meadows. An increasing westward flow vector in southern NTS may be due to preferential flow paths subparallel to the northeast-trending Rock Valley fault zone (Grauch and Hudson, 1995) and/or a northward gradient from the Spring Mountain recharge area (International Technology Corporation [IT], 1999a; 1999b).

At the NTS, localized perched water occurs principally within the tuff and lava aquitards in the foothills and ridges flanking the basins. Perched water is not known to occur beneath Frenchman Flat (Shott et al., 1998).

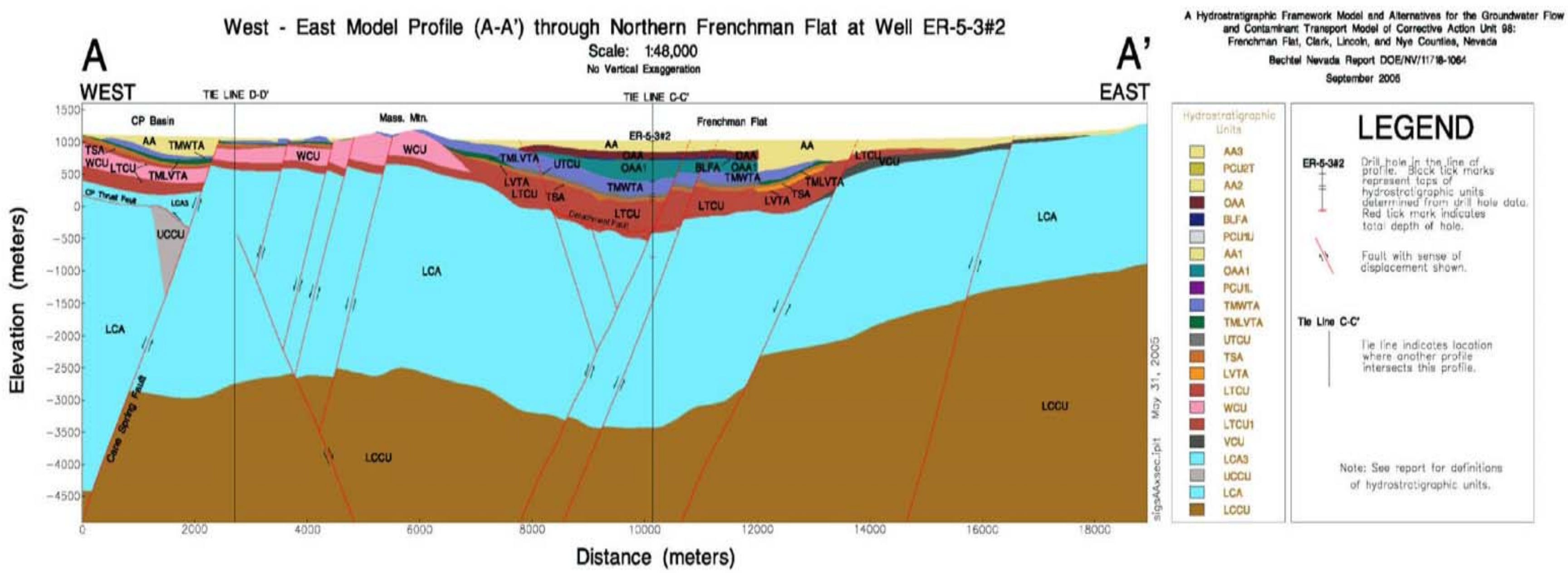


Figure 2-10. Regional Cross-Section of Northern Frenchman Flat.

2.10 GEOCHEMISTRY

Three types of groundwater chemistry facies dominate the region: (1) a calcium-magnesium bicarbonate (Ca-Mg-HCO_3) facies within the carbonate units, (2) a sodium and potassium bicarbonate (Na-K-HCO_3) facies derived from groundwater in volcanic rocks, and (3) a mixed facies containing components from both (1) and (2). The Ca-Mg-HCO_3 composition (1) is found within the Paleozoic carbonate units, such as the LCA and the valley-fill aquifers that are composed of carbonate detritus. Most of the calcium and magnesium present is from the dissolution of limestone and dolomite ($CaCO_3$ and CaMg $[CO_3]_2$) mineralization in the unit as it conducts flow. The Na-K-HCO_3 facies (2) is found within the lava-flow aquifer and tuff-aquitard units. The facies also is seen in portions of the valley-fill aquifer, where a major portion of the alluvial-fill material has been derived from the erosion of volcanic units. Water of the mixed facies (3) contains portions of both the Na-K and Ca-Mg ions groups (Chapman, 1994; Winograd and Thordarson, 1975).

2.10.1 Soil Geochemistry

The geochemistry of the native alluvium affects the transport of radionuclides by affecting their solubility and sorption characteristics. The alluvium is dominated by quartz, feldspar, and cristobalite, with calcite, gypsum, and minor amounts of clays and zeolites. Measured pH values range between 7 and 9, indicating neutral to alkaline conditions (Cochran et al., 2001). The presence of clays and zeolites in an alkaline environment generally inhibit the mobility of radionuclides. The geochemical environment of the closure cover is anticipated to be largely determined by the geochemistry of the constituent alluvium.

2.11 NATURAL RESOURCES

Exploration and exploitation of natural resources near the RWMSs potentially could have an impact on closure and monitoring over both the short- and long-terms. A natural resource is economically viable if it is available in sufficient quality and quantity and a demand for the resource exists. Four potentially viable resources are identified for the NTS: sand and gravel, minerals, hydrocarbons, and water. A detailed evaluation of the resources near the RWMS is provided in the assurance requirements document for the GCD PA 40 CFR 191 compliance, in preparation. It is determined that the Area 5 RWMS was not sited near any significant economic mineral deposits, viable petroleum or natural gas deposits, valuable geologic formations, or irreplaceable sensitive water supplies.

The Area 5 RWMS is located on alluvial fans composed primarily of sand and gravel. Most sand and gravel is used for road base, building pads, and other fill structures. Construction of closure covers may require a relatively large volume of sand and gravel, derived from within the RWMS. Exploitation of sand and gravel from near the RWMS for other than local use is unlikely because the gravels are composed largely of silicic volcanic rocks, which tend not to be durable. Additionally, good quality sand and gravel are generally available elsewhere.

Four mining districts are present on the NTS: Calico Hills, Oak Spring, Mine Mountain, and Wahmonie. Of these four districts, Calico Hills is considered to be sufficiently distant from Yucca Flat and Frenchman Flat to not impact the RWMS significantly if the district should be developed.

The Oak Spring district is in northern Yucca Flat, the Mine Mountain district is in southwestern Yucca Flat, and the Wahmonie district is in Jackass Flats. The Oak Spring district is considered to have moderate potential for tungsten, and silver may be present (Science Applications International Corporation/Desert Research Institute, 1991). Although economic deposits of silver and gold were extracted from the Mine Mountain and Wahmonie districts, the current economic potential for these districts is uncertain (Richard-Haggard, 1983; Gustafson et al., 1993). Overall, especially considering that DOE anticipates institutional controls over the NTS for the foreseeable future, the probability of mineral exploration and exploitation that would impact the RWMS is low.

The potential for oil and natural gas in southern Nye County is thought to be low (Garside et al., 1988; Castor et al., 1990). Trexler et al. (1996), however, suggest a “cautiously optimistic view of the hydrocarbon potential” for the NTS and surrounding area based on the occurrence of thrust plates that provide potential reservoir space and a favorable thermal history. Studies in southern Nye County and the NTS do not indicate the presence of coal, tar sand, or oil shale (Gustafson et al., 1993).

Groundwater under the NTS is generally acceptable for drinking water and industrial and agricultural uses (Chapman, 1994). Industrial and agricultural uses currently are precluded because of land use and institutional controls over the NTS into the foreseeable future. Human consumption of water has the greatest probability for impacting the RWMS. Such impact is unlikely to occur in the near term because current demand is low, the cost of extracting water from below Frenchman Flat is high, and water is available from other sources.

2.12 FACILITY CHARACTERISTICS

Information on facility characteristics (engineered features and their effectiveness) that are important to implementation of closure activities and the long-term performance of the disposal system are discussed below. Facility characteristics are discussed in detail in the PAs for the Area 5 RWMS (Shott et al., 1998; BN, 2006). The LLW PA evaluated the post-closure performance of the Area 5 RWMS assuming a closure cover of 4 m (13 ft), made of a monolith of native alluvium. PAs also demonstrated that the DOE O 435.1 performance objectives can be met with only operational covers over the waste (2.4 m [8 ft]). An ALARA [as low as reasonably achievable] optimization will be performed to determine the final closure cover thickness. The closure cover, which is the primary closure design feature, is discussed below in terms of water infiltration, disposal unit cover integrity, and its stability and effectiveness as a barrier against intrusion.

2.12.1 Water Infiltration

The monolayer-ET cover will reestablish the natural desert conditions that have controlled and eliminated recharge at the site for at least the last 10,000 years. Under natural conditions, rainfall on Mojave Desert valleys infiltrates at most a few meters into the ground and then is evapotranspired back to the atmosphere. Recharge occurs along the edges of mountain ranges and in drainage channels near mountain fronts. The chloride accumulation observed below the root zone supports the conclusion that recharge ceased in these areas at the end of the last pluvial period, approximately 10,000 to 15,000 years ago. A 4-m (13-ft) vegetated cover will effectively isolate waste from infiltrating precipitation. Transpiration by desert plants is believed to be essential for maintaining current water balances. The monolayer-ET cover will be revegatated with native plant species.

Localized infiltration may also occur if storm run-on is captured by depressions on the site cover. Previous studies have shown that a 100-year flood zone occurs along the southwest border of the Area 5 RWMS and that the operationally active area of the site is not located within the flood zone. The site is currently protected from a 25-year, 24-hour flood event by engineered berms, levee extensions, and flood control channels. Construction of closure covers above grade has also been identified as a design feature mitigating the potential for infiltration of run-on. Closure covers will be constructed above grade and contoured to reduce infiltration of storm water runoff.

2.12.2 Disposal Unit Cover Integrity

The integrity of operational covers at the Area 5 RWMS will be monitored and maintained during the operational period. The monitoring program documents and repairs all subsided areas.

After the period of active institutional control, closure cover integrity will be affected by plant rooting, animal burrowing, erosion, and subsidence. The assumed effect of plant rooting and animal burrowing is to increase the porosity of surface soils. Previous calculations indicate that erosion over 1,000 years should be negligible (Shott et al., 1998; DOE, 1998) and that the Area 5 RWMS is in an area of accumulating sediments. Subsidence occurring after institutional control is assumed to cause the formation of local depressions in the closure cover. Cracks caused by subsidence are expected to be infilled naturally by intergranular movement of unconsolidated alluvial soils used for the final closure cover.

2.12.3 Structural Stability

Wastes disposed at the Area 5 RWMS are expected to subside over time. Voids within waste containers, uncompacted waste, voids between waste containers, and decomposition of organic material are all expected to contribute to the subsidence potential. A previous analysis of subsidence concluded that maximum settlement at the Area 5 RWMS could range from 1.8 to 5.5 m (5.9 to 18 ft) (DOE, 1998). Wooden boxes and steel drums are expected to be 75 percent degraded by the end of the 100-year period of site maintenance. Steel boxes have the longest expected lifetime, being only 20 percent degraded at 100 years.

Most subsidence is expected to occur and be repaired during active site maintenance. The monolayer-ET cover includes no engineered or layered features that will be disrupted by subsidence. Subsidence occurring after active institutional control is expected to have a minimal impact on site performance. A 4-m (13-ft) thick cover should remain above grade with the limited subsidence expected after institutional control. Cracks formed by subsidence should be filled by the intergranular movement of unconsolidated alluvium used in cover construction.

2.12.4 Inadvertent Intruder Barrier

Current NNSA/NSO land-use plans are to limit access to the NTS in perpetuity. Construction and drilling within the Area 5 RWMS will be permanently restricted. In the event that institutional controls become ineffective, site conditions are expected to continue to deter intrusion. Site conditions making inadvertent human intrusion (IHI) unlikely include physical evidence of underground nuclear testing, lack of attractive resources, and the great depth to groundwater.

A Bayesian analysis using the opinions of subject matter experts (SMEs) has been used to estimate the probability of intrusion at the Area 5 RWMS (BN, 2001). Two types of intrusion events were evaluated: drilling for groundwater, and excavation of a basement, septic tank, or swimming pool during construction of a residence on the site. The probability of a borehole or a construction excavation penetrating a waste disposal unit is documented in the GoldSim® model.

The SMEs also considered the effectiveness of intruder barriers including placards, markers, surface barriers, and subsurface barriers. The SMEs concluded that cost-effective intruder barriers were not available. The SMEs believed that placards and markers would not be understood for 1,000 years and effective physical barriers would be too costly to install.

The closure cover design does not include intruder barriers because active institutional control is planned in perpetuity, site characteristics render intrusion a low probability event, and barriers are unlikely to be cost-effective. The TRU waste disposed in GCD boreholes before September 26, 1988, is regulated under 40 CFR 191, which has regulatory requirements for the use of natural and engineered barriers. The closure program will evaluate what barriers are required and necessary for TRU wastes.

2.13 WASTE CHARACTERISTICS

Radiological waste from the DOE Complex is accepted at the NTS for disposal. Discussion below describes the containers, any treatment or processing prior to disposal, and the inventory of wastes.

2.13.1 Waste Containers

Containers disposed at the Area 5 RWMS are categorized as boxes, drums, or nonstandard. Cardboard, octagonal “tri-wall” boxes were commonly used prior to the mid-1980s. These cardboard boxes were 0.6 or 1.2 m (2 or 4 ft) high and banded to wooden pallets with steel strapping. Waste was contained in plastic bags inside the cardboard boxes. These boxes were stacked as close to each other as the underlying pallet allowed and were susceptible to crushing if stacked too high. Plywood boxes came into wide use thereafter and range in size from 0.6 m (2 ft) high, 1.2 m (4 ft) wide, and 2.1 m (7 ft) long to 1.2 m (4 ft) high, 1.2 m (4 ft) wide, and 2.1 m (7 ft) long. Runners are typically attached to the bottom of the box to facilitate handling with a forklift. Steel boxes became popular in the 1990s. These boxes have standard sizes similar to those of plywood boxes. Steel runners or slots for handling with a forklift are typically part of the box design. Both the cardboard and steel boxes are stacked as close to each other as practicable; typically, several inches separate adjacent boxes.

Steel drums in various sizes have been used for disposal at the Area 5 RWMS. Standard 209-liter (L) (55-gallon [gal]) drums and 315-L (83-gal) overpack drums are common; less commonly used are six-drum overpack containers. Drums are stacked vertically on pallets in Pit P09U. Containers other than standard-sized boxes and drums are nonstandard. Many nonstandard containers have been disposed and include unusual shapes or nonstandard-sized boxes or drums. Nonstandard containers are typically stacked to make best use of available pit volume. Figure 2-11 and Figure 2-12 show P01U1 and P02U in operational status, respectively. Waste containers and stacking geometries shown are representative of historic practices.

Figure 2-11. P01U in operational status.

Figure 2-12. P02U in operational status.

2.13.2 Treatment or Processing Prior to Disposal

Treatment or processing of waste is conducted by the waste generator prior to shipment to the RWMS for disposal. Generators desiring to ship waste to the NTS must have their waste certification program and waste stream(s) approved by NNSA/NSO. A waste stream is described on a waste profile. In addition to a description of the waste, a waste profile includes a description of the waste generation processes and an estimate of the low and high activity concentration of significant radionuclides. Approval to ship is granted on a waste-stream-specific basis once a generator's certification program has been approved. Waste shipped to the NTS for disposal must meet the requirements of the Nevada Test Site Waste Acceptance Criteria (NTSWAC) (DOE, 2008). Information on characterization of radiological waste is reported to the site operator, generally electronically, for entry into the site inventory at the time of shipment.

2.13.3 Waste Inventory

Waste inventories for the radionuclides and hazardous materials are provided below.

Waste inventory has been well established through numerous historical studies conducted to support the compliance assessments of the facility under DOE O 435.1, and closure and monitoring activities. Uncertainty of the inventory was addressed by utilizing bounding estimates in the original PA, and treated probabilistically in the second addendum to the PA. As the sensitivity analyses performed in the PAs show, the inventory is insensitive as far as the long-term performance of the facility is concerned because of limited releases of waste from the waste zones in the disposal cells to the atmosphere above the disposal cells. The sections below discuss historical disposal practices and provide information regarding data archives and data warehousing efforts. They also describe the GoldSim® inventory model developed for the Area 5 RWMS, which is updated annually as new waste disposal occurs.

Waste has been accepted at Area 5 since January 1960 and placed in disposal cells since January 1961. The oldest records for the original Sugar Bunker Dump generally show load origin, a brief description of the material and containers, estimated radioactivity, and date of disposal. When necessary, a specific trench or pit can be inferred from burial date and history of the development of the disposal features. The original paper records were scanned into a digital format and then archived. The quality of some of these scanned images is poor, and some of the data are difficult to read. There is also uncertainty as to the completeness of the scanned records.

The Radioactive Waste Management (RWM) System was developed in 1988. The RWM System tabulated basic information on a per-shipment basis for waste received from August 13, 1974, through 1992. The RWM System had design flaws, typical in early databases due to limited programming capabilities, which resulted in inconsistent entries, incomplete records, and the creation of orphan records due to poor interrelationships between the master tables and detail tables. Users of the system could modify, delete, and add data in sub-tables without changing, deleting, or adding records to the master table.

After September 30, 1992, the Low-Level Waste Information System (LWIS) Oracle application was implemented. Data in this database were stored in a single record, indexed by package. The level of characterization and burial location detail improved. Burial location was provided based on an alphanumeric grid. The tier and location within the cell were recorded. The Oracle relational database structure of the LWIS prevented some of the quality and orphan data problems that plagued the RWM System. The web applications used by generators and waste operations personnel to input data also had built-in validation features to reduce errors in the database. Bar-coding and scanning systems were implemented to facilitate package tracking.

In May 1997, the NTSWAC system, an enhancement to LWIS, was implemented. The improved waste-tracking system accepts multiple waste profiles, includes more detailed information on waste form and treatment, and is the system currently in use.

To document and improve the accuracy of the historic waste inventory for 1961 through 1978 and make the scattered information more usable, several historic tracking systems, including paper records and previously scanned records, were reviewed and cross-checked. The waste disposal data were incorporated into one searchable spreadsheet. Chemical hazards were not routinely profiled before landfill regulations and RCRA were implemented; therefore, the presence of hazardous constituents and suspected hazardous constituents, and consequently the classification of some waste in these trenches as being potential mixed waste, was inferred from general waste descriptions, historic photographs, and other sources. The early RWM System database covering waste disposal from the mid-1970s through 1992 was also checked and cross-checked with other documentation to attempt to verify the locations, volumes, and characteristics of the wastes disposed.

Table 2-4 provides information on waste and material buried at the Area 5 RWMS from 1961 through December 2004. These data are from three sources: scanned paper records, the RWM System database, and the LWIS database, with slightly overlapping periods of record. The waste tracking systems have no data regarding classified material deposited at some of the classified disposal cells and very limited data at other classified disposal cells.

Table 2-4. Waste Status of the 92-Acre Area Units.

Disposal Unit	First Record	Last Record	Recorded Volume (ft^3)†	Curies	Operational Status	Contents
P01U	20-Sep-78	25-Apr-85	1.6E+06	2.6E+06	Operationally Closed	LLW, lead, lead shielding, barium source, organic solvents
P02U	18-Dec-84	19-Nov-95	8.9E+05	2.0E+05	Operationally Closed	LLW, lead, lead shielding, barium source, organic solvents
P03U	18-Sep-85	17-Jul-08	1.5E+06	1.4E+05	Active	MW (RCRA permitted)
P04U	14-Jun-88	25-Oct-95	2.5E+06	1.2E+05	Operationally Closed	LLW
P05U	15-May-95	27-Sep-07	2.2E+06	2.2E+06	Operationally Closed	LLW
P06U/P06UA	3-Dec-04	7-Feb-08	5.0E+05	4.0E+02	Active	Asbestiform LLW
P07U	15-Sep-97	10-Feb-03	1.8E+05	6.6E+01	Operationally Closed	Asbestiform LLW
P09U	10-Dec-03	9-Oct-07	2.7E+05	2.9E+04	Active	LLW
P11U	27-Jan-04	5-Apr-05	1.2E+05	2.9E+04	Operationally Closed	LLW
T01U	7-Jan-61	29-Jun-65	2.9E+04	8.9E+00	Operationally Closed	LLW, lead bricks, lead shielding, cadmium, chromium, mercury, organic solvents

Disposal Unit	First Record	Last Record	Recorded Volume (ft^3)†	Curies	Operational Status	Contents
T02U	5-Jul-72	5-May-78	3.5E+04	2.8E+00	Operationally Closed	LLW, organic solvents, lead
T03U	2-Mar-92	10-Sep-92	2.4E+04	2.1E+00	Operationally Closed	LLW
T04U	25-Feb-70	29-Nov-77	5.1E+04	3.3E+06	Operationally Closed	LLW, organic solvents, lead shielding, mercury
T06U	1-Jul-65	25-May-70	1.7E+05	1.3E+04	Operationally Closed	LLW, laboratory waste containing lead, cadmium and mercury, organic solvents, lead bricks
T07U	16-May-78	22-Sep-78	1.1E+05	5.3E+05	Operationally Closed	LLW
T01C	10-Oct-65	19-May-76	1.8E+04	2.1E+03	Operationally Closed	LLW, lead
T02C	7-Nov-88	22-Jul-93	6.0E+04	1.4E+02	Operationally Closed	LLW
T03C	26-Aug-69	10-Dec-76	2.5E+04	2.0E+03	Operationally Closed	LLW, organic solvents, chromium, lead
T04C/T04C-1	12-Dec-85	3-Aug-95	6.4E+04	1.7E+03	Operationally Closed	LLW, TRU (2.6 pounds TRU inadvertently disposed in T04C in 1986)
T05C/T06C	31-Jan-74	31-Jan-74	2.0E+03	0.0E+00	Operationally Closed	LLW, organic solvents
T07C/T08C	14-May-01	23-Apr-03	6.6E+05	2.5E+03	Operationally Closed	LLW
T09C	3-Aug-95	31-Oct-02	4.4E+04	7.1E+04	Operationally Closed	LLW
Unknown	30-Jun-70	15-Nov-90	1.8E+06	2.7E+05	-	-
Total	**7-Jan-61**	**18-Dec-07**	**1.4E+07**	**9.5E+06**		

Disposal Unit	First Record	Last Record	Recorded Volume (ft^3)†	Curies	Operational Status	Contents
GCDT	15-Dec-83	6-Mar-84	5.8E+02§	5.3E+05	Operationally Closed	LLW
GCD-01C	1984	1984	1.4E+03§	1.8E+02	Operationally Closed	TRU, lithium deuteride (may contain melted high explosives, lead, mercury)
GCD-02C	1984	1984	9.8E+02§	1.0E+03	Operationally Closed	TRU (may contain melted high explosives, lead, mercury)
GCD-03C	1984	1984	1.9E+02§	1.1E+02	Operationally Closed	TRU (may contain melted high explosives, lead, mercury)
GCD-04C	19-Jul-85	14-Jan-87	1.3E+03†	6.8E+00	Operationally Closed	LLW, TRU, lithium hydride
GCD-05U	26-Jun-85	9-Apr-87	3.2E+03†	2.1E+06	Operationally Closed	LLW
GCD-06U	16-Jul-86	20-Feb-87	2.4E+02†	6.5E+03	Closed to waste, not yet backfilled	LLW
GCD-07C	7-Jul-89	7-Jul-89	3.8E+02†	1.9E+00	Closed to waste, not yet backfilled	LLW
GCD-10U	11-Dec-87	27-Oct-89	2.0E+03†	6.0E+05	Operationally Closed	LLW
GCD Total	**23-Feb-83**	**27-Oct-89**	**1.0E+04**	**3.2E+06**		

2.13.3.1 Hazardous Waste Inventory

The hazardous waste inventory has been compiled from the best available records for all units that contain hazardous materials. The Pit P03U MWDU and the Asbestiform Unit are permitted units with well-kept records. Waste in the CAU 111 units and the GCD boreholes contain hazardous materials of uncertain quantities. Estimates of hazardous components in these two units are discussed below.

CAU 111 Disposal Units

The CAU 111 disposal units were in operation prior to the implementation of a detailed recordkeeping system. Table 2-5 presents the Sugar Bunker Dump designations, if applicable. Waste was typically disposed in bulk form or containerized in plastic bags, steel drums, and cardboard, plywood, or steel boxes. Waste stream descriptions are limited. Typical waste stream descriptions include laundry wastes, laboratory wastes, scrap metal, contaminated soil, personal protective equipment, and samples.

Material shipped to classified units was typically described only as “classified waste.” Other waste streams include farm wastes from the historic EPA Farm operations, which may have included animal wastes. Many records do not indicate the exact location where the waste was disposed. Analytical waste profiling focused primarily on radioactivity but typically only stated a total curie estimate without identifying specific radionuclides. From process knowledge and general waste descriptions, it can be inferred that some wastes contain hazardous constituents. Approximately 40 percent of available records indicate hazardous constituents may be present; however, the amount of hazardous constituents present in these wastes is unknown.

Table 2-5. CAU 111 Cell Designations.

Current Designation	Sugar Bunker Designation
P01U	none
P02U	none
T01U	Pit No.1
T02U	UF
T04U	UD
T06U	UA
T01C	CA
T03C	CC
T05C	N-HA
T06C	S-HA

Past laboratory operations at the NTS have typically included the use of organic solvents. Waste streams denoting laboratory wastes are therefore assumed to contain an unknown amount of organic solvent. Solvents may include those typically found in laboratories (e.g., toluene, acetone, trichloroethylene, benzene, and carbon tetrachloride). Lead shielding, loose lead, and lead bricks have also been noted in disposal records. Lead shielding is assumed to be present from any record denoting the disposal of radioactive sources.

Table 2-6 presents the known or suspected hazardous constituents present in each CAU 111 disposal unit. Constituents consist primarily of organic solvents and lead. A closure radionuclide inventory was developed based on historic characterization data, assumptions regarding the isotopic composition of uncharacterized waste streams, and estimated waste volumes as described in the PA (BN, 2006). The approach is consistent with the methods used to estimate the pre-1998 inventory and accounts for 100 percent of the estimated waste volumes.

Table 2-6. CAU 111 Hazardous Waste Constituents.

Disposal Unit	Known or Suspected Hazardous Constituents
P01U	lead, lead shielding, a barium source, organic solvents
P02U	lead, lead shielding, a barium source, organic solvents
T01U	lead bricks, lead shielding, cadmium, chromium, mercury, organic solvents
T02U	organic solvents, lead
T04U	organic solvents, lead shielding, mercury
T06U	laboratory wastes containing lead, cadmium and mercury, organic solvents, lead bricks
T01C	lead
T03C	organic solvents, chromium, lead
T05C	organic solvents
T06C	organic solvents

GCD Boreholes

Known hazardous waste in the GCD boreholes includes an estimated 60.5 kilograms of lithium hydride in borehole 4 and 45.0 kilograms of lithium deuteride in borehole 1 (Chu and Bernard, 1991). These exhibit the hazardous characteristic of reactivity. Some of the classified nuclear weapons accident residue (NWAR) waste in boreholes 1, 2, and 3 may contain melted high explosives in the waste matrix. Lead and mercury are also believed to be present in the NWAR waste matrix, which exhibit characteristics of toxicity.

2.13.3.2 Inventory Model

The first attempt to compile the radionuclide inventory in the Area 5 RWMS disposal cells occurred in the early 1990s to support the development of the Area 5 RWMS PA and CA documents (Shott et al., 1998; BN, 2000). The second major review and revision to the inventory estimates occurred in 2004 during the preparation of the addendum to the Area 5 PA (BN, 2006).

To support the addendum, an inventory model was developed using GoldSim® software. The model includes all historic records and accounts for uncertainty of the inventories and volumes of the disposed waste. The Area 5 Inventory Model (currently at version v2.014) estimates the inventory of radionuclides disposed in various virtual disposal units at the RWMS.

The model is implemented in the probabilistic GoldSim® modeling platform, allowing estimation of inventory uncertainty by Monte Carlo simulation. Inventory radioactive decay and ingrowth during the operational period are also handled by native GoldSim® routines for solution of the Bateman equations. Model input data, data sources, assumptions, and methods are documented in notes, comments, hyperlinks, and graphics included within the model.

Inventory records for the Area 5 RWMS are maintained in three sources: the waste management logbook, the Waste Management Database (WMD), and the LWIS. The waste management logbook is a paper record summarizing disposal at the Area 5 RWMS from 1960 until 1978. Beginning in 1976, some disposal records were entered into the WMD, an electronic database in use until 1993. From 1993 until the present, the LWIS has been in use. In addition to the database records, original records sent by the generator, survey records, and receipt records are maintained in an electronic imaging system. Records of disposals regulated under DOE O 435.1 are maintained in the WMD and LWIS.

The data sources have numerous limitations (Shott et al., 1998). Records before 1994 are especially uncertain. Known problems include:

- Waste characterization before 1994 is not complete. Important radionuclides may not have been reported. In early records, radionuclides may not have been identified, and disposal is simply recorded as “curies.” Some records indicate mixtures of radionuclides, such as mixed fission products (MFPs), depleted uranium, enriched uranium, plutonium, or American National Standards Institute (ANSI) plutonium scrap codes (PU51, PU52, or PU57).
- Inventory records are incomplete. Not all disposals were entered into waste management records. This problem occurs more commonly for older records and for classified wastes.
- The pre-1993 relational database tables are not completely populated with data. Consequently, some records in different database tables cannot be linked and retrieved in queries. Detailed review of the database and supporting records in FY 2004 has reduced this problem significantly. It is estimated that there are approximately 3,300 packages that cannot be associated with an inventory. This represents less than 1 percent of the package records.
- The pre-1993 database radionuclide quantity data is recorded by shipment rather than by container. If containers within a shipment were sent to different disposal units, the total shipment inventory would have been recorded as disposed in each unit. This may cause multiple counting of some inventories.

2.13.3.3 Inventory Revisions

The 1998 PA added the activity of a limited list of fission products based on the activity recorded in the database as MFPs or disposed as strontium-90 or cesium-137. The fission product scaling factors were estimated from a literature source of fission yields for fast neutron fission of plutonium-239. The current model assigns activity to individual fission products based on the activity of only MFP or gross activity disposed. The list of radionuclides included and their scaling factors are based on an estimate of the radionuclide composition of the NTS underground testing areas.

The 1998 PA estimated the inventory of unreported uranium isotopes by assuming an isotopic mixture for each generator. The current model assumes that uranium-238 and uranium-235 disposed before FY 1994 were depleted and enriched uranium, respectively. Enriched uranium is stochastically divided for each FY into low and high enrichment fractions. The level of enrichment in each category (i.e., depleted, low enrichment, high enrichment) is selected randomly for each FY. The isotopic composition of each mixture is based on a published empirical relationship between specific activity and enrichment for the gaseous diffusion process. In addition to corrections for uranium isotopes, scaling factors for fission product and transuranic contamination from recycled uranium are estimated from generator estimates.

The 1998 PA estimated the inventory of unreported radionuclides in weapons-grade plutonium disposed as PU52. The current model performs similar revisions, but also includes calculations for PU51 and PU57. The inventory of plutonium-239 disposed before FY 1994 is assumed to represent the activity of PU52 weapons-grade plutonium, and corrections are made for other transuranic radionuclides expected to be present.

Important model inputs are set up as probability density functions (pdfs) representing uncertainty. Input pdfs are repeatedly sampled and propagated through the model to produce a distribution of model results. The model output distributions are well represented by lognormal distributions and are entered into the Area 5 RWMS GoldSim® model as lognormal distributions with the geometric mean and standard deviation of the inventory model outputs.

The assumptions made in the inventory model include:

- Waste disposed from October 1, 1988, through September 30, 2028, is regulated by DOE O 435.1. There is no official closure date for the site. The 2028 closure date is an arbitrary assumption based on an assumed 50-year operational period starting in 1978, when the Area 5 RWMS opened to offsite generators.
- Uncertainty in disposed waste inventories is poorly known. Therefore, waste uncertainty is represented by what is believed to be a conservative distribution. The annual sums of radionuclide activity disposed after October 1, 1988, are assumed to be the median of a lognormal distribution. The 99th percentile of the distribution is assumed to be equal to ten times the median (geometric standard deviation = 2.69).
- Waste disposed before FY 1994 is assumed to be incompletely characterized. Radionuclide disposal rates before FY 1994 are corrected for unreported radionuclides. Activity disposed as gross activity or MFP activity is scaled to estimate individual radionuclide activities by assuming that the mixture has the same radionuclide composition as the NTS underground testing areas (Bowen et al., 2001). The reported gross activity or fission product activity is assumed to be the activity of cesium-137, and all other fission product and activation product activity is scaled from cesium-137. The activity of uranium-238 and uranium-235 disposed before FY 1994 is assumed to be the activity of depleted and enriched uranium, respectively. Scaling factors for other uranium isotopes are based on a published relationship between specific activity and enrichment of uranium for the gaseous diffusion process (DOE, 2001a). Scaling factors for minor contaminants in uranium are estimated from data provided by generators. Plutonium disposed as PU51, PU52, and PU57 are assigned individual radionuclide activities based on isotopic composition of standard plutonium scrap codes (ANSI, 1987) and typical values expected for weapons-grade plutonium.
- WMDs do not include data for all disposed wastes. Some waste shipments were not recorded in the databases. Some database tables are not fully populated, and waste inventories cannot be retrieved by queries. The potential missing waste has been estimated by subtracting the volume of disposed waste retrieved from the databases from the physical volume of filled waste disposal units. The missing volume has been added to the inventory assuming it has the mean concentration of disposed waste. This correction is applied to pre-1988 waste only.
- The volume of future waste is based on estimates provided by waste generators. The concentration of waste in future FYs is assumed to be equal to randomly selected concentrations from past FYs.

2.13.3.4 FY 2007 Closure Inventory Estimate for the Area 5 RWMS

The Area 5 RWMS PA GoldSim model divides the site inventory into three virtual disposal units based on the depth of burial. Most wastes are disposed in the shallow land burial (SLB) disposal unit below a 4-m (13-ft) cover. Wastes capable of producing significant radon-222 (^{222}Rn) flux densities are disposed below thicker covers in two radium disposal units (RaDUs), the lower cell of Pit 6 (P06U) and Pit 13 (P013U). High-specific-activities wastes have been disposed in GCD boreholes. The inventory of the three virtual disposal units is further divided into pre-1988, post-1988 disposed, and future portions.

The FY 2007 estimate of the Area 5 RWMS closure inventory was prepared using the Area 5 Inventory v2.022 GoldSim model (NSTec, 2008a). The model sums past disposals, revisions, and future inventory estimates probabilistically. Stochastic distributions representing uncertainty in annual activity disposed are sampled each FY during operations. Radioactive decay and ingrowth during the operational period are explicitly included in the model. The estimated inventories are decayed until the assumed date of closure on September 30, 2028.

The inventory volume and activity for the SLB are shown in Figure 2-13 and Figure 2-14. The SLB inventory is divided into pre-1988, post-1988, and future inventories (Table 2-7). Closure of the Area 3 RWMS has increased the Area 5 RWMS future SLB inventory and reduced the uncertainty in the future inventory. Previously, the division of future waste between the Area 3 and Area 5 RWMSs was a source of future inventory uncertainty.

Eleven new long-lived radionuclides were disposed in FY 2007. All of these radionuclides have extremely long half-lives and are listed as stable by some nuclear physics databases. Only radionuclides having published dose conversion factors were included in the performance assessment models. Eight radionuclides (^{98}Tc, indium-115 [^{115}In], tellurium-123 [^{123}Te], lanthanum-138 [^{138}La], neodymium-144 [^{144}Nd], samarium-146 [^{146}Sm], ^{147}Sm, and ^{148}Sm) met this criterion. Through FY 2007, these radionuclides have been disposed in insignificant trace quantities. The new radionuclides are tracked in the A5 RWMS Inventory model, but are not implemented in the PA model.

Table 2-7. FY 2007 Estimate of the Area 5 RWMS SLB Inventory.

Nuclide	Pre-1988 SLB		Post-1988 SLB		Future SLB	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
H-3	3.0E+16	1.58	3.2E+16	1.57	3.7E+16	1.89
C-14	2.5E+11	1.59	7.4E+11	1.93	2.0E+11	2.45
Al-26	8.0E+06	1.66	3.7E+04	2.38	*Negligible*	
Cl-36	4.5E+10	1.66	2.2E+08	2.16	5.5E+06	2.77
Ar-39	2.0E+11	1.67	9.8E+08	2.25	0.0E+00	1.01
K-40	1.2E+10	1.60	1.3E+10	1.62	4.2E+09	1.98
Ca-41	3.2E+11	1.66	1.5E+09	2.25	1.2E+05	217
Co-60	2.1E+12	2.22	1.9E+14	2.02	1.3E+14	2.45
Ni-59	8.5E+09	1.64	8.8E+11	1.94	2.4E+11	2.71
Ni-63	6.4E+11	1.66	6.6E+13	2.00	1.6E+13	2.62

Nuclide	Pre-1988 SLB		Post-1988 SLB		Future SLB	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
Se-79	*Negligible*		2.6E+12	2.19	2.2E+10	1867
Kr-85	4.4E+11	2.25	4.8E+09	1.76	1.4E+09	2.44
Sr-90	1.6E+15	3.55	1.9E+15	2.17	6.3E+14	3.22
Zr-93	1.1E+09	1.61	5.1E+07	1.90	3.6E+06	16.0
Nb-93m	1.1E+11	1.66	1.0E+09	2.26	5.4E+06	4.30
Nb-94	2.7E+11	1.68	1.9E+11	2.17	6.2E+10	3.48
Tc-99	1.1E+13	2.29	3.0E+14	1.93	6.1E+13	2.31
Pd-107	4.9E+07	1.60	5.8E+05	1.75	3.1E+04	10.4
Ag-108m	0.0E+00	1.01	6.6E+06	1.96	1.4E+06	2.39
Cd-113m	8.9E+10	1.66	9.0E+08	2.28	1.8E+06	33.9
Sn-121m	2.4E+12	1.66	1.4E+10	2.22	7.6E+04	11.9
Sn-126	4.7E+08	1.60	2.7E+10	2.17	1.2E+09	51.9
I-129	3.5E+07	1.60	2.0E+09	1.61	4.3E+08	2.02
Ba-133	1.7E+08	2.64	1.2E+09	1.93	2.8E+09	2.93
Cs-135	8.6E+08	1.60	2.3E+07	1.86	1.5E+06	14.3
Cs-137	3.6E+15	2.95	7.2E+14	2.28	1.9E+14	2.67
Pm-145	*Negligible*		8.0E+04	2.15	1.6E+04	47.0
Pm-146	*Negligible*		1.1E+05	1.79	5.1E+04	4.19
Sm-146	*Negligible*		4.8E-02	1.64	4.4E-03	7.72
Sm-151	1.0E+12	1.60	1.4E+10	1.75	2.0E+09	2.55
Eu-150	3.6E+11	1.74	2.1E+09	2.59	*Negligible*	
Eu-152	2.5E+12	2.10	4.8E+13	1.96	1.5E+13	2.61
Eu-154	2.9E+11	1.92	3.6E+13	1.97	1.3E+13	2.37
Gd-148	*Negligible*		1.5E+04	1.73	4.8E+03	2.95
Gd-152	1.5E+00	2.17	3.8E+00	1.96	4.8E-01	3.36
Ho-166m	1.1E+10	1.65	5.0E+07	2.27	*Negligible*	
Bi-207	5.7E+05	2.92	1.2E+07	1.98	2.5E+06	2.61
Pb-210	1.1E+12	2.51	4.8E+10	1.51	2.9E+10	1.74
Ra-226	1.4E+12	2.52	6.3E+10	1.55	3.9E+10	1.84
Ra-228	4.5E+10	2.00	5.4E+11	1.51	2.7E+11	1.91
Ac-227	1.1E+10	1.59	3.4E+09	1.37	8.7E+08	1.48
Th-228	5.9E+10	1.74	7.3E+11	1.44	3.0E+11	1.76
Th-229	1.6E+08	1.82	1.1E+09	1.71	1.7E+08	1.79
Th-230	4.0E+10	1.51	2.4E+11	1.69	1.8E+11	2.19

Nuclide	Pre-1988 SLB		Post-1988 SLB		Future SLB	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
Th-232	4.5E+10	2.00	5.6E+11	1.51	3.3E+11	1.91
Pa-231	7.1E+09	1.51	5.0E+09	1.42	1.1E+09	1.48
U-232	1.1E+10	1.64	1.6E+11	1.87	3.5E+10	2.00
U-233	3.4E+10	1.89	3.7E+11	1.82	8.9E+10	1.93
U-234	8.1E+13	1.66	8.4E+13	1.42	2.5E+13	1.51
U-235	3.3E+12	1.68	3.7E+12	1.38	1.3E+12	1.36
U-236	1.2E+12	2.51	2.5E+12	1.52	4.9E+11	1.89
U-238	8.8E+13	1.86	1.4E+14	1.42	5.7E+13	1.46
Np-237	2.1E+11	1.69	1.1E+11	1.66	2.5E+10	2.28
Pu-238	6.1E+12	1.61	5.5E+12	1.57	2.0E+12	1.74
Pu-239	1.3E+13	1.64	1.0E+13	1.61	3.0E+12	1.80
Pu-240	2.9E+12	1.58	4.5E+12	1.78	1.3E+12	2.25
Pu-241	3.4E+12	1.62	2.6E+13	1.98	1.2E+13	2.28
Pu-242	6.4E+08	1.50	4.7E+11	2.20	2.1E+11	3.36
Pu-244	4.9E+09	3.76	4.6E+04	2.13	2.3E+03	19.4
Am-241	3.9E+12	1.50	6.4E+12	1.66	1.8E+12	1.94
Am-242m	*Negligible*		1.5E+09	1.76	3.6E+08	2.19
Am-243	4.3E+08	2.15	2.9E+10	2.22	8.4E+09	3.11
Cm-243	5.6E+09	2.14	3.0E+08	1.85	9.6E+07	2.56
Cm-244	7.4E+10	2.78	4.4E+11	1.91	1.3E+11	2.06
Cm-245	1.4E+05	2.73	3.7E+11	2.06	1.1E+11	3.41
Cm-246	8.3E+04	2.50	6.5E+10	2.21	2.0E+10	2.96
Cm-247	*Negligible*		1.1E+03	2.01	8.2E+01	16.1
Cm-248	8.1E+04	2.59	2.7E+05	2.22	1.9E+04	11.9
Cf-249	*Negligible*		4.8E+07	1.94	1.2E+07	2.42
Cf-250	2.6E+05	2.14	1.2E+05	2.23	6.6E+03	27.4
Cf-251	*Negligible*		7.4E+07	2.06	5.9E+06	16.1
Total	3.6E+16		3.6E+16		3.8E+16	

Negligible – No disposals recorded, inventory assumed to be negligible

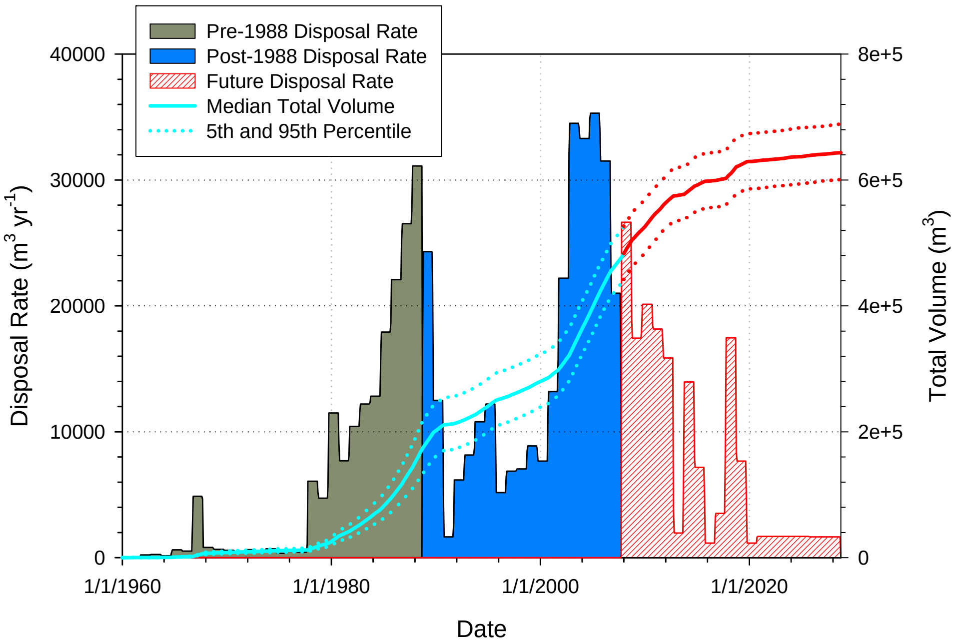


Figure 2-13. Volume Disposed per Year and Median of Cumulative Volume for the Area 5 RWMS Shallow Land Burial Disposal Units.

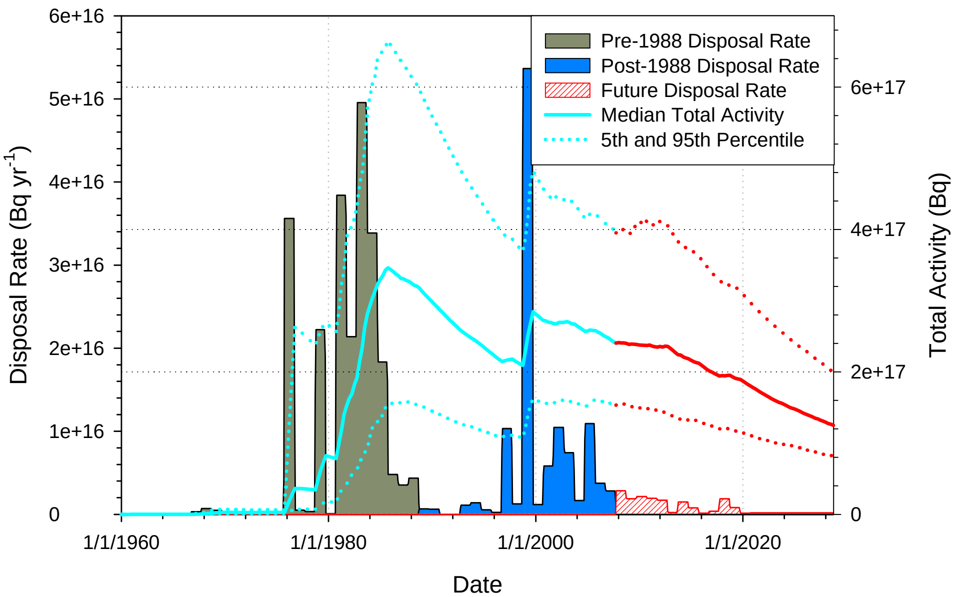


Figure 2-14. Activity Disposal Rate and Median Inventory for the Area 5 RWMS Shallow Disposal Units.

RaDU Inventory

The lower cell of Pit 6 (P06U) and Pit 13 (P013U) were excavated to greater depth to contain thorium wastes that have the potential to generate ^{222}Rn in the future as radium-226 (^{226}Ra) is produced by the decay of ^{230}Th. The inventory of both disposal units is predominately thorium-232 (^{232}Th). The lower cell of Pit P06U was operational from FY 1992 until FY 2002. The Pit 6 inventory remains unchanged from previous years. Pit P013U began operations in FY 2004 with disposal of the Defense National Stockpile Center thorium nitrate waste stream. The entire thorium nitrate waste stream was disposed in FY 2004 and 2005. Pit P013U remains open for disposal of additional radium-bearing waste streams and other low-level wastes. The inventory of wastes disposed in Pit P06U and Pit P013U through FY 2007 are summarized in Table 2-8.

Table 2-8. 2007 Estimate of the Area 5 RWMS RaDU Inventory Disposed.

Nuclide	P06U		P013U	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
H-3	*Negligible*		1.6E+12	2.12
C-14	*Negligible*		1.9E+09	2.15
Co-60	*Negligible*		1.1E+09	2.15
Ni-63	*Negligible*		1.3E+10	2.27
Sr-90	1.8E+07	2.64	2.5E+10	1.85
Tc-99	1.1E+09	2.74	2.5E+10	1.83
Sn-126	*Negligible*		1.5E+07	2.22
Cs-137	*Negligible*		3.1E+11	2.22
Eu-152	*Negligible*		7.3E+10	2.26
Eu-154	*Negligible*		1.6E+07	2.19
Gd-152	*Negligible*		5.0E-03	2.26
Pb-210	6.9E+09	1.67	7.3E+10	1.53
Ra-226	2.0E+10	1.68	1.5E+11	1.52
Ra-228	6.0E+12	1.57	5.5E+12	1.05
Ac-227	2.4E+06	1.89	9.0E+08	2.05
Th-228	5.9E+12	1.57	5.4E+12	1.05
Th-229	5.1E+09	2.21	3.2E+02	1.75
Th-230	1.5E+12	1.69	2.0E+12	2.16
Th-232	6.1E+12	1.58	5.9E+12	1.05
Pa-231	6.4E+06	1.89	1.8E+09	2.02
U-232	*Negligible*		1.9E+08	2.25
U-233	1.9E+12	2.21	3.0E+05	1.74
U-234	1.8E+11	1.88	8.9E+11	2.15

Nuclide	P06U		P013U	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
U-235	9.4E+09	1.89	1.3E+11	2.09
U-236	1.9E+08	2.09	9.4E+09	2.13
U-238	2.1E+11	1.85	5.0E+12	2.18
Np-237	7.9E+05	2.74	3.0E+09	1.74
Pu-238	1.3E+10	1.91	1.3E+09	1.85
Pu-239	3.3E+06	2.23	1.1E+10	1.84
Pu-240	*Negligible*		9.0E+08	1.95
Pu-241	1.1E+10	2.19	1.2E+10	1.79
Pu-242	*Negligible*		4.9E+06	2.13
Am-241	1.0E+09	2.19	5.9E+09	1.93
Am-243	*Negligible*		2.9E+07	2.11
Cm-243	*Negligible*		4.2E+06	2.30
Cm-244	*Negligible*		3.3E+10	2.23
Cm-245	*Negligible*		9.3E+06	2.20
Cm-246	*Negligible*		1.6E+06	2.25
Total	2.2E+13		2.7E+13	

Negligible – No disposal recorded, inventory assumed to be negligible

GCD Inventories

The GCD boreholes have received high specific activity wastes, including TRU waste regulated under 40 CFR Part 191. The GCD boreholes were active from FY 1984 through FY 1991. The PA divides the GCD inventory into pre- and post-1988 portions. The majority of the waste on an activity and volume basis was disposed in the pre-1988 period. The GCD inventories are unchanged from previous years (Table 2-9).

Table 2-9. 2007 Estimate of the Area 5 RWMS GCD Borehole Inventory.

Nuclide	Pre-1988 GCD		Post-1988 GCD	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
H-3	2.0E+16	2.04	1.9E+14	2.25
C-14	7.0E+04	2.56	*Negligible*	
Al-26	2.6E+00	2.64	*Negligible*	
Cl-36	1.5E+04	2.58	*Negligible*	
Ar-39	7.0E+04	2.58	*Negligible*	
K-40	3.9E+03	2.45	*Negligible*	

Nuclide	Pre-1988 GCD		Post-1988 GCD	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
Ca-41	1.1E+05	2.56	*Negligible*	
Co-60	8.6E+11	2.20	*Negligible*	
Ni-59	2.7E+03	2.53	*Negligible*	
Ni-63	2.3E+05	2.60	*Negligible*	
Kr-85	6.1E+04	2.46	*Negligible*	
Sr-90	4.8E+15	3.75	1.1E+08	3.83
Zr-93	3.7E+02	2.46	*Negligible*	
Nb-93m	6.3E+04	2.57	*Negligible*	
Nb-94	8.6E+04	2.59	*Negligible*	
Tc-99	7.4E+09	3.06	6.8E+09	3.75
Pd-107	1.6E+01	2.46	*Negligible*	
Cd-113m	5.7E+04	2.63	*Negligible*	
Sn-121m	9.9E+05	2.58	*Negligible*	
Sn-126	1.6E+02	2.46	*Negligible*	
I-129	8.5E+00	2.46	*Negligible*	
Cs-135	2.9E+02	2.45	*Negligible*	
Cs-137	2.6E+14	3.51	*Negligible*	
Sm-151	3.7E+05	2.46	*Negligible*	
Eu-150	1.5E+05	2.92	*Negligible*	
Eu-152	4.4E+05	2.52	*Negligible*	
Eu-154	9.1E+04	2.52	*Negligible*	
Gd-152	1.1E-07	2.51	*Negligible*	
Ho-166m	3.5E+03	2.65	*Negligible*	
Pb-210	2.3E+12	3.68	4.1E+04	2.20
Ra-226	3.1E+12	3.68	1.3E+05	2.20
Ra-228	1.0E+09	2.85	3.4E-08	3.66
Ac-227	7.2E+10	3.75	5.8E+05	2.27
Th-228	1.0E+09	2.85	2.9E-08	3.65
Th-229	7.9E+01	1.69	5.1E+01	2.16
Th-230	5.3E+07	2.85	1.6E+07	2.20
Th-232	1.0E+09	2.85	5.0E-08	3.66
Pa-231	4.5E+06	2.81	1.4E+06	2.27

Nuclide	Pre-1988 GCD		Post-1988 GCD	
	Geometric Mean (Bq)	Geometric Standard Deviation	Geometric Mean (Bq)	Geometric Standard Deviation
U-232	4.2E+03	2.55	*Negligible*	
U-233	3.8E+04	1.70	2.7E+04	2.16
U-234	1.3E+11	2.83	4.3E+10	2.20
U-235	4.9E+09	2.79	1.6E+09	2.28
U-236	3.4E+08	3.60	5.2E+01	3.66
U-238	3.7E+10	2.31	7.8E+10	2.16
Np-237	2.3E+08	1.73	1.6E+08	2.16
Pu-238	3.0E+11	2.75	3.7E+06	3.69
Pu-239	1.5E+13	2.81	2.1E+08	3.69
Pu-240	3.7E+12	2.74	4.4E+07	3.66
Pu-241	4.2E+12	3.01	6.1E+07	3.91
Pu-242	3.6E+08	2.75	*Negligible*	
Am-241	5.9E+12	2.13	3.9E+07	3.69
Am-243	3.4E+01	2.47	*Negligible*	
Cm-244	7.5E+03	2.48	*Negligible*	
Total	2.5E+16		1.9E+14	

Negligible – No disposal recorded, inventory assumed to be negligible

3.0 TECHNICAL APPROACH TO CLOSURE

This section describes the specific activities that will be conducted to close the facility to meet the requirements of DOE O 435.1 and DOE M 435.1-1 and other applicable requirements. Section 3.1 describes the approach that will be taken to meet each of the performance objectives contained in DOE M 435.1-1 and 40 CFR 191. Section 3.2 describes the specific activities that will be conducted during each phase of closure. Finally, Section 3.3 describes the monitoring activities that will be conducted during each phase of closure.

3.1 COMPLIANCE WITH DOE O 435.1 PERFORMANCE OBJECTIVES AND OTHER REQUIREMENTS

3.1.1 All-Pathways Dose

The Area 5 RWMS PA was approved with conditions by DOE in August 1996 (Shott et al., 1998). The DAS conditions were removed in May 2002 with acceptance of an addendum to the PA (BN, 2001). Under the PA maintenance program, disposal site operations, waste inventories, research and development results, and environmental monitoring results are reviewed annually, and the adequacy of the PA is evaluated. The 2004 annual review concluded that significant changes have occurred since preparation of the Area 5 RWMS PA, and consequently, a second addendum was prepared and accepted without conditions in 2006 (BN, 2006).

The latest update of the Area 5 RWMS closure inventory was done in 2008 using the Area 5 RWMS v4.004 GoldSim® model to assess the continuing validity of PA conclusions. The disposal unit area, disposal unit volume, and waste volumes were updated with FY 2007 data. All disposal units were assumed to be closed with a 4-m (13-ft) thick cover. The model was run assuming an approximately 250-year median period of active institutional control, 100-year period of passive institutional control, and a 1,000-year compliance period. The model was run in GoldSim version 9.6 with 5,000 Latin Hypercube Sampling realizations.

The PA results (both mean and the 95% upper confidence limits of the mean) for the all-pathways dose for all PA MOP scenarios were below the performance objective (Table 3-1). The closure cover, the thickness of which will be optimized for the final design, is the only designed engineered feature to minimize future maintenance and provide long-term stability. There are no additional closure features needed with respect to this performance objective.

The conceptual model of flow and transport for the Area 5 RWMS, and the sensitivity and uncertainty analyses of the PA model are summarized below.

Table 3-1. Area 5 RWMS PA Results for the Member of Public.

Pathway/Scenario	Limit (mSv yr^{-1})	Mean (mSv yr^{-1})	95th Percentile (mSv yr^{-1})	Time of Maximum(yr)
Air Pathway/Transient Visitor	0.1	3.3e-6	NA	100
Air Pathway/Resident	0.1	2.7E-6	6.2E-6	1000
Air Pathway/Resident Farmer	0.1	3.7E-6	8.5E-6	1000
Air Pathway/Open Rangeland (Cane Spring)	0.1	1.8E-9	NA	100
Air Pathway/Open Rangeland (NTS Boundary)	0.1	2.4E-8	NA	100
All Pathways/Transient Visitor	0.25	0.0011	0.0025	1000
All Pathways/Resident	0.25	4.6E-5	1.1E-4	1000
All Pathways/Resident Farmer	0.25	0.0023	0.0066	1000
All Pathways/Open Rangeland (Cane Spring)	0.25	9.2E-4	NA	100
All Pathways/Open Rangeland (NTS Boundary)	0.25	0.0038	NA	100

NA – not available; insufficient non-zero realizations

3.1.1.1 Conceptual Model of Flow and Transport for the Area 5 RWMS

The following discussion of the conceptual model is a summary from the second addendum to the PA (BN, 2006). Further details, including the implementation of the conceptual model in GoldSim® and the analyses performed to identify the sensitivities, are included in the PA.

The 1998 PA model of unsaturated flow in the vadose zone was developed to understand liquid fluxes capable of transporting radionuclides. The model, based primarily on observed water potential and chloride profiles, hypothesized four regions of liquid flow in the vadose zone (Figure 3-1). Zone boundaries are approximate and may vary from location to location within Frenchman Flat where the Area 5 RWMS is located. In Zone I, a near-surface zone approximately 35 m (115 ft) thick, the water potential indicates a potential for upward liquid flux. Zone II, occurring from approximately 40 to 90 m (131 to 295 ft), is a static region with negligible liquid flux. Zone III, an intermediate region with downward liquid fluxes driven by gravity, occurs from approximately 90 m (295 ft) to within a few inches of the saturated zone. The final region, Zone IV, which is a few inches thick, is a transitional zone between the vadose zone and the saturated zone where water potential and flow are negligible.

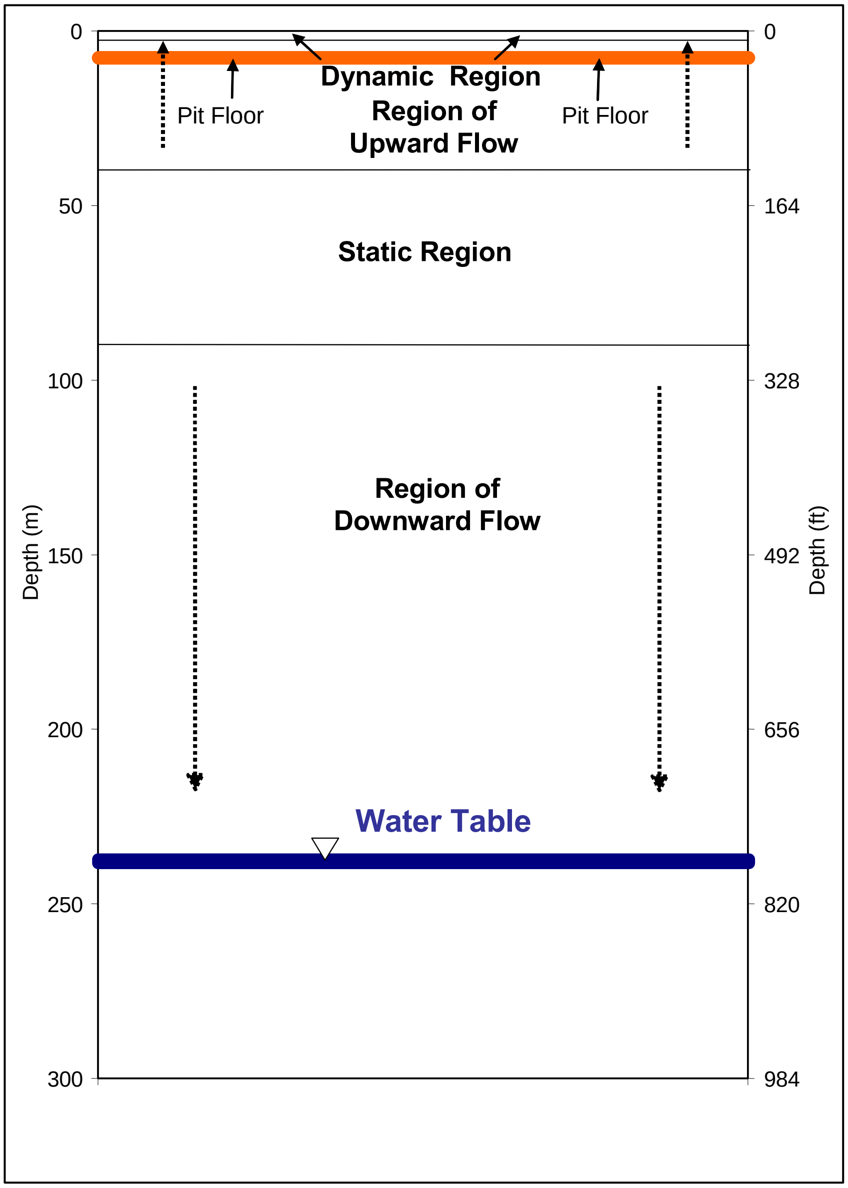
Zone I includes a dynamic region in the upper few feet of the vadose zone where the water potential gradient periodically reverses as precipitation infiltrates and is returned to the atmosphere by evapotranspiration. A strong upward potential for flow is maintained in Zone I by the roots of xeric desert plants. Although there is a potential for upward flow in Zone I, the soil is normally so dry that liquid water advection is very slow. In the very near-surface, where plant roots maintain low moisture contents, upward water movement occurs predominantly in the vapor phase (and through plant roots), and the upward advection of soluble radionuclides may become negligible. The boundary where upward liquid advection rates approach zero is referred to as the no-flux boundary (NFB) in the PA model.

The large accumulation of chloride in Zone I below 2 m (6.6 ft) indicates that transient infiltration events are impeded above this depth and returned to the atmosphere by evapotranspiration.

Assuming a constant atmospheric chloride source and downward liquid advection, the observed near-surface chloride accumulation below the root zone is estimated to require from 10,000 to 15,000 years to form, which corresponds with the end of the last pluvial period, approximately 8,000 to 15,000 years ago (Tyler et al., 1996; Walvoord et al., 2002a).

The chloride accumulated throughout the entire profile at pilot wells UE5PW-1 and UE5PW-3 suggests that infiltration at these locations has not reached the water table for 95,000 to 110,000 years (Tyler et al., 1996). The chloride profile at UE5PW-2 suggests that the sub-root zone chloride bulge was flushed from this profile at some time before 15,000 years ago, indicating that spatially variable recharge occurred during an earlier pluvial period. The chloride profiles in the vadose zone near the Area 5 RWMS suggest that recharge through the alluvium ended after the last pluvial period when the climate became drier and woodlands were replaced by more xeric desert shrubs.

The 1998 PA estimated upward liquid fluxes in Zone I using a process model. The estimated liquid flux, 5×10^{-6} mm/yr, was so low that upward liquid advection of radionuclides was not included in the 1998 PA release and transport model. Diffusion of radionuclides in the liquid phase was considered as an alternative upward release pathway, but was assumed to be negligible at the low water contents observed in the near-surface based on theoretical considerations and literature reports.



Dynamic Region (within Zone I): Magnitude and direction of liquid fluxes are variable and determined by episodic infiltration, evapotranspiration, and processes of biotic transport. NFB at mean depth of 6 ft.

Zone I-Region of Slow Upward Flow: Region where the combination of low precipitation and high potential evapo-transpiration leads to a dry zone, inducing upward flow of pore water in the unsaturated zone from as deep as about 100 ft. Mean upward flux is 0.004 mm/yr.

Waste zone located in region of upward flow.

Zone II-Static Region: Region of no vertical liquid (balance of matric suction and gravitational forces). The thickness and the depth below the surface of this region changes with the physical/textural properties of alluvium and in situ water content.

Zone III-Region of Slow Downward Flow: Region of steady downward flow (increased water contents allow downward drainage). Water in the vadose zone is currently recharging the water table most likely infiltrated during past pluvial climate cycles.

Figure 3-1. Conceptual Unsaturated Zone Flow Model

3.1.1.2 Recent Deep Vadose Zone Research and Development Results

The understanding of how matric potential and chloride profiles develop in thick desert vadose zones has advanced since the 1998 PA. Although conditions in thick vadose zones appear to be stable over long periods, the upward liquid flux in Zone I and the downward liquid flux in Zone III suggest that the system cannot be at steady-state. Previous interpretations of the observed profiles had conceptual inconsistencies. Upward flow in Zone I and downward flow in Zone III cannot be maintained unless there is a water source in Zone II. If the source of water in Zone II is transient surface infiltration, the near-surface chloride accumulation is not expected. The chloride accumulation suggests that recharge is not occurring. However, purely physical models (i.e., without plants) that assume no recharge cannot simulate the large negative matric potentials observed in the near-surface.

Walvoord et al. (2002b) have developed and tested the Deep Arid System Hydrodynamic (DASH) model for thick desert vadose zones that supports the 1998 PA conceptual model and resolves apparent inconsistencies between the observed water gradients and chloride profiles. The DASH conceptual model assumes a constant, strongly negative matric potential maintained below the root zone by desert vegetation, a mean annual geothermal temperature gradient, and allows water vapor movement driven by temperature (thermal vapor flux) and matric potential (isothermal vapor flux). Implementing this model with the finite element heat and mass transfer (FEHM) model, Walvoord et al. (2002b) have shown that matric potential and chloride profiles similar to those observed at the Area 5 RWMS can be maintained at equilibrium. The model identifies water vapor driven upward from the water table by the geothermal temperature gradient as the probable source of water to the deep vadose zone. The water fluxes are extremely small, and the profiles are not currently at equilibrium. Zones II and III are most likely still draining infiltration that occurred during prior pluvial periods.

Using surface boundary conditions for infiltration and root-zone matric potentials based on an 110,000-year paleoclimate reconstruction for southern Nevada, Walvoord et al. (2002a) were able to simulate matric potential and chloride profiles observed at the Area 5 RWMS pilot wells, UE5PW-1, UE5PW-2, and UE5PW-3. Sub-root zone upward liquid fluxes were estimated to range from 2×10^{-5} to 1×10^{-3} mm/yr under the current climatic conditions. The hydraulic response time, the time required for an e-fold ($1–e^{-1}$) change in matric potential from the initial to steady-state profile, was estimated to be 300,000 years for Frenchman Flat, again suggesting that the pilot well profiles are not at equilibrium, but drying very slowly.

3.1.1.3 Recent Shallow Vadose Zone Research and Development Results

A key assumption of the DASH model is that plants maintain a large negative matric potential in the root zone and extract all infiltrating water. Andraski (1997) has investigated water movement in the upper 4.9 m (16 ft) of the vadose zone in the Amargosa Desert. On a vegetated native soil plot, no evidence of water accumulation or percolation below 1 m (3.3 ft) was observed over a five-year period. Non-vegetated plots showed a small increase in water storage and percolation to depths of 1.8 m (6 ft).

The Area 5 weighing lysimeter facility, located approximately 396 m (1,300 ft) southwest of the Area 5 RWMS, has been continuously recording water storage in two 2-m (6.6-ft) deep precision weighing lysimeters since March 1994. One lysimeter has been revegetated with native plants, and the other is maintained bare. No increase in water storage has been observed for the vegetated lysimeter. Early increases in water content for the vegetated lysimeter were caused by irrigation performed to establish native plants. The bare lysimeter shows a slowly increasing trend in water storage. Although water has never been observed to drain from the bottom of either lysimeter, it is likely that a small fraction of infiltrating precipitation will eventually drain from the bare lysimeter (BN, 2005b).

Water content in the near-surface has also been monitored at the Area 5 RWMS since 1995. Water content monitoring began with neutron moisture measurements in boreholes at Pit P03U. Beginning in 1998, automated water content monitoring systems using time-domain reflectometry (TDR) were installed in the operational cover and floor of Pit P03U and Pit P05U in the cover of Pit P04U, and outside the Area 5 RWMS near UE5PW-1. With the installation of the automated TDR system, neutron moisture logging has been discontinued.

Automated TDR moisture content monitoring in the weighing lysimeter indicates that wetting fronts penetrate a short distance in the vegetated lysimeter before being evaporated. Wetting fronts, including some occurring during the particularly wet fall of 2004, are not observed to penetrate below 1.3 m (4.3 ft) in the vegetated lysimeter. Percolation to greater depths may occur in unvegetated areas, including operational covers at the Area 5 RWMS. Wetting fronts from the fall of 2004 have been observed to penetrate to a depth of 1.5 m (4.9 ft) at Pit P03U and Pit P04U (BN, 2005b). Monitoring systems installed below Pit P03U and Pit P05U continue to show constant water contents, indicating that no water has percolated through the waste.

3.1.1.4 Current Vadose Zone Conceptual Model

The vadose zone conceptual model implemented in the Area 5 RWMS GoldSim® model is similar to the 1998 PA model. The mathematical implementation of the model in the Area 5 RWMS GoldSim® model includes a number of refinements and additional detail for the shallow vadose zone. Both models assume Zone I has a potential for upward transport of soluble radionuclides by upward liquid advection and diffusion in the liquid phase. The 1998 PA assumed that the upward liquid flux and liquid diffusion rate were negligible in Zone I. The Area 5 RWMS GoldSim® model divides Zone I into two regions with different upward liquid fluxes. Above the NFB, assumed to be at a mean depth of 2 m (6.6 ft), upward liquid flux is assumed to be zero. Below the NFB, a pdf of upward liquid fluxes is assumed. Complete documentation of the vadose zone conceptual model is found in the Area 5 RWMS GoldSim® model and its references.

Upward liquid fluxes cannot be directly measured under the dry conditions at the Area 5 RWMS. Since preparation of the 1998 PA, upward water fluxes ranging over nearly six orders of magnitude have been estimated by several different modeling methods. Water balance and stable isotope methods have produced the highest estimates ranging from 0.1 to 1 mm/yr (Tyler et al., 1999). Physical models of liquid flow have produced lower estimates ranging from 5×10^{-6} to 0.2 mm/yr (BN, 2001; Shott et al., 1998). The Area 5 RWMS CA (BN, 2001) and Area 3 RWMS PA/CA used a mean water flux (vapor and liquid flux) of 0.3 mm/yr and 0.2 mm/yr, respectively, estimated using stable isotope methods (Chapman, 1995; 1997).

Although each of these methods has its advantages and disadvantages, the physical models are considered to give the most reliable estimates. The water balance and stable isotope methods are suspected to produce overestimates because they calculate average rates over long time intervals when rates were likely changing. The stable isotope method assumptions may also be violated as applied at the Area 5 RWMS (Wolfsberg and Stauffer, 2003). The physical model results are uncertain because of uncertainty in the unsaturated hydraulic conductivity at low moisture contents. Unsaturated hydraulic conductivities are difficult to measure at the low Area 5 moisture contents. Most past efforts to estimate upward liquid fluxes with physical models have used unsaturated hydraulic conductivities predicted from moisture retention data.

The simulations of Wolfsberg and Stauffer (2003) are assumed to be the best available estimate of upward liquid flux. Their simulations consider a full range of surface boundary conditions and material properties, including unsaturated hydraulic conductivities measured at expected water contents. The 32 realizations of upward liquid flux from the Wolfsberg and Stauffer (2003) simulations were used to develop an upward liquid flux pdf for the Area 5 RWMS GoldSim® model. The development of the upward liquid flux pdf is documented in the Area 5 RWMS GoldSim® model and its references.

3.1.1.5 Conceptual Model of Transport

The transport conceptual model is shown in Figure 3-2. The release of contaminants from the shallow waste zones is primarily due to plant uptake, animal burrowing activity, liquid advection and diffusion. Once transported to the ground surface, potential transport mechanism for the particulates is due to wind and water erosion.

These conceptual models have been numerically implemented using the GoldSim modeling platform in the PAs of the LLW and TRU waste in the GCD boreholes.

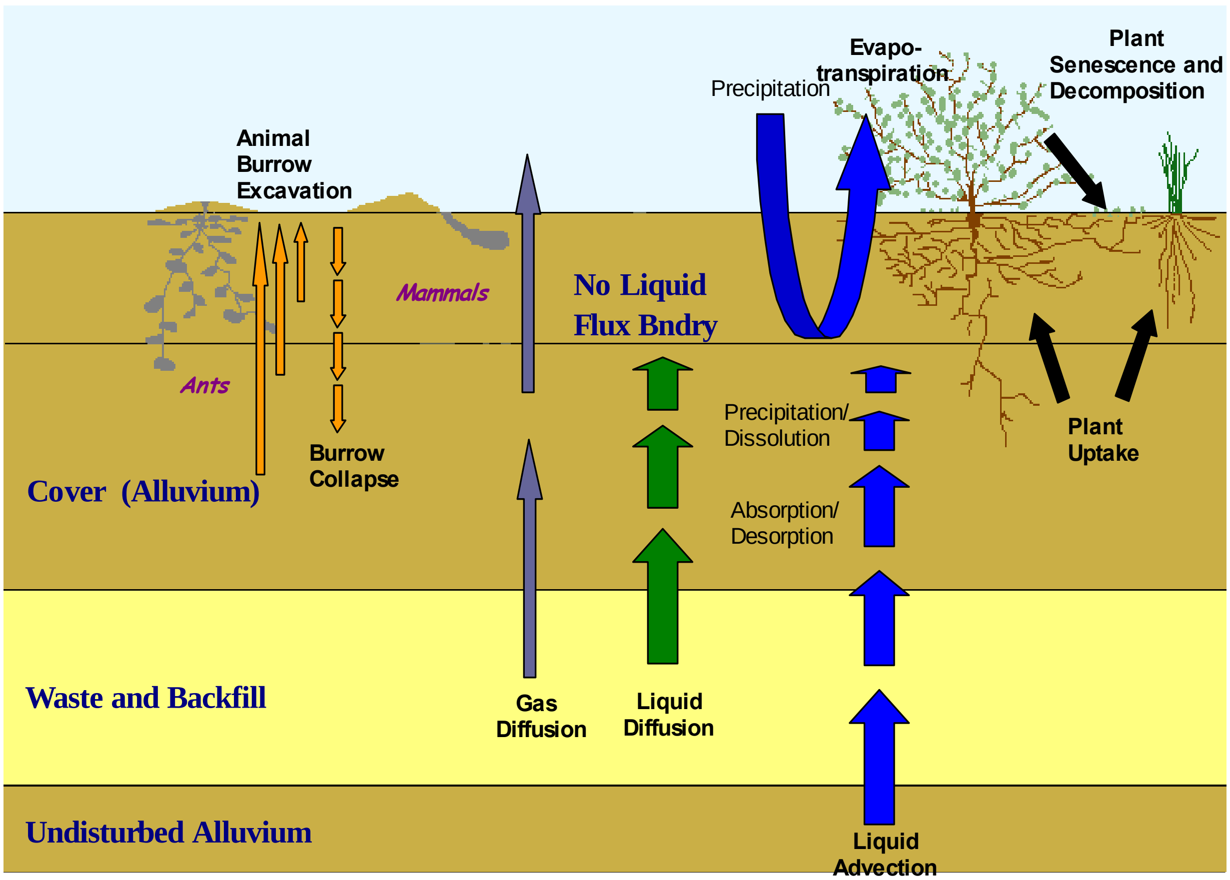


Figure 3-2. Transport Conceptual Model.

3.1.1.6 Conclusions

The Area 5 RWMS is well suited for the isolation and disposal of waste. The site is located in an access controlled government facility many miles from residential populations. The site has a windy, arid climate. Average annual PET is 152.9 cm (60.2 in.), many times the average precipitation rate of 12.5 cm (4.92 in.). On an annual basis, even in wet, cool years, evaporative demand is high.

The site is far from surface waters. Surface runoff and run-on is insignificant, and engineered berms provide 25-year flood protection. Risks of significant earthquake hazards are low. Minor subsidence of the ground surface above the edges of waste containers and the margins of the cells is likely; however, this localized subsidence can be mitigated through monitoring and maintaining the covers to preclude cracks or depressions from allowing infiltration of rainwater.

Plant evapotranspiration minimizes potential water transport through the cover, and the plant canopy and roots help control erosion of the surface by wind and rain. The vadose zone below the waste cells has low water potentials, low unsaturated hydraulic conductivity rates, and ample water storage capacity. Therefore, the potential for significant downward transmission of water is extremely low. Below this zone, water potential measurements indicate the existence of a static zone where essentially no vertical liquid flow is currently occurring. Conservative modeling estimates suggest it would take more than 50,000 years for water to move from beneath the static region to the groundwater, which is over 213.4 m (700 ft) below ground surface. If water were to carry contaminants to the groundwater, water levels indicate that the gradient is nearly flat, and calculated groundwater flow velocities have generally been less than 0.15 m (0.5 ft) per year. Effectively, there is no groundwater pathway, and the potential for groundwater contamination from waste disposal activities at the Area 5 RWMS is negligible.

The majority of the waste inventory is LLW, and much of the LLW contains radionuclides that will decay significantly over the next several decades. Much of the radioactivity in the waste inventory is in relatively immobile forms, with the exception of tritium, a volatile radionuclide that can readily move with water.

The conceptual site model indicates that contaminants are not readily released or transported. The waste acceptance criteria, packaging requirements, monitoring, climate characteristics, and other factors minimize the potential for release and transport of contaminants.

3.1.1.7 Sensitivity Analysis of the LLW PA

Sensitivity analysis (SA) has been used throughout the PA model development and maintenance process to identify parameters for which uncertainty reduction would be pursued. This strategy has proven to be effective, and has resulted in an iteration of model improvement, followed by SA that usually identifies new or different parameters of concern, followed again by model improvement.

A global SA of the Area 5 RWMS was performed using a variance decomposition approach from the machine-learning field referenced as boosting. The SA identified which input parameters have distributions that exert the greatest influence on the model results (response). Generalized boosting models (GBMs) were used to quantify the relative importance of explanatory variables through metrics based on the explained variance in the response. The details of the analysis and the method used are presented in the second addendum to the Area 5 RWMS PA (BN, 2006). A summary follows below.

SAs were performed using probability distributions for the model input parameters summarized in Table 3-2. The GoldSim PA model was run for 5,000 realizations. Sensitivity indices were estimated for each input parameter and include results for three exposure scenarios (responses): (1) the resident farmer total effective dose equivalent (TEDE) from the all-pathways resident farmer TEDE, (2) the transient occupancy air pathway TEDE, and (3) the average radon flux density. Two modeling case studies for each scenario were performed, one with constant inventory and one with stochastically sampled inventories.

Table 3-2. PA Model Input Parameters.

Group	Sub-group/Parameters	
Facility	Pit areas, pit volumes	
Global	Institutional control period	
Inventory	Waste volume, Waste layer thickness, Radionuclide activity distributions	
Waste Zone parameters	Dry bulk density, particle density, water content, porosity, tortuosity, radionuclide partitioning coefficients, effective air diffusion, radon emanation factor	
Soil Backfill and cover	Dry bulk density, particle density, water content, porosity, tortuosity, radionuclide partitioning coefficients, effective air diffusion	
Atmosphere	Mixing height, Atmospheric diffusion length	
Local Air	diffusivities	
Contaminant Transport	**Plant Transport**	Fraction of plants: (Creosote bush, Big Basin sage, Grasses, Saltbush, Other shrubs); total shrub biomass, total grass biomass, root/shoot rations, maximum rooting depths
	Animal transport	Ants 1 and ants 2: Nest volume, Colony span life, Colony density, Burrowing depth, Mammals: Mound density, Mound volume, Burrowing depth
	Water Transport	Upward advective flux distribution, molecular diffusion coefficients, no flux depth
	Air Transport	Resuspension rate; Chi/Q factors
Dose Assessment	Plant/soil concentration ratios for food plant ingestion	
	Dose conversion factors: ingestion, inhalation, inhalation-gas, air immersion, external irradiation	
	Behaviors	Ventilation rates, Mass-loading rates, Fraction of time for activities, Transmission factors, Inadvertent soil ingestion rate
	Member of public dose	Pathway dose conversion factors (Inhalation, external irradiation, ingestion)
	Inadvertent Human Intrusion	Basement area, basement depth, well diameter, well depth, garden area, facility design factor, bulk-density of excavated materials, drilling access time, basement access time, probability of intrusion

For the case of constant inventory at 1,000 years, the SA identified the following variables as most influential:

- For the resident farmer all-pathways TEDE, “Technetium plant soil concentration ratio for the garden”
- For the transient air pathway TEDE, the “*Messor pergandei* nest shape” and the “small mammal burrow nest shape
- For the average radon flux, “radon emanation coefficient for the SLB disposal units”

For the case of the stochastic inventory at 1,000 years, the GBM identified the following variables as most influential.

- For the resident farmer all-pathways TEDE, the “Technetium plant soil concentration ratio for the garden”
- For the transient air pathway TEDE the “*Messor pergandei* nest shape parameter” parameter
- For the average radon flux density, “radon emanation coefficient for the SLB disposal units”

3.1.1.8 Uncertainty Analysis

The results for the FY 2007 inventory indicate that there is reasonable expectation of compliance with the member of public performance objectives (Table 3-1). The mean and 95th percentile for the all-pathways scenarios are less than the 0.25 mSv yr^{-1} performance objective.

3.1.2 Air Pathway Dose

The mean and 95th percentile for the atmospheric pathway for all scenarios is less than the 0.1 millisieverts per year (mSv yr^{-1}) limit. There are no additional closure features needed with respect to this performance objective.

3.1.3 Radon Flux

Table 3-3 shows the PA radon flux results. The mean and 95th percentile ^{222}Rn flux density is less than the 0.74 becquerel per square meter per second (Bq/m^2/s) performance objective averaged over the entire site (Table 3-3). The same is true for all virtual disposal units, except for Pit P013U, where the 95th percentile ^{222}Rn flux density exceeds the performance objective.

The cover thickness is the primary factor in the calculation of the radon flux, with greater cover thickness resulting in greater diffusion path length and reduction in radon flux. The PA radon flux result is well below the radon performance objective, and is expected to remain so in the final PA with an optimized cover thickness.

There are no additional closure features needed with respect to this performance objective.

Table 3-3. Area 5 RWMS PA Results for Radon Flux Density.

Virtual Disposal Unit	Limit ($Bq\ m^{-2}\ s^{-1}$)	Mean ($Bq\ m^{-2}\ s^{-1}$)	95th Percentile ($Bq\ m^{-2}\ s^{-1}$)	Time of Maximum (yr)
All	0.74	0.041	0.083	1000
SLB	0.74	0.024	0.050	1000
Pit 6	0.74	0.041	0.096	1000
Pit 13	0.74	0.47	1.4	1000
GCD	0.74	3.4E-9	9.0E-4	1000

3.1.4 Other Requirements

3.1.4.1 Groundwater Resource Protection

The site conceptual model that was developed based on multiple lines of evidence derived from the several decades of site characterization activities and vadose zone modeling of flow and transport does not include a groundwater pathway. However, in the original PA (Shott et al., 1998), a bounding analysis of the groundwater pathway was evaluated to demonstrate that in the unlikely event of releases from the disposal cells to the groundwater table, groundwater performance objectives could be met.

No impact to the groundwater from the disposal activities at the Area 5 RWMS is expected over the compliance period. Therefore, the closure system design has no special provisions for groundwater protection, other than the cover thickness, which assures minimal contact of water with the waste zone.

3.1.4.2 Inadvertent Human Intrusion

The mean of the probability weighted intruder total effective dose equivalent is less than the 1 mSv performance objective for the postdrilling and intruder-agriculture scenario (Table 3-4). The 95th percentile of all scenarios is less than the performance objective.

Table 3-4. Area 5 RWMS v4.004 GoldSim Model PA Results for Intruders.

Disposal Unit/Scenario	Limit (mSv)	Mean (mSv)	95th Percentile (mSv)	Time of Maximum (yr)
SLB/Postdrilling	1	0.033	0.015	950
Pit 6/Postdrilling	1	0.0044	0.0022	1000
Pit 13/Postdrilling	1	0.0011	0.0023	1000
GCD/Postdrilling	1	3.0E-7	9.2E-7	1000
SLB/Intruder-Agriculture	1	0.047	0.17	1000
Pit 6/Intruder-Agriculture	1	0.0016	0.0055	1000
Pit 13/Intruder-Agriculture	1	4.6E-4	1.7E-3	1000
GCD/Intruder-Agriculture	1	1.2E-10	NA	100

NA – not available; insufficient non-zero realizations

In the future updates of the PA , only acute intrusion scenarios will be considered recognizing NNSA/NSO's refined institutional control policies for the NTS disposal facilities, which preclude chronic scenarios (further discussed in Section 3.2.3).

The lack of significant economically exploitable natural resources in the region, the cost of drilling and pumping from deep wells, and land-use restrictions that prohibit public access to groundwater within compliance boundaries to be established for the UGTA Frenchman Flat CAU, will help mitigate the risk of IHI for water drilling and residential agriculture during the 1,000 year compliance period under DOE O 435.1.

3.1.4.3 Performance Assessment of the TRU Waste in the GCD Boreholes

The TRU waste in GCD boreholes 1 through 4 was evaluated to demonstrate compliance with the requirements of 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes" (EPA, 1993). Relevant standards for TRU waste disposal are found in 40 CFR 191 Subpart B, "Environmental Standards for Disposal, and Subpart C, Environmental Standards for Groundwater Protection." Subpart B standards include containment requirements (CRs), assurance requirements, and individual protection requirements (IPRs). The CRs are probabilistic limits for the normalized cumulative radionuclide release to the accessible environment for 10,000 years. The cumulative release is normalized to release limits scaled to the total TRU inventory disposed. The CRs limit the probability of exceeding the release limit to 1 chance in 10, and the probability of exceeding 10 times the release limit to 1 chance in 1,000. The assurance requirements specify institutional controls and disposal system features to increase confidence in the long-term compliance with the CRs. The required controls and features are active and passive institutional controls, monitoring, natural and engineered barriers, lack of attractive natural resources, and ability to retrieve wastes for a reasonable time period. The IPRs limit the committed effective dose to a MOP through all pathways for 10,000 years to 0.15 mSv/yr. Subpart C requires that sources of underground drinking water in the accessible environment comply with the limits in 40 CFR 141 for a period of 10,000 years.

SNL prepared a PA for the TRU GCD boreholes in 2001 (Cochran et al., 2001). In 2002, DOE determined that the PA met all requirements with the exception of the 40 CFR 191.14 assurance requirements for institutional controls; a monitoring program; markers, records, and other passive institutional controls; an engineered barrier system; information to support the claim that there are no economically useful minerals in the area; and removal of waste. NNSA/NSO committed to resolve these issues during the closure planning process for the Area 5 RWMS (Colarusso et al., 2003) and that TFRG would review closure and post-closure documents to determine compliance with the 1993 version of 40 CFR 191 (Fiore and Berube, 2002).

As part of the PA/CA Maintenance Program, NNSA/NSO migrated the NTS PAs/CAs to a probabilistic modeling platform, GoldSim. The purpose was to implement the conceptual site model probabilistically so that uncertainty of model parameters could be accounted for in the assessments directly, to replace the bounding assumptions of the original PAs' parameter values with distribution of values derived from site-specific data obtained through field investigations performed after the original PAs were published, and to bring uniformity to numerical model implementation of the various components of the conceptual model by integrating them in a single platform.

The 40 CFR 191 TRU model, version 1.002, was developed from the Area 5 RWMS GoldSim PA model, which has been subjected to external peer review. The most recent review was the update of the Area 5 RWMS PA (BN, 2006), which was accepted by LFRG without conditions (DOE, 2007).

The Area 5 RWMS PA model was initially modified to calculate the regulatory requirements of 40 CFR 191. Starting with the Area 5 RWMS PA model v4.000, a process of simplification and modification was begun to create the final 40 CFR 191 model for the GCD boreholes and the TRU in T04C. The steps involved were:

- Adding model elements to implement stochastic climate regime periods.
- Adding additional model parameters describing hydrologic conditions, plant uptake, and animal burrowing during future climate regimes.
- Deleting unneeded model components including cost-benefit optimization, composite analysis, and unused disposal configurations (i.e., SLB, Pit P06U, Pit P013U, Candidate 1, Candidate 2), and unused waste inventories (i.e., post-1988 SLB, future waste inventory, thorium nitrate, Fernald thorium, pre-1988 GCD, post-1988 GCD, Fernald Silo wastes).
- Adding an onsite residential exposure scenario without agriculture as the IPR scenario.

The original GCD PA implemented the 1985 version of 40 CFR 191. The 1993 version of the 40 CFR 191 (the current version) was implemented in the current 191 TRU model, version 1.002, considering:

- The 1993 version is more restrictive than the 1985 version with respect to the IPRs.
- The 1993 version uses dosimetric quantities that are consistent with quantities currently used to regulate radiation exposure in the U.S.
- DOE/HQ has issued guidance to the U.S. Department of Energy, Nevada Operations Office (DOE/NV; now NNSA/NSO), requiring the GCD PA show compliance with the 1993 version of 40 CFR 191 (DOE 1999b; 2002; Cochran et al., 2001).

The 1993 Part 191.15 IPRs reduced the MOP dose limit from 0.25 to 0.15 milliSievert (mSv) in a year, increased the compliance period from 1,000 to 10,000 years, and changed the dose calculation method. The Subpart C groundwater protection standards were changed to broaden the definition of groundwaters protected, to move the point of compliance to the accessible environment, and to increase the compliance period from 1,000 to 10,000 years. Major differences from the original TRU PA model also include the parameter distributions for plants and animals, upward flux rates, mixes of plant species, and climate change scenarios.

The new 40 CFR 191 TRU PA model is documented in the Special Analysis of Transuranic Waste in Trench T04C at the Area 5 RWMS, which has been reviewed and accepted by the LFRG in 2008 (Shott et al., 2008).

The 40 CFR 191 TRU PA model was run for the GCD boreholes for the CRs and the IPRs. The results of the IPRs are shown in Figure 3-3 for the 10,000-year facility performance with the operational cover and with the final cover. The results shown in Figure 3-3 are for a MOP residing on top of the cover, with co-located LLW in the GCD TRU boreholes included in the assessment. As shown in the figure, the mean as well as the 95 percentile dose results are well below the performance objective of 0.15 mSv in a year. Therefore, the PA IPR result presented in the original 2001 PA remains valid.

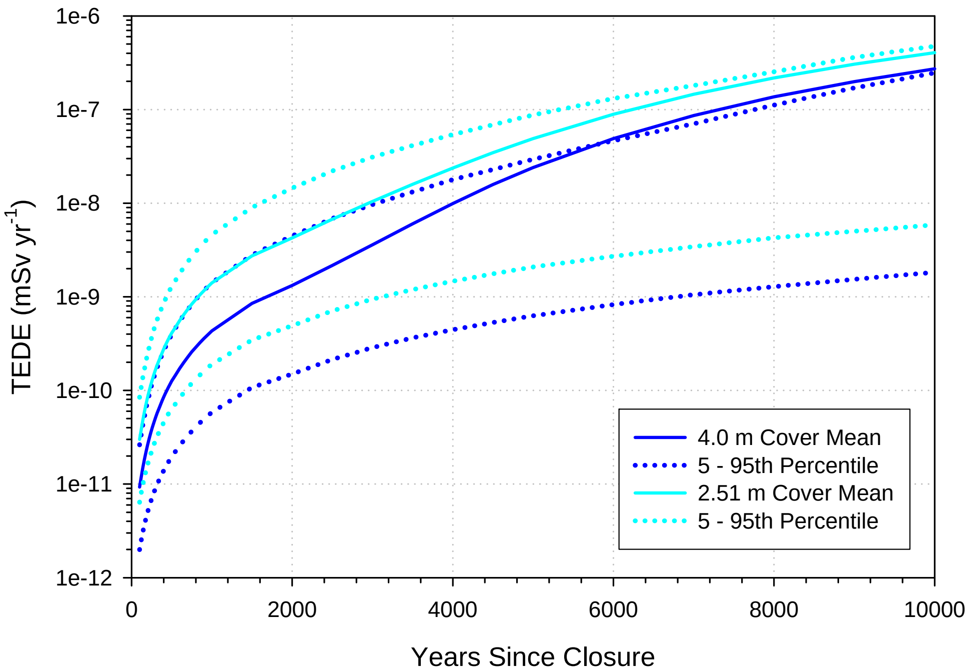


Figure 3-3. Individual Protection Requirements.

The CR results are presented in Figure 3-4. CRs were computed with co-located LLW and drilling intrusion. The CRs limit the probability of the normalized cumulative release, R, exceeding one times the release limit to less than 1 chance in 10 (Pr[R>1] < 0.1) and the Pr(R>10) to less than 1 chance in 1,000. The CR results are below the performance objectives; therefore, the CR results of the original GCD TRU PA remain valid.

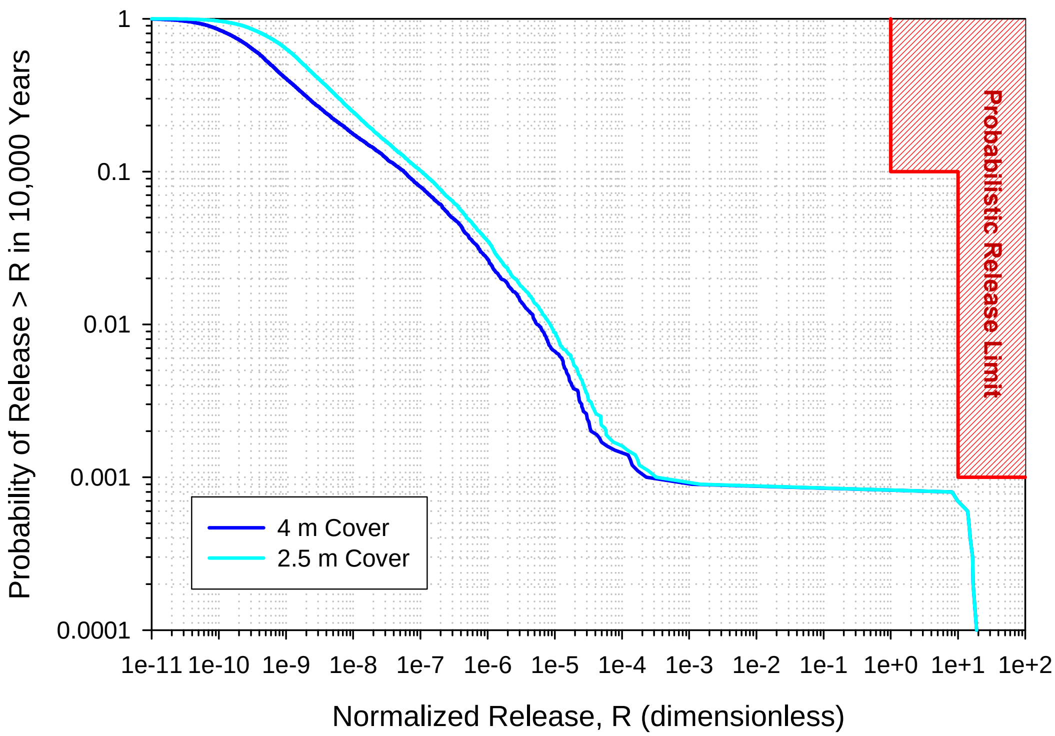


Figure 3-4. Containment Requirements.

3.1.4.3.1 Sensitivity Analysis of the GCD TRU PA

The SA of the GCD TRU PA model was performed for the input parameters shown in Table 3-5 for the normalized cumulative release as the response variable, using the global methods of sensitivity analyses described in the second addendum to the PA and the Special Analysis of the TRU in Trench T04C (BN, 2006; Shott et al., 2008).

Table 3-5. GCD TRU PA Input Parameters.

Group	Sub-group/Parameters	
Facility	Pit areas, pit volumes	
Global	Institutional control period	
Climate Change	Present-day, monsoon, glacial transition periods	
Inventory	Waste volume, Waste layer thickness, Radionuclide activity distributions	
Waste Zone parameters	Dry bulk density, particle density, water content, porosity, tortuosity, radionuclide partitioning coefficients, effective air diffusion, radon emanation factor	
Soil Backfill and cover	Dry bulk density, particle density, water content, porosity, tortuosity, radionuclide partitioning coefficients, effective air diffusion	
Atmosphere	Mixing height, Atmospheric diffusion length	
Local Air	diffusivities	
Contaminant Transport	Plant Transport	Fraction of plants: (Creosote bush, Big Basin sage, Grasses, Saltbush, Other shrubs); total shrub biomass, total grass biomass, root/shoot rations, maximum rooting depths
	Animal transport	Ants 1 and ants 2: nest volume, colony span life, colony density, burrowing depth Mammals: mound density, mound volume, burrowing depth
	Water Transport	Upward advective flux distribution, molecular diffusion coefficients, no flux depth
	Air Transport	Resuspension rate; Chi/Q factors
Dose Assessment	Plant/soil concentration ratios for food plant ingestion	
	Dose conversion factors: Ingestion, inhalation, inhalation-gas, air immersion, external irradiation	
	Behaviors	Ventilation rates, mass-loading rates, fraction of time for activities, transmission factors, water ingestion rate, inadvertent soil ingestion rate
	Member of public dose	Pathway dose conversion factors (Inhalation, external irradiation, ingestion)
Containment Requirements	Human Intrusion	Probability of well drilling (drilling rate),basement area, basement depth, well diameter, well depth, garden area, facility design factor, bulk-density of excavated materials, drilling access time, basement access time, probability of intrusion

As shown in Figure 3-5, the normalized cumulative release is most sensitive to the number of boreholes hitting the GCD boreholes, which explains 76 percent of the GBM model variation alone and 99 percent of the variation interacting with other parameters (see Table 3-6). The no liquid flux boundary depth and upward advection rate show zero sensitivity acting alone but acount for approximately 12 percent of the GBM model variation when interacting with other parameters.

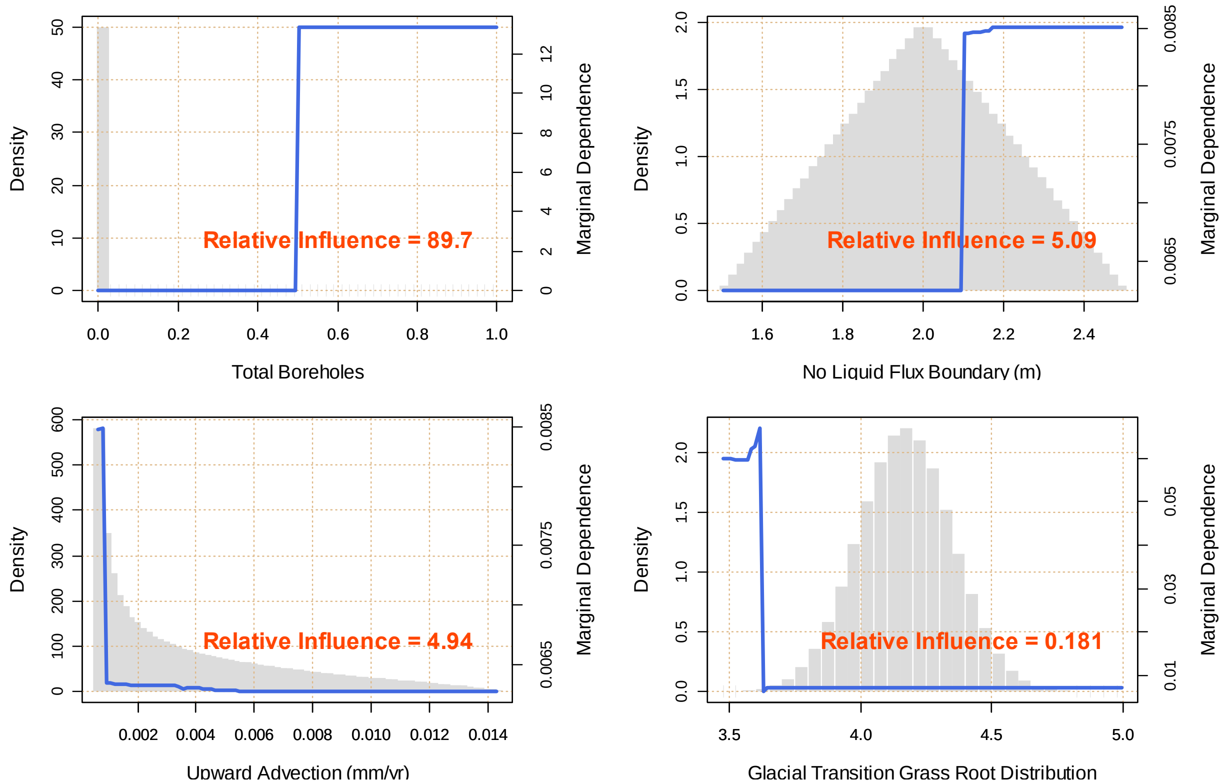


Figure 3-5. Histogram (Grey) and Marginal Dependence (Blue) of Four Most Sensitive Parameters as Measured by the Relative Influence.

The total effects sensitivity indices (SIs) for these parameters are equal, and it is suspected that the interaction is between these two parameters.

Table 3-6. Sobols' First Order and Total Effect Sensitivity Indices.

Parameter	First Order Effects SI	Total Effects SI
Number of Boreholes	0.76	0.99
No Liquid Flux Boundary	N.D.	0.12
Upward Advection	N.D.	0.12
Glacial Transition Grass Root Distribution	0.003	0.008
Am-241 Inventory	0.002	0.004
Total	0.76	1.24

N.D. – not detected

3.1.4.3.2 Barrier Evaluation

One of the primary concerns leading to the requirement for engineered and natural barriers is the reduction of risk given extremely poor performance of any single barrier. Thus, EPA has adopted the multiple barrier principle or “defense in depth.” EPA puts an emphasis on “the best performance reasonably achievable” through such design principles and onsite selection to provide the best isolation capabilities available.

The EPA made it clear in 40 CFR 194, “Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant’s Compliance with the 40 CFR Part 191 Disposal Regulations,” that it does not require specific engineered barriers or the implementation of more than one engineered barrier.

The EPA defines a barrier as “any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment. For example, a barrier may be a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides.”

Previous PAs have identified numerous natural barriers at the Area 5 RWMS including:

- The thick dry vadose zone below the site. The extremely low hydraulic conductivity of the dry alluvium (approximately 1×10^{-10} cm s^{-1}) and thickness of the vadose zone (236–272 m [774–892 ft]) leads to extremely long travel times. The median travel time for water under current conditions has been estimated to be 51,000 years (Shott et al. 1998).
- The thick homogenous alluvium below the site. Contaminants must migrate through a tortuous porous medium rather than through rapidly flowing fractures in rock.
- The nearly flat groundwater table below the site. If any contaminants were to reach the saturated zone, lateral migration to the edge of the controlled area would be extremely slow because of the negligible gradient.
- The extremely dry cover soil conditions. Mean cover volumetric water contents range from 0.058 to 0.079. The low water contents are maintained by high PET and low precipitation.
- The alkaline soil conditions that retard the migration and reduce the solubility of most cationic metals.
- The adaptations of native plants to xeric conditions. Native Mojave Desert plants are able to efficiently withdraw water from cover soil and maintain extremely negative soil matric potentials.
- The low primary productivity of native plants. The present-day Mojave Desert assemblage has a primary production of only approximately 300 kg ha^{-1} yr^{-1}.
- The shallow rooting depth of native plants. Native plants’ roots seldom penetrate below the dynamic range of infiltrating precipitation, 2 to 3 m (6.5 to 9.8 ft).
- The shallow burrowing depth of rodents, the most abundant burrowing animals.

Engineered barriers are interpreted to be materials or structures intentionally placed at the site to increase the isolation of the waste from the accessible environment.

All of the TRU material in the GCD boreholes is solid material packed in containers. According to Chu and Bernard (1991), the nuclear weapon accident residues in GCD-1C, GCD-2C, and GCD-3C were packaged in metal boxes, metal barrels, and plywood boxes coated with fiberglass. Probertite was backfilled around the packages. The Rocky Flats Plant material in GCD-4C was packed in fiberboard containers packed in plastic bags, placed in a rigid drum liner, packed in 55-gallon metal drums. Material from Lawrence Livermore National Laboratory in GCD-4C was packed in boxes. These packages are 21 m (70 ft) to 36 m (120 ft) below ground surface and covered by at least 21 m (70 ft) of backfill, and the 2.4-m (8-ft) operational closure cover.

The GCD PA did take credit for the backfill and the operational cover but not for the waste containers in determining the cumulative release from the facility to show compliance with the CRs.

As the TRU PA demonstrates, the releases from the GCD boreholes are mainly due to human intrusion through drilling. The waste packages in the GCD boreholes are buried 21.3 m (70 ft) below ground surface, below the rooting depth of native plants and the digging depth of native insects and mammals. Drilling rate in the PA is represented with a distribution, which accounts for the uncertainty of the drilling rate. Because of small foot-print of the GCD boreholes, the risk of drilling into the waste is quite small.

The regulations do not identify the criteria or process for engineered barrier selection and do not require technical analysis. For the WIPP, EPA proposed that DOE select barriers using cost-benefit analysis (EPA, 1995).

The cost-effectiveness of 12 engineered barrier alternatives (barriers that modify release processes due to biointrusion and/or human intrusion) was recently evaluated for shallow trench T04C, which contains inadvertently disposed TRU waste (Shott et al., 2008). T04C is within 150 m (492 ft) of the GCD boreholes and has similar environmental and site conditions. The performance of alternatives was evaluated against a 2.8-m (9-ft) operational cover without additional intrusion barriers (base case) using the 90th and 99.9th percentile of the normalized cumulative release and the MOP TEDE at 10,000 years (CRs and IPRs under 40 CFR 191). Hydrologic performance and reliability were other benefit criteria. Cost factors included cost of construction, materials, and maintenance; worker safety; and compatibility with the cover plans for surrounding closure units.

The results of the benefit-cost analysis of these 12 barrier alternatives are shown in Table 3-7. The most costly alternative was the reinforced concrete subsurface intruder barrier, followed closely by the 9-m (30-ft) waste rubber tire and bailing wire subsurface intruder barriers. Only three alternatives were judged to be more cost-effective than the base case option. The best benefit/cost ratio is obtained for the 4-m (13-ft) monolayer-ET cover. The second most cost-effective barrier is the 4-m (13-ft) monolayer-ET barrier combined with the boulder mound surface intruder barrier. The final alternative ranked above the base case was the 4-m (13-ft) monolayer-ET barrier combined with the boulder field surface intruder barrier.

Table 3-7. Engineered Barriers Comparison.

Alternative	Description	Benefit Rank	Cost Rank	Benefit/ Cost Rank	Rank
Base	2.8 m ET Cover	0.160	0.147	1.085	4
Alt. 1	Asphalt Layer, 4-m Cover	0.301	0.510	0.589	13
Alt. 2	Capillary Break Layer, 4-m Cover	0.307	0.352	0.870	8
Alt. 3	9 m Rubber Tire Layer, 12.5-m Cover	0.619	0.626	0.988	6
Alt. 4	9 m Bailing Wire Layer, 12.5-m Cover	0.628	0.642	0.978	7
Alt. 5	1.5 m Reinforced Concrete Barrier, 5-m Cover	0.428	0.661	0.646	12
Alt. 6	Boulder Field, 2.8-m ET Cover	0.170	0.202	0.843	10
Alt. 7	Boulder Wall, 2.8-m ET Cover	0.154	0.231	0.666	11
Alt. 8	Boulder Mound, 2.8-m ET Cover	0.234	0.270	0.865	9
Alt. 9	Thick (4-m) ET Cover	0.337	0.227	1.481	1
Alt. 10	Boulder Field, 4.0-m ET Cover	0.318	0.284	1.121	3
Alt. 11	Boulder Wall, 4.0-m ET Cover	0.337	0.336	1.005	5
Alt. 12	Boulder Mound, 4.0-m ET Cover	0.659	0.475	1.388	2

Extrapolating from the T04C special analysis, the relative merits of barrier alternatives can be qualitatively evaluated for the GCD boreholes. Most of the waste containers in the GCD boreholes are already buried under 21.3 m (70 ft) of native alluvium. The incremental benefits of a thicker final cover are small compared to the performance of the existing 21.3 m (70 ft) of backfill. The PA shows that cumulative release is far more sensitive to human intrusions (e.g., drilling boreholes) than movement of radionuclides by bioturbation and upward water/vapor transport. Comparison of the cost of constructing and maintaining a barrier compared to the increased human-intrusion prevention benefits suggest a boulder mound over each GCD borehole may cost-effectively marginally reduce the risk of drilling into the GCD wastes. The risk reduction is above and beyond the significant risk-reduction benefits of the remote site location, the lack of economically exploitable natural resources, the significant cost to develop groundwater, and institutional controls after closure of the GCD units. Therefore, NNSA/NSO will not implement any additional engineered barriers.

3.1.4.4 Special Analysis for the TRU Waste in Trench T04C

In 1986, 102 55-gal drums of classified TRU waste from Rocky Flats were inadvertently buried in T04C. The T04C TRU inventory was included in the 2001 CA; however, in order to provide further assurance that this small quantity of TRU in T04C will not pose a risk to future MOPs, a 40 CFR 191 evaluation is considered relevant.

The SA was performed in 2007 to determine the likelihood that T04C meets the requirements of 40 CFR 191 (Shott et al., 2008). The SA concludes that there is a reasonable expectation that all 40 CFR 191 disposal requirements for a period of 10,000 years under climate change are met.

There are no closure requirements and activities stemming from this evaluation.

3.1.4.5 Compliance with RCRA Hazardous Waste Regulations

The closure requirements and cover design standards of 40 CFR 265 will be met in closing the Pit P03U MWDU. Pits P06U and P07U are permitted Class III asbestiform low-level solid waste disposal units at the Area 5 RWMS and will meet the requirements of NAC 444.743. NDEP-agreed closure of the 92-Acre Area under a FFACO-like process will assure that 40 CFR 265 and NAC 444.743 requirements are met. The closure cover design utilizes a cover design that has been proven equivalent to a RCRA cover. This equivalency was accepted by the NDEP for closure of the CAU 110 (U-3ax/bl unit) in the Area 3 RWMS in 2001 (DOE, 2001b). The evaluation of alternative covers in the Pit P03U closure and post-closure care plan also demonstrates that the ET-cover will perform better than the EPA's standard RCRA cover for hazardous waste landfills (DOE, 2005b; Crowe et al., 2005).

3.2 DETAILED CLOSURE ACTIVITIES

Closure of the Area 5 RWMS includes operational closure followed by final closure. Operational closure provides the initial protection and containment of disposed waste containers. Final closure provides containment of disposed wastes for an indefinite period. The concept of the cover design is such that evapotranspiration is the driving mechanism for removing moisture from the cover. Sloping minimizes ponding and reduces infiltration by promoting water flow off the cover; cover thickness provides the necessary storage for moisture.

3.2.1 Operational/Interim Closure

Containerized waste is disposed in pits or trenches starting at the closed end of the disposal unit and progressing toward the open or ramp end. An alphanumeric grid system along the perimeter of the disposal unit is used to track the location of all disposed waste. Within a short time (days to weeks) after disposal of the waste, stockpiled soil is screened to remove rocks larger than 9 cm (3.5 in.) and is placed over the waste containers from the top of the stacked containers. The working face of the stacked waste containers is not immediately covered with soil so that additional waste can be stacked easily. The soil cover is not placed in lifts but is compacted by the heavy equipment running over the total thickness of soil.

Native soil excavated to form trenches at the Area 5 RWMS is typically stockpiled for later use in operational closure. Waste containers are stacked in the disposal unit to approximately 1.2 m (4 ft) below grade. Previously, aluminum tubes used for neutron logging of soil moisture were placed at intervals between the waste containers during stacking, and extend to the bottom of the disposal unit. Since the neutron monitoring technology has now been replaced by TDR probes, the existing neutron monitoring tubes are not being used and are planned to be filled and abandoned. Neutron monitoring tubes will not be installed during future waste-disposal activities.

Past operational closure included placement of soil over the waste containers to a total thickness of about 2.4 m (8 ft), so that about 1.2 m (4 ft) of soil stood above grade. New operational closures will place soil over the waste containers to a total thickness of about 4 m (13 ft), so that 2.8 m (9 ft) of soil stand above grade. This additional thickness will preclude biotic intrusion into the waste zone. The final cover will also optimize performance in terms of attenuating the flux of gaseous radionuclides, and accommodating infiltration of water and any later subsidence. Lower existing operational covers, when adjacent to a new cover, will be thickened to match the total thickness of the newly placed operational cover and sloped uniformly to provide for drainage from the unit as well as away from adjacent units.

After a disposal unit is completely filled, the operational cover is graded to provide a smooth surface. Maintenance of the cover includes filling of fissures and depressions resulting from compaction and piping of soil between waste packages, compaction of the surface with a roller, and re-grading. Operational closure covers are not vegetated because of the need for continued maintenance activities.

Two weighing lysimeters installed near the Area 5 RWMS (one vegetated and the other bare) serve as analogs for the operational closure covers. Data collected show that soil in the unvegetated lysimeter stores more water than similar soil in the vegetated lysimeter and, over a period of approximately five years, could experience slight infiltration through the thickness of the soil column (approximately 1.8 m [6 ft]).

3.2.2 Final Closure

Results of past characterization studies, and ongoing measures of water balance at the Area 5 RWMS and elsewhere, are believed to provide sufficient characterization data to support the DQO for the closure of the 92-Acre Area under the NDEP FFACO process.

The closure cover for the 92-Acre Area consists of two monolayer-ET closure covers. Monolayer-ET closure covers were selected as the preferred alternative design to a multilayered landfill closure cover and other alternative designs only after a comprehensive evaluation of many alternatives. Evaluation of alternative designs included review of relevant literature, research on water balance in vegetated and unvegetated weighing lysimeters in Area 5 of the NTS, hydrogeologic modeling, site visits to closure cover test facilities at SNL and LANL, NNSA/NSO-sponsored workshops, and a conference on vadose zone monitoring. The various forums included representatives from industry, academia, and government, including SNL and LANL, and provided the opportunity to discuss closure and monitoring of waste-disposal units. Multiple lines of evidence suggest that a monolayer-ET design in an arid environment will perform according to performance criteria over long periods of time even under conditions of subsidence and will meet the regulatory design standards of 40 CFR 265, NAC 444.743, and performance objectives under DOE O 435.1 and 40 CFR 191. The monolayer-ET cover and natural conditions at the NTS will integrate and operate as a system.

Title II engineering design drawings and supporting calculations are presented in the appendices. Design features of the final closure cover are summarized below.

The Area 5 RWMS Expansion Area will be closed with a single closure cover in a fashion similar to the 92-Acre Area. Areas between the final covers at the Expansion Area and the 92-Acre Area will be graded so that drainage will exit the sites without impacting adjacent closed units.

3.2.2.1 Cover Thickness

The current design includes a closure cover thickness of 3 m (10 ft), which is deemed adequate to meet the PA performance objectives. This thickness, which includes the thickness of the operational covers, is the minimum thickness of cover over the waste. It may be greater than 3 m (10 ft) at certain locations in order to accommodate the design cover slopes. The cover thickness will be optimized for the final design.

3.2.2.2 Cover Slope

The top surface of the cover is sloped sufficiently to provide free drainage without ponding of water while minimizing erosion due to runoff. The surface slope and cover side slopes are established so as to minimize erosion and the need for side slope armoring.

3.2.2.3 Cover Material

Materials for constructing the cover will be natural soils obtained from the Area 5 RWMS. The soils will be compatible with the materials used for the operational covers. If necessary, soil samples may be collected and analyzed using the following methods to determine suitability based on the PA and comparability with existing operational covers:

- American Society for Testing and Materials (ASTM) D422: Standard Test Method for Particle-Size Analysis of Soils
- ASTM D854: Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
- ASTM D1557: Standard Test Methods for Laboratory Compaction Characteristics of Soil
- ASTM D2216: Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D2434: Standard Test Method for Permeability of Granular Soils
- ASTM D2487: Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- ASTM D2922: Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
- ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D5084: Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter
- ASTM D6527: Standard Test Method for Determining Unsaturated and Saturated Hydraulic Conductivity in Porous Media by Steady-State Centrifugation

3.2.2.4 Cover Infiltration

Measurement and modeling of water balance in test monolayer-ET covers at the Area 5 RWMS and at National Laboratories in arid regions of the United States show that the design will minimize infiltration of water (Desotell, 2006).

Water balance studies conducted at the Area 5 RWMS have shown that a monolayer-ET closure cover is most effective when vegetated (Levitt et al., 1999; Desotell, 2006). Under current climatic conditions, any water that infiltrates into the soil is quickly extracted by evaporation and uptake by plant roots, even with a relatively low density of plant cover. Closure covers constructed over waste units at both the Area 3 and Area 5 RWMSs will be planted with species native to the area. Shallow-rooted, invasive plant species will also be allowed to vegetate the closure covers. Over the long term, an established plant assemblage that will survive the ambient range of environmental conditions is expected. Plants will also serve to maintain stability of the closure covers. The cover will have adequate slope to safely carry any precipitation runoff without significant erosion.

Infiltration of water into the waste zone below the cover is minimized by planting native vegetation on the cover, sloping the cover, and providing an adequate cover thickness.

3.2.2.5 Cover Erosion

Erosion will be controlled through a combination of vegetation and cover slope.

3.2.2.6 Cover Subsidence

Subsidence could occur due to infilling of void spaces around containers, plus the degradation and subsequent collapse of buried waste containers. The cover design (monolayer) is sufficient to maintain structural stability in the event of incidental subsidence. Subsidence or localized settling would be mitigated shortly after discovery.

3.2.2.7 Cover Vegetation

Vegetation is an integral component of cover design and minimizes both infiltration and erosion. The cover will be seeded and/or planted with plant species native to the area in a density similar to natural conditions. The surface of the cover will be disked to a depth of approximately 0.3 m (1 ft) prior to seeding. Short-term irrigation may be required to accelerate seed germination and rooting until vegetation is established.

3.2.2.8 Cover Monitoring

Individual closure covers will not be monitored since the Area 5 RWMS lysimeter facility will serve as a surrogate monitoring station.

3.2.2.9 Drainage

The Area 5 RWMS is currently surrounded by engineered berms and drainage channels. Flooding within the RWMS will be controlled by the cover-slope design, in conjunction with new engineered drainage channels, to direct runoff away from the closure covers and ultimately outside the RWMS.

3.2.3 Institutional Control

The following institutional controls currently in place for the Area 5 RWMS will continue to be implemented during post-closure:

- Access controls and site security provided through government control of the NTS
- Agreements and discussions with the Nellis Air Force Range (also known as the Nellis Test and Training Range), BLM, the U.S. Fish and Wildlife Service, and NDEP regarding long-term ownership and control of the lands including and surrounding the NTS
- Maintenance operations, remedial actions, and decommissioning steps necessary to establish the proper post-closure condition for the site
- Monitoring of parameters related to performance of waste disposal systems

- Implementation of specific controls: (a) fences and signs, (b) facility guards for roadways and patrols, (c) land use control and permits, (d) land reclamation, (e) inspection and maintenance, and (f) reporting of activities and incidents that impact access control and security, and any corrective actions

The length of the institutional control period was treated probabilistically in the Area 5 RWMS PA. A probability distribution was assigned to the length of the institutional control period based on the results of an expert judgment elicitation of the probability of IHI. Human intrusion was assumed to occur (probability = 1) after loss of institutional control (Black et al., 2001). The PA also weighted the dose to inadvertent intruder by the probability of IHI.

In response to concerns over consistency issues in institutional control and land-use policies implemented in the NTS PAs/CAs, NNSA/NSO conducted an evaluation of program assumptions across the waste management and environmental restoration programs. As a result, a new institutional control policy was developed and adopted in FY 2008. Following is a summary of the implementation of the NNSA/NSO's institutional control policy in the future PAs/CAs (Crowe et al., 2007):

- Timing of the onset of the loss of active institutional control will continue to be assessed as a probability distribution that is based on, and justified by, local conditions.
- The probability of IHI will no longer be applied in risk-modified dose calculations consistent with the guidance of the National Academy of Science.
- The Area 5 and Area 3 facilities will assume land-use restrictions consistent with NNSA directives and the UGTA/FFACO policies for the NTS.
- The land-use restrictions will prohibit public access to contaminated groundwater within the NDEP compliance-negotiated boundaries for 1,000 years. The 1,000-year duration for land-use restrictions is not specified in the FFACO (1996 [as amended, 2008]) but is a recognized requirement of the definition of the contaminant boundary (page VI-3-3), the performance criteria (page VI-3-4), and the requirements for implementing the Safe Drinking Water Act (page VI-3-12). (All page references from Appendix VI of the FFACO [1996 (as amended, 2008.)])
- The PA and CA for the Area 5 and Area 3 facilities demonstrate that there is insufficient transport to establish a downward pathway beneath the facilities to groundwater for contaminants during the 1,000-year compliance period (Shott et al., 1998; 2001; BN, 2006). The only release pathways that allow interaction between the disposal facility inventory and the UGTA groundwater contamination is from drilling to groundwater near the waste disposal facilities (combined atmospheric and groundwater pathways).

The land-use restrictions are assumed to eliminate long-term access to groundwater for the chronic post-drilling and intruder agriculture scenarios. The policies are not expected to be 100% effective for shorter time spans (months) and will not prevent the acute groundwater drilling and construction scenarios.

Consistent with this policy, the next update of the Area 5 RWMS PA will evaluate acute drilling and construction IHI scenarios. The acute drilling scenario estimates the dose to a drill crew drilling a water well through a disposal cell. The acute construction scenario estimates the dose to a construction crew excavating a septic tank or basement during construction of a residence. The PA will assume the MOP to be located 100 m from the facility boundary and continue to use the probability distribution for the onset of loss of institutional controls. Cover thickness optimization for the disposal units will be based on this new set of assumptions.

3.2.4 Post-Closure Care and Strategy

Following certification of closure of the Area 5 RWMS, according to DOE O 435.1 and DOE M 435.1-1, the facilities will be subject initially to a period of active institutional control followed by an indefinite period of passive control. The NNSA position is that the NTS will be controlled in perpetuity. However, should this position change for part or all of the NTS, institutional control shall continue until the facility can be released pursuant to DOE O 5400.5, Change 2, “Radiation Protection of the Public and Environment.”

3.2.4.1 Site Inspection and Maintenance

The inspection program addresses inspection requirements for environmental monitoring equipment, fire protection systems, safety and emergency equipment, security devices, and operating or structural equipment that are critical to prevent, detect, or respond to human health or environmental hazards. Records will be maintained by the RWMS personnel for tracking purposes to ensure that inspections are conducted according to established schedules.

Inspections will consist of visual observations to ensure that closure cover integrity is maintained and fencing and boundary monuments are intact. Inspections and associated repairs will ensure the continuing protection of human health and the environment.

Post-closure inspection and maintenance will be minimized to the extent possible by the design of the closure cover system and additional site security measures. Post-closure inspections and maintenance activities will include the following:

- General Facility Inspection: visually inspect condition of fences, gates, and locks for breaks, gaps, and damage; inspect monuments for condition and legibility; confirm that gates properly close and lock; and inspect condition of vegetative cover.
- Warning Sign Inspection: inspect visibility from at least 8 m (25 ft) and legibility from 8 m (25 ft).
- Cover Inspection: observe cover for erosion, settlement, subsidence, displacement, burrowing, and plant growth.
- Run-on/Runoff Inspection: visually inspect control structures and drainage system for presence of erosion and shifting from storms or precipitation.
- Maintenance activities will be based on inspection results. Custodial maintenance or repair actions may include repairing of fences, replacing warning signs, re-establishing location control monuments, removing unwanted vegetation, reconstructing slopes, covers, or embankments.
- The condition of any surveyed subsidence marker will be inspected every six months. In addition, all survey markers will be resurveyed on an annual basis to determine if the covers have subsided.
- A survey of the boundary monuments regarding their placement and verification of the condition of each boundary marker will be performed. Any problems will be noted on the inspection form and repairs made.

- During each inspection, any changes in the condition of the closure cover, vegetation, or fenced area will be documented. Specific changes noted on the current condition of the cover include, but are not limited to, trash and debris within the fenced compound, animal burrows or nesting activity, and erosion of the cover.
- Cracks or settling imperfections of 2.5 to 15 cm (1 to 6 in.) deep on the cover will be documented and scheduled for repair on an annual basis. No action will be taken for cracks or settling imperfections of less than 2.5 cm (1 in.). Larger disruptions of the cover (animal diggings or erosion) will be immediately evaluated, repaired within 90 days, and documented.

All repair work to the cover will ensure that the integrity of the cover and design is maintained "as built." For RCRA-regulated disposal units, if cover repair requires modifications of the closure-cover design, NNSA/NSO will present a formal design modification request to NDEP prior to making the design modification.

Closure and post-closure monitoring documentation will be maintained in the Area 5 RWMS files and at the NNSA/NSO Technical Library in North Las Vegas. The files will be available for inspection and review upon request.

3.2.4.2 Protection from Adverse Impact

Protection of the groundwater, human health, and the environment are primary concerns following final closure of the Area 5 RWMS. The following sections discuss measures to ensure that these resources are not adversely impacted by the facility.

3.2.4.2.1 Groundwater

Sections 2.6 and 2.9, which include discussions of the geology and hydrology of the sites and how moisture migrates through the unsaturated zone, demonstrate that past, current, and future operations at the Area 5 RWMS will not impact the underlying groundwater in the alluvial aquifer.

Performance monitoring of the unsaturated zone during the operational phase of the RWMSs has not detected migration of moisture deeper than 2.1 m (7 ft) at the base lysimeter. Although this does not reflect evapotranspiration of vegetated landfill cover, no impact to the groundwater has occurred using the current design of the disposal units. During the closure and post-closure phase, the design of the closure cover and drainage system limits infiltration to less than that during operations and prevents water runoff.

Performance monitoring at the Area 5 RWMS lysimeters will provide data on the moisture content of soils and the potential for downward or upward movement of liquids. By conducting performance monitoring, any potential changes in moisture content will be detected and appropriate remedial measures implemented to prevent continued downward movement of liquid.

3.2.4.2.2 Human Health and Environment

The Area 5 RWMS will be monitored and inspected during the closure and post-closure care periods to ensure public safety and human health and to prevent damage to the environment. The monolayer-ET closure cover design does not include a barrier against IHI. The thickness of the cover provides partial protection, since significant effort must be undertaken to expose the waste zone. Site security, long-term institutional control, and controlled facility access will prevent human intrusions.

3.2.4.3 Site Security

The security plan for the Area 5 RWMS will be part of the final closure plan. The disposal areas currently are secured 24 hours a day, 7 days a week. Security is maintained with the following systems:

- Access requiring prior authorization and an escort, if not previously authorized to enter
- Perimeter markers, a perimeter fence, and gated access road to the disposal-unit area, with postings of the hazards and access requirements

The fences will prevent access to most animals to eliminate their ingestion of the native vegetation, while keeping unauthorized personnel from performing intrusive activities at the site.

Overall security at NTS is maintained 24 hours, 7 days a week by highly trained security personnel. Security of the Area 5 RWMS will continue during the post-closure care period and will include the following:

- Posted warning signs designating site dangers
- Fences to keep out unauthorized personnel
- Controlled site access for specific disposal units
- Perimeter inspections to check for signs of intrusion or fence deterioration/damage

3.2.5 Unrestricted Release of Sites

Public access to the NTS is currently restricted and will continue to be restricted as long as the NTS has an active national security mission. An active national security mission is assumed into the foreseeable future. If the NTS national security mission ends, the release of NTS land for public access will be constrained by historical contamination from atmospheric nuclear testing, underground nuclear testing, nuclear rocket testing, and radioactive waste disposal. Remediation and closure of historically contaminated sites on the NTS is regulated by the FFACO (1996 [as amended, 2008]) between NNSA/NSO, the State of Nevada, and the U.S. Department of Defense. The FFACO defines a RCRA-like process for remediation and closure of CAUs and requires the State of Nevada to review and approve all corrective actions. Release of land for public access is also subject to the requirements of DOE O 5400.5, Change 2.

NNSA/NSO has implemented the UGTA Sub-Project and the Environmental Restoration Project (Soils Project) to close UGTAs and contaminated soil sites under the FFACO (1996 [as amended, 2008]). The State-accepted remediation option for UGTA closures is the identification of areas within the NTS where public access or groundwater use will be restricted in perpetuity. The dose to a future MOP who may have access to lands in Frenchman Flat has been evaluated in the CA for the Area 5 RWMS. The CA considered all sources of residual radioactive material, assuming that the soils sites may not be cleaned up and restricted areas that will be identified by the UGTA program will be in effect, and showed that a cumulative dose to a MOP who resides in Frenchman Flat will be below the CA dose limit of 100 millirem per year (mrem/yr) and dose constraint of 30 mrem/yr. The current CA does not show the extent of the restricted areas. The restricted areas will be incorporated into the CA under the PA Maintenance Plan when the UGTA Program completes the necessary site characterization and modeling and the boundaries of the restricted areas are agreed upon between the State of

Nevada and NNSA/NSO. The CADD identifying the UGTA CAU boundaries is expected to be finalized in FY 2012.

3.3 MONITORING

Monitoring at the Area 5 RWMS and its surroundings is conducted under a variety of regulatory drivers, including federal regulations and DOE orders.

The NTS-wide monitoring follows the Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 2003). The RREMP brings together site-wide environmental surveillance, site-specific effluent monitoring, and operational monitoring conducted by various missions, programs, and projects on the NTS. The plan provides an approach to identifying and conducting routine radiological monitoring at the NTS, based on integrated technical, scientific, and regulatory compliance data needs. The RREMP uses a decision-based approach to identify the environmental data that must be collected and provides Quality Assurance, Analysis, and Sampling Plan (QAASP), which ensures that defensible data are generated. The approach is based on a modification of the EPA's DQO process (EPA, 1994), a seven-step process that calls for identification of the decisions that data collection activities must support, and uses a logical structure to develop the plan for data collection and analysis.

The detailed steps of the process for each media are presented in Appendix E of the RREMP. During the design process, existing and historical site information and regulatory requirements were reviewed. A summary of the site characteristics, transport and exposure pathways, regulatory requirements, and historical data were evaluated for each medium in preparation of the RREMP to support the monitoring designs.

Monitoring data specifically collected at the Area 5 RWMS are used for the following:

- Demonstrate compliance with DOE O 450.1 and DOE O 435.1
- Confirm PA assumptions regarding the hydrologic conceptual model including soil-water contents and upward and downward flux rates
- Test the PA performance objective of protecting groundwater resources
- Demonstrate negligible infiltration of precipitation into waste zones
- Detect changing trends in performance
- Establish baseline levels for long-term monitoring
- Comply with NDEP-negotiated requirements at Pit P03U MWDU

Monitoring is also conducted at the Area 5 RWMS to ensure the integrity of operational covers over waste disposal units. The monitoring program is designed to sufficiently forewarn management and regulators of any need for mitigative actions and to record the utility of any mitigative actions.

Review of monitoring data for routine PA maintenance is an iterative process that will ultimately dictate which monitoring data should continue to be collected during the post-closure care period, and which monitoring data are no longer required.

The elements of the pre-closure and post-closure monitoring plan for the Area 5 RWMS are presented.

3.3.1 Pre-Closure Monitoring

The current monitoring at the Area 5 RWMS consists of both regulatory-driven monitoring elements as well as best management practices. The current monitoring system consists of the following elements:

- Vadose zone monitoring
- Groundwater detection monitoring
- Radon monitoring
- Meteorology monitoring
- Direct radiation monitoring
- Biota monitoring
- Subsidence monitoring
- Air monitoring
- Soil temperature monitoring around disposed radioisotope thermonuclear generators (RTGs)

Monitoring activities are summarized in Table 3-8. Current monitoring locations are shown in Figure 3-6 and Figure 3-7.

3.3.1.1 Vadose Zone Monitoring

Vadose zone monitoring is conducted to confirm the key assumption of no downward pathway of the NTS PAs, to detect changes in system performance, and to establish baseline data for long-term monitoring. The vadose monitoring system consists of weighing lysimeters and instrumented operational covers. Two precision weighing lysimeters have been in continuous operation since March 1994. One lysimeter is vegetated with native plant species at the approximate density of the surrounding desert, and the other lysimeter is kept bare to simulate operational covers. The lysimeters are capable of measuring changes in storage of ± 800 grams or ± 0.1 millimeter of water. Additionally, both lysimeter soil columns are instrumented with TDR probes for volumetric water content and heat dissipation probes (HDPs) for matric potential and soil temperature measurements. Three operational covers and one pit floor are instrumented with TDR probes. Sensors are installed throughout the cover profile to a depth of 180 cm. HDP arrays are also installed in two of the operational covers. Vadose zone sensors are typically read once a day.

Table 3-8. Monitoring Activities at the Area 5 RWMS.

Monitoring Element	Area 5 RWMS
Vadose Zone Monitoring	• Measurements of soil water content and water potential in waste disposal unit covers • Measurements of soil water content in waste disposal unit floor • Two weighing lysimeters (vegetated and bare) for water balance since 1994
Groundwater Monitoring	• RCRA detection monitoring at three wells
Radon Monitoring	• Radon flux measurements from waste covers (various locations)
Meteorology Monitoring	• Air temperature at two heights • Relative humidity at two heights • Wind speed at two heights • Wind direction at two heights • Barometric pressure • Solar radiation • Precipitation
Direct Radiation Monitoring	• Ten thermoluminescent dosimeters (TLDs)
Biota Monitoring	• Sampling vegetation for tritium
Subsidence Monitoring	• Routine inspection of operational covers
Air Monitoring	• Air particulates sampled at two locations; atmospheric moisture sampling for tritium at two locations
Soil Temperature Monitoring around RTGs	• Vertical and horizontal sensor arrays

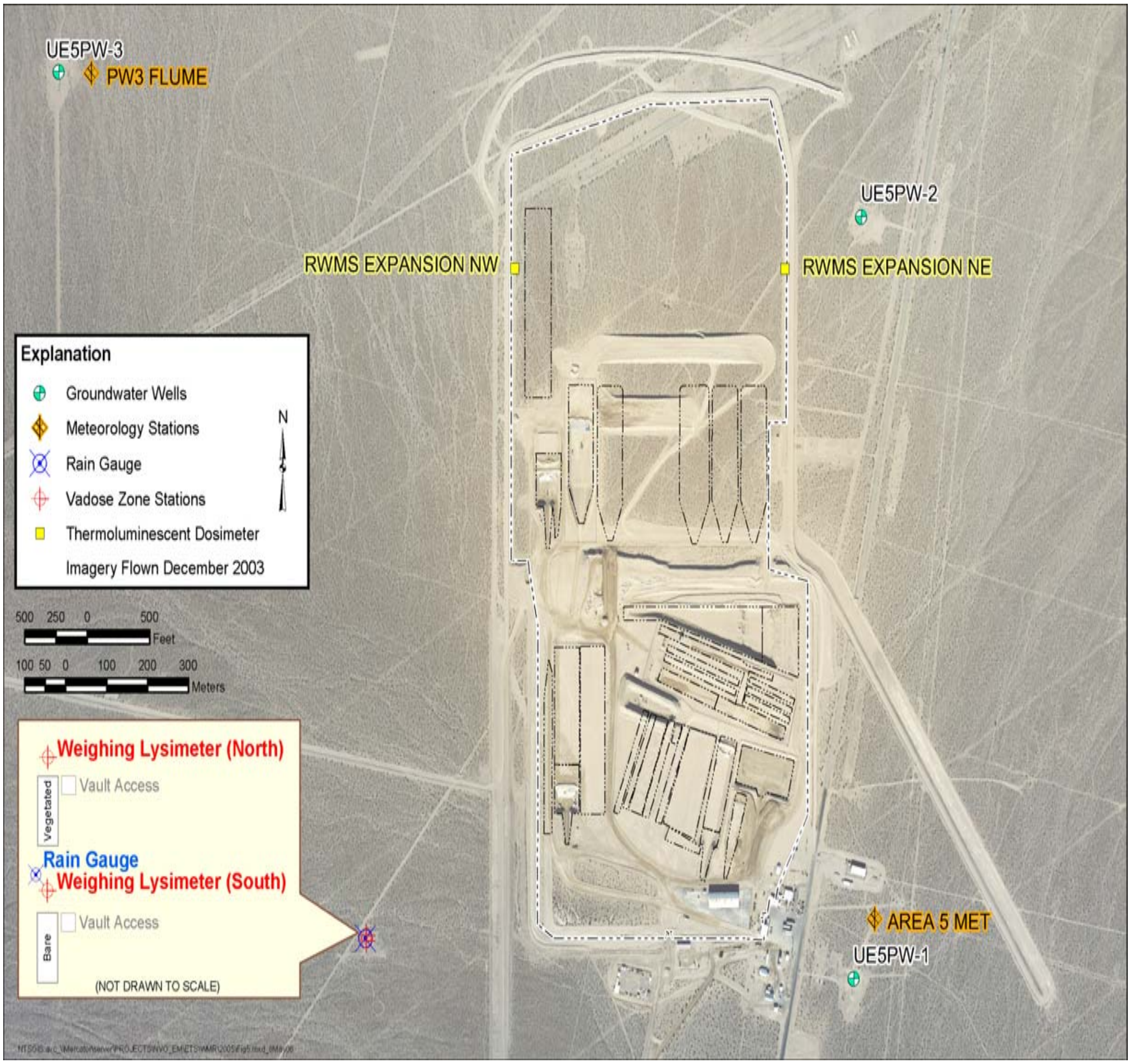


Figure 3-6. Location of the Area 5 RWMS Pilot Wells and Weighing Lysimeter Facility.

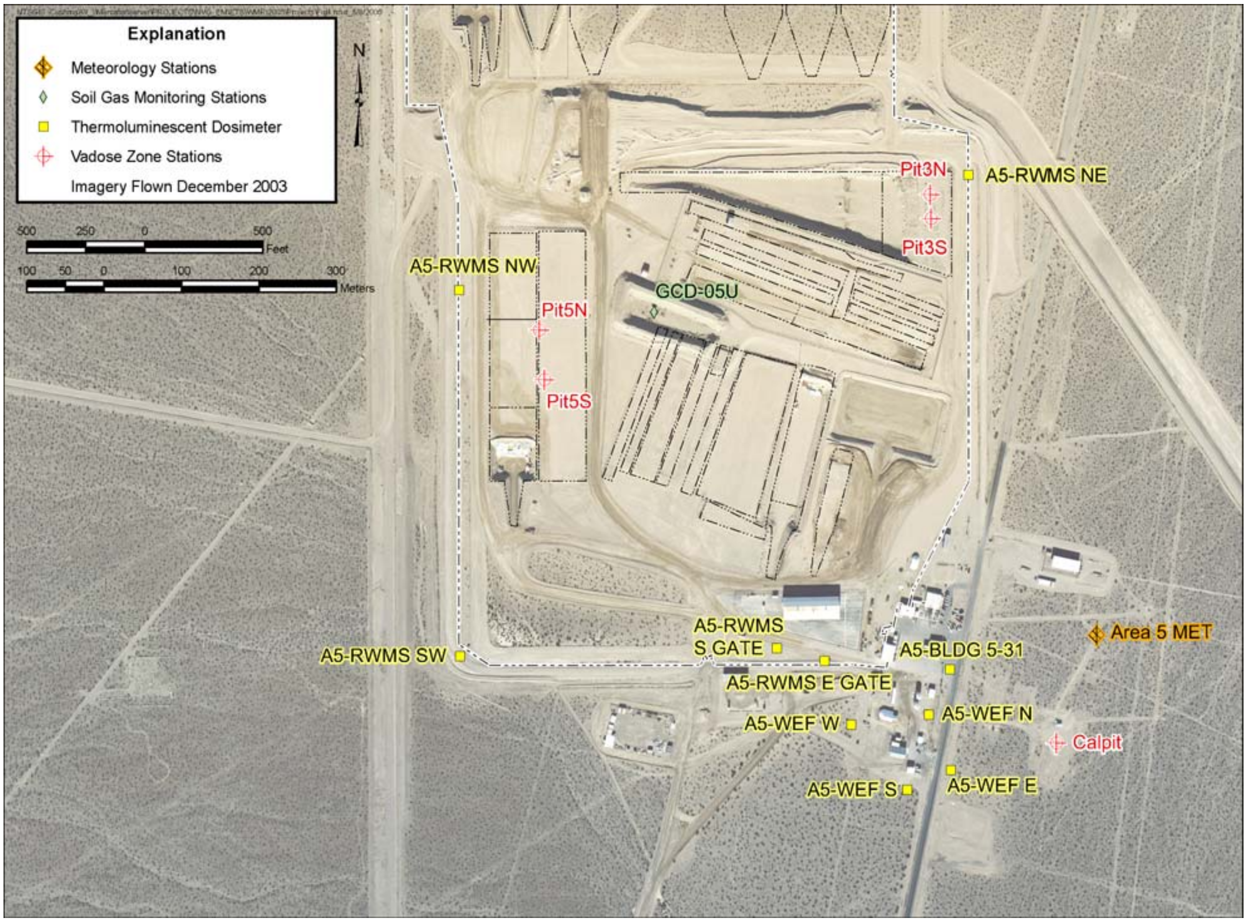


Figure 3-7. Monitoring Stations at the Area 5 RWMS.

In the past, soil moisture contents were measured using neutron logging. This has been replaced with TDR probes. Heat dissipation probes are used to measure soil-water potentials.

This strategy provides an accurate estimate of the water balance for the disposal units including any drainage through the waste covers and, therefore, potential percolation below the waste zone.

The current vadose zone monitoring program is designed based on a strong understanding of the vadose zone system from the results of extensive vadose zone characterization studies (Shott et al., 1998; 2000; Tyler et al., 1996) and modeling studies (Crowe et al., 1998b; Levitt et al., 1999). In addition, the vadose zone monitoring program is designed in part from the results of an Alternative Evaluation Study on vadose zone monitoring (BN, 1998a) using an organized team approach and, in part, from successful vadose zone monitoring field experience.

Vadose zone monitoring data are reported in an annual monitoring report (NSTec, 2008b). Details of the RWMS vadose zone monitoring activities can be found in NSTec OI-2154.111, “Instructions for Datalogger Monitoring Stations.”

Results from the lysimeter facilities at the NTS will help assess performance of future monolayer-ET covers at the Area 5 RWMS.

3.3.1.2 Groundwater Monitoring

Groundwater monitoring is conducted at the three pilot wells surrounding the Area 5 RWMS as required by 40 CFR 265. These wells were originally drilled in 1993 as characterization wells for determination of physical and chemical properties of drill core, chemical properties of groundwater in the uppermost aquifer, and depth to the uppermost aquifer. In February 1994, NDEP stated that the pilot wells appear to meet the applicable design, construction, and development criteria for RCRA groundwater monitoring wells. On March 31, 1998, NDEP concurred with the sampling frequency, indicator parameters, and investigation levels submitted in the groundwater monitoring outline in the March 1, 2008, Groundwater Monitoring Program.

Groundwater from pilot wells is sampled semiannually for the following parameters (BN, 1998b):

Indicators of contamination:

- pH
- specific conductance
- total organic carbon
- total organic halogen
- tritium

General Water Chemistry Parameters:

- total Ca, Fe, Mg, Mn, K, Na, SiO_2
- total SO_4, Cl, F
- alkalinity

Investigation levels for these indicators of contamination can be found in BN (1998b). Details of pilot well construction can be found in BN (2004).

Additional groundwater monitoring requirements were driven by DOE orders and, independent of EPA requirements, were determined through a DQO-driven process and are detailed in the RREMP (BN, 2003). Groundwater monitoring analytes identified in the RREMP include:

- tritium
- gross alpha
- gross beta
- gamma spectroscopy
- plutonium-238 and plutonium-239+240

The groundwater monitoring frequency identified in the RREMP is biennial. All groundwater sampling data from the Area 5 RWMS pilot wells to date indicate that the groundwater in the uppermost aquifer has not been affected by RWMS or past weapons testing activities. Tritium concentrations in groundwater beneath the Area 5 RWMS have never exceeded the method detection limit for enriched tritium analysis (approximately 15 picocuries per liter). Groundwater elevation data indicate that the water table beneath the Area 5 RWMS is nearly flat, with groundwater flowing in a northeastern direction at a horizontal velocity of approximately 23 cm (9 in.) per year (BN, 2004).

Groundwater monitoring data are presented in detail in the annual groundwater monitoring data report (e.g., BN, 2004). Details of the Area 5 RWMS groundwater monitoring activities can be found in Appendix B of the RREMP (BN, 2003) and the Area 5 RWMS groundwater monitoring Organization Instructions OI-2154.108, "Instructions for Area 5 RWMS Groundwater Well Preparation and Groundwater Sampling," and OI-2154.104, "Preparing and Sampling Routine Radiological Environmental Monitoring Plan (RREMP) Groundwater Wells."

3.3.1.3 Radon Monitoring

Radon flux monitoring has been conducted at various locations within the Area 5 RWMSs since 2000. In 2006, radon flux measurements resulted in a mean flux of 0.037 Bq/m^2/s for the Area 5 RWMS. Results indicate that radon flux from waste covers is similar to undisturbed background locations and well below the 0.74 Bq/m^2/s performance objective of the DOE O 435.1. These results are consistent with radon flux calculations in the PA models.

3.3.1.4 Meteorology Monitoring

Detailed meteorological data are collected at the Area 5 RWMS. Measurements include precipitation, air temperature, relative humidity, wind speed and direction, barometric pressure, and incoming solar radiation. Hourly data are recorded. These basic meteorological parameters are required to quantify the exchange of water and heat between the soil and atmosphere. Meteorological measurements are taken to (1) confirm that the RWMS is sited in an arid environment, (2) use as input for process level models, and (3) refine PA/CA parameter distributions.

Meteorology monitoring data are reported in an annual monitoring report (NSTec, 2008b). Details of the RWMS meteorology monitoring activities can be found in NSTec OI-2154.111, "Instructions for Datalogger Monitoring Stations."

3.3.1.5 Direct Radiation Monitoring

The direct radiation monitoring is conducted to confirm that RWMS activities do not result in significant exposure above background levels, in compliance with DOE O 450.1, DOE O 5400.5, and DOE O 435.1, and the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE, 1991).

Figure 3-7 shows thermoluminescent dosimeter (TLD) locations at the Area 5 RWMS. Details of the direct radiation monitoring activities can be found in the NTS Routine RREMP and Organization Instruction OI-2154.109, "Radiation Monitoring Using Thermoluminescent Dosimeters."

3.3.1.6 Biota Monitoring

On January 15, 2003, DOE O 450.1, "Environmental Protection Program," was approved and added specific requirements for the protection of other natural resources including biota, and to evaluate the potential impacts to biota in the vicinity of DOE activities. To demonstrate compliance with these requirements, DOE technical standard DOE-STD-1153-2002, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," was developed by the DOE's Biota Dose Assessment Committee. This standard describes a graded approach for evaluating radiation doses to biota and set the following dose limits that, based on current scientific understanding, are protective of populations of biota:

- Dose limit to aquatic animals = 1 rad/day (10 milligray/day)
- Dose limit to terrestrial plants = 1 rad/day (10 milligray/day)
- Dose limit to terrestrial animals = 0.1 rad/day (1 milligray/day)

Monitoring of radionuclides in biota are done to evaluate potential dose to biota, and to humans consuming game animals, and to evaluate the possible transport of radionuclides from waste disposal areas.

Biota monitoring consists of sampling vegetation for analyses including tritium, gamma-emitting radionuclides, and transuranics. If radionuclide concentrations in vegetation are high, wild game animals may be sampled. Vegetation sampling may be limited year to year, depending on rainfall and waste cover operations during operational closure. Vegetation from, on, and near waste covers, as well as vegetation from control areas far from waste covers, typically are sampled in mid-summer and analyzed for tritium. Timing of the sampling is important because vegetation is forced to remove soil-water from greater depths (closer to waste) as surface soils dry out in summer. Plant water is extracted from the vegetation samples by room temperature vacuum distillation and analyzed by liquid scintillation for tritium. Animals (and soil from animal burrows) will be monitored for radionuclides if warranted by increasing tritium concentration trends in vegetation or if animal burrows on or near waste covers are observed in significant numbers.

3.3.1.7 Subsidence Monitoring

Subsidence monitoring consists of routine inspections of operational and final waste covers for subsidence features such as cracks and depressions, ponding, and erosion. When such features are observed, their locations are recorded using a Global Positioning System unit and digital camera, and operations personnel are informed to take corrective action.

Subsidence monitoring is conducted monthly at all disposal units. Subsidence has been formally monitored since 2000. Subsidence occurs most commonly in recently filled disposal units, especially along the edges where soil backfill may not be completely compacted. Subsidence monitoring ensures that subsidence features are repaired to maintain the integrity of the closure cover. No significant subsidence was observed at the Area 5 RWMS.

Details of the RWMS subsidence monitoring activities can be found in an annual monitoring report (NSTec, 2008b). The effectiveness of subsidence monitoring will be periodically evaluated.

3.3.1.8 Air Monitoring

The regulatory drivers for the air monitoring network include 40 CFR 61, Subpart H; DOE O 450.1; DOE O 5400.5; and Guidance Document DOE/EH-0173T (DOE, 1991). Details of the DQO, sampling strategy, field operations, analytical design, analytes, and methods, and quality control checks are described in Appendix A of the RREMP (BN, 2003). Air particulate samples are collected using continuously operated low-volume air samplers and are analyzed for gross alpha/beta radioactivity, gamma emitters, americium, and plutonium concentrations in air. Atmospheric moisture is collected and analyzed for tritium. Tritium is a volatile radionuclide and is therefore a conservative indicator of waste-disposal unit performance.

Air particulate samples are collected at air sampling stations at two locations at the Area 5 RWMS. Tritium in atmospheric moisture is collected at the Area 5 RWMS at two locations.

Siting of the air samplers was based on the RREMP DQO process. Important siting decision factors included wind patterns and historic analytical data. In Area 5, wind direction is generally northerly or southerly. Therefore, air sampling stations are sited at locations north and south of of the RWMS.

Annual air monitoring data are reported in the Nevada Test Site Environmental Report (NTSER) (NSTec, 2008d), the National Emissions Standards for Hazardous Air Pollutants (NESHAP) report (NSTec, 2008e), and the Annual Waste Management Monitoring Report (NSTec, 2008b).

Details of the RWMS air monitoring activities are in Appendix A of the RREMP (BN, 2003); NSTec OI-2154.102, "Preparing and Sampling Routine Radiological Environmental Monitoring Plan for Airborne Particulates"; and OI-2154.103, "Tritiated Water Vapor Sampling."

3.3.1.9 Soil Temperature Monitoring

Four RTGs were disposed in P05U in 2006 in an approximately square configuration. To monitor the heat field generated from these waste packages, vertical and horizontal arrays of temperature sensors were installed adjacent to the largest curie inventory RTG package. Starting at the RTG package, sensors were placed every 0.3 m (1 ft) to a distance of 4 m (13 ft) from the package in each array. Hourly average temperature measurements are collected. Temperature data collected will be used to calibrate a heat flow model and optimize spacing between future RTG disposals and other low-level waste with volatile radionuclides.

3.3.1.10 Data Management

Auditable and defensible data management practices are used throughout the environmental monitoring planning and execution processes from developing the DQOs bases for the monitoring designs to reporting and archiving. The systems used vary depending on the type of data being managed and the management needs for the data.

The primary data management mechanisms supporting radiological environmental monitoring are the following:

- RREMP (BN, 2003) – Documents application of a modified version of the EPA's DQO process (EPA, 1994).
- Procedures and Instructions – These categories of documents implement the RREMP, and provide execution direction to employees to ensure clear and consistent work execution.
- Field Operations documentation – Data generated during field activities are entered by personnel in the field in logbooks, notebooks, hardcopy forms, and/or electronic forms loaded on a laptop or tablet PC. Field data may subsequently be entered or transferred to an electronic data management system.
- Measurement data – These data cover a variety of types:
    - Vadose and meteorological data are downloaded remotely via cellular communications.
    - Environmental thermoluminescent dosimeters (ETLDs) are processed by the NSTec Radiological Control Department and the data provided in electronic form.
    - Analytical Laboratory data are produced from analyses of samples collected under the RREMP, and are provided in hardcopy and electronic format.
    - All data are processed through quality reviews determined necessary to ensure the validity of the data for their intended use.

- All RWMS monitoring data are managed in an electronic data management system. An Environmental Integrated Data Management System is currently used to manage ETLDs and laboratory generated data. An Oracle™-based relational database management system used for the comprehensive management and processing of environmental data, the Environmental Integrated Data Management System, ensures consistency and promotes advanced planning, while providing a central repository for all unclassified environmental data.
- Monitoring Reports – Data are presented in reports as required by CFRs, DOE orders and directives, or as otherwise determined necessary.
- Archiving – All data are archived as required, and in a manner (hardcopy and/or electronic) that allows for retrieval.

3.3.1.11 Data Evaluation and Data Reporting

Evaluation of all monitoring data is conducted routinely (minimum once per year), and conclusions of those evaluations are incorporated into one or all of the applicable annual data reports including the NTSER (NSTec, 2008d); the NESHAP report (NSTec, 2008e); and the Annual Waste Management Monitoring Report (NSTec, 2008b). Examples of review performance documents include:

- OI-2154.117, "Verification, Validation, and Data Review of Environmental Monitoring Program Data Stored in the NSTec Environmental Integrated Data Management System Database"
- OI-2154.457, "Radioanalytical Data Verification and Validation"
- OI-2154.458, "Organic Data Verification and Validation"
- OI-2154.459, "Inorganic Data Verification and Validation"

The NSTec performance documents describing preparation of the NESHAP report and NTSER (also referred to as Annual Site Environmental Report) include:

- OI-2154.105, "Development of the Annual National Emission Standards for Hazardous Air Pollutants (NESHAPS) Report for the NTS and Offsite Dose Assessment"
- Company Directive CD-B500.001, "Preparation of the Annual Site Environmental Report"

3.3.1.12 Organizational Instructions

The OIs required for routine monitoring include:

- OI-2154.102, "Preparing and Sampling Routine Radiological Environmental Monitoring Plan for Airborne Particulates"
- OI-2154.103, "Tritiated Water Vapor Sampling"
- OI-2154.106, "Neutron Moisture Logging"
- OI-2154.107, "Radon Monitoring Using the E-PERM System"
- OI-2154.108, "Instructions for Area 5 RWMS Groundwater Well Preparation and Groundwater Sampling"
- OI-2154.109, "Radiation Monitoring Using Thermoluminescent Dosimeters"

- OI-2154.110, "Biota Sampling and Sample Preparation for Animals and Vegetation"
- OI-2154.111, "Instructions for Datalogger Monitoring Stations"

3.3.1.13 Quality Assurance

The RREMP is designed to ensure satisfying the quality assurance requirements of 10 CFR 830, Subpart A, and DOE O 414.1C.

The RREMP QAASP specifies the sampling, analytical, quality assurance, and quality control procedures for obtaining technically defensible data of acceptable quality to satisfy the project objectives. The QAASP includes guidance for data verification, validation, and quality assessment. Detailed QAASPs for air, water, biota, and direct radiation media can be found in Appendices A through D of the RREMP (BN, 2003).

3.3.2 Post-Closure Monitoring

Post-closure monitoring will be performed at the Area 5 RWMS during the 100-year institutional control period. The current monitoring activities that are regulatory driven in agreement with the State of Nevada will likely continue past the 2028 closure date of the Area 5 RWMS, such as the groundwater monitoring. NNSA/NSO will identify the elements of the final post-closure monitoring plan for the Area 5 RWMS, consistent with the following criteria in 40 CFR 194.42:

- Address significant disposal system parameters.
- Address important disposal system concerns.
- Obtain meaningful data in a short period of time.
- Preserve disposal system integrity.
- Be consistent and complementary with other monitoring programs.

Significant and important system parameters are identified through the sensitivity analyses of the performance assessments of the Area 5 RWMS. First, a summary description of the hydrologic conceptual model of the Area 5 RWMS is presented. This conceptual model is implemented in the probabilistic PAs of the Area 5 RWMS (LLW PA under DOE O 435.1 and the GCD TRU PA under 40 CFR 191). Second, sensitivity analyses performed for each PA are summarized. A preliminary monitoring plan is developed, considering the results of the SA. In the final post-closure monitoring plan, the monitoring data collected at the Area 5 RWMS through 2028 will also be evaluated to aid the determination of the monitoring elements and frequencies and durations.

3.3.2.1 Elements of the Post-Closure Monitoring

The SAs of the LLW PA and the GCD PA indicate that the radon emanation factor for waste in shallow land burial, the parameters for small mammal burrowing, technetium plant/soil concentration ratio for the garden scenario are the significant parameters for the Area 5 RWMS performance under DOE O 435.1, and the number of boreholes, and upward advection are the most significant parameters for the performance of the GCD TRU boreholes. Long-term disposal system concern includes subsidence of the cover with the consequent enhancement of moisture in the subsided cover and of plant and animal activity. There is small risk that enhanced moisture, plant, and animal activity may result in increased releases from the Area 5 RWMS disposal cells that are not accounted for in the ranges of parameter values used in the

PAs for these parameters. The only significant factor for release of TRU waste from the GCD boreholes, which is also a disposal system concern, is the drilling rate.

Monitoring for cover subsidence and cover maintenance, biota monitoring, and vadose zone monitoring may be included in the post-closure monitoring at the Area 5 RWMS. Groundwater monitoring at the Pilot wells for RCRA compliance for Pit P03U MLLW unit may continue past the closure date of 2028 for the Area 5 RWMS. No additional monitoring for the GCD TRU boreholes is warranted. However, NNSA/NSO may decide to further evaluate the drilling rates before the facility closes.

In summary, monitoring activities during the post-closure period are expected to be reduced and limited to:

- Vadose zone monitoring of at the lysimeter facility
- Biota monitoring
- Subsidence monitoring

The decision to continue or terminate any monitoring activities during the post-closure period will be based on PA modeling, assessment of monitoring results against conceptual models, uncertainty and sensitivity analysis as well as the evaluation of the past monitoring records for future trends in the data.

3.3.2.2 Data Management

A database similar to the Environmental Integrated Data Management System is expected to be used for the comprehensive management and processing of environmental data during the post-closure period. Details of such a data management system will be presented in the final closure plan.

3.3.2.3 Data Evaluation and Data Reporting

Frequency of data evaluation and reporting for the post-closure care period will depend upon the monitoring program to be implemented in the final closure plan.

3.3.2.4 Organization Instructions

The organization instructions required for routine monitoring during the post-closure period will be similar to the ones presented previously, and will be presented in the final closure plan.

3.3.2.5 Quality Assurance

The currently applicable QAASPs will remain in effect during the post-closure care period.

4.0 CLOSURE SCHEDULE

As operations continue at the Area 5 RWMS, this closure plan will be updated to reflect the most current operational features that must be considered during closure. The schedule for final closure of the facility will be developed in 2028.

A schedule for post-closure monitoring and maintenance activities will also be developed as part of the final closure plan.

Activities associated with the final closure of the 92-Acre Area are scheduled to be completed in FY 2011. Activities associated with final closure of the Area 5 Expansion Area north of the 92-Acre Area are scheduled to start in FY 2028 and be completed in FY 2029. The major activities scheduled for the closure of the 92-Acre Area are the following:

- 92-Acre Area DQO document submittal and approval by the NDEP by the end of 2008
- Draft 92-Acre Area CADD/CAP document submittal to NDEP by the end of 2008
- Development of the final CADD/CAP and approval by NDEP in March 2009
- Completion of the final closure cover design, issued for construction in February 2009
- Construction of the closure cover starting in February 2011
- Completion of the closure report (certification of closure) in July 2011

Near-term actions that will support the closure of the 92-Acre Area include:

- Optimizations of the final closure cover thickness to be incorporated into the final closure cover design
- Acceptance by the TRFG of the measures implemented in this plan to meet the GCD assurance requirements under 40 CFR 191
- Placements of soil to improve performance of interim soil covers and ensure appropriate site drainage
- Filling the neutron probes and the GCD boreholes
- Removing the GCD trailer

Major activities that would be undertaken prior to the closure of the Area 5 RWMS in FY 2028 and those immediately after the final cover construction over the expansion area disposal cells include the following:

- Preparation and approval of the final PA document by LFRG
- Preparation and approval of the final CA document by LFRG
- Preparation of the final closure and post-closure care plan
- Design and implementation of the assurance requirements for the GCD boreholes
- Final design of the closure cover over the disposal cells in the Expansion Area
- Construction of the closure cover over the disposal cells in the Expansion Area
- Initiation of the post-closure monitoring

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APPENDIX A

TITLE II ENGINEERING COVER DESIGN DRAWINGS

08023-G-0001	Title Sheet
08023-G-0002	Abbreviations
08023-C-0001	Civil Symbols, notes, and legend
08023-C-0002	Area 5 RWMS Location Maps
08023-C-0003	Existing Site and Demolition Plan
08023-C-0004	New Site and Horizontal Control Plan
08023-C-0005	New Closure Cover Grading Plan
08023-C-0006	North Drainage Plan and Profile
08023-C-0007	Center Drainage Plan and Profile
08023-C-0008	East Drainage Plan and Profile
08023-C-0009	South Drainage Plan and Profile
08023-C-0010	New Fencing Plan (South)
08023-C-0011	New Fencing Plan (North)
08023-C-0012	New Monument and Signage Plan
08023-C-3001	Closure Cap Grading Sections
08023-C-3002	Closure Cap Grading Sections
08023-C-3003	Closure Cap Grading Sections
08023-C-3004	Closure Cap Grading Sections
08023-C-0005	Closure Cap Grading Sections
08023-C-5001	Chain Link Fencing Details
08023-C-5002	Smooth Wire Fencing Details
08023-E-0001	Electrical Site Plan
08023-E-1002	Electrical Plan
08023-E-5001	Trench Detail

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NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

RADIOACTIVE WASTE MANAGEMENT SITE

FINAL CLOSURE COVER DESIGN

AREA 05 (SOUTH 92 ACRES)

DRAWING INDEX

DRAWING NUMBER		DRAWING TITLE
TITLE		
08023-G-0001	REV A	TITLE SHEET
08023-G-0002	REV A	ABBREVIATIONS
CIVIL		
08023-C-1001	REV A	CIVIL SYMBOLS, NOTES & LEGEND
08023-C-1002	REV A	AREA 5 RWMS LOCATION MAPS
08023-C-1003	REV A	EXISTING SITE & DEMOLITION PLAN
08023-C-1004	REV A	NEW SITE & HORIZONTAL CONTROL PLAN
08023-C-1005	REV A	NEW CLOSURE COVER GRADING PLAN
08023-C-1006	REV A	NORTH DRAINAGE PLAN & PROFILE
08023-C-1007	REV A	CENTER DRAINAGE PLAN & PROFILE
08023-C-1008	REV A	EAST DRAINAGE PLAN & PROFILE
08023-C-1009	REV A	SOUTH DRAINAGE PLAN & PROFILE
08023-C-1010	REV A	NEW FENCING PLAN (SOUTH)
08023-C-1011	REV A	NEW FENCING PLAN (NORTH)
08023-C-1012	REV A	NEW MONUMENT & SIGNAGE PLAN
08023-C-3001	REV A	CLOSURE CAP GRADING SECTIONS
08023-C-3002	REV A	CLOSURE CAP GRADING SECTIONS
08023-C-3003	REV A	CLOSURE CAP GRADING SECTIONS
08023-C-3004	REV A	CLOSURE CAP GRADING SECTIONS
08023-C-3005	REV A	CLOSURE CAP GRADING SECTIONS
08023-C-5001	REV A	CHAIN LINK FENCING DETAILS
08023-C-5002	REV A	SMOOTH WIRE FENCING DETAILS
ELECTRICAL		
08023-E-1001	REV A	ELECTRICAL SITE PLAN
08023-E-1002	REV A	ELECTRICAL PLAN
08023-E-5001	REV A	TRENCH DETAIL

SCOPE OF WORK

THE PURPOSE OF THIS PROJECT IS TO PROVIDE DETAILED TITLE II DESIGN FOR RCRA EQUIVALENT 3 METER FINAL CLOSURE COVERS TO BE PLACED ON THE EXISTING WASTE DISPOSAL PITS LOCATED WITHIN THE SOUTH 92 ACRE PORTION OF THE NTS AREA 5 RWMS.

THIS CLOSURE CAP DESIGN DOES NOT IMPACT THE CONTINUED OPERATIONS OF ACTIVE STORAGE PITS LOCATED IN THE AREA 5 RWMS NORTH EXPANSION AREA.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

Reviewed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.

Derivative Classifier: RICHARD RM MORTON NSTE Engr (Name/Organization)

Date: 4/1/08

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
TITLE SHEET

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

National Security Technologies LLC
Vision • Service • Partnership
NEVADA OPERATIONS
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER 08023-G-0001
REVISION A

ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION

ABBREVIATIONS

ABANDON IN PLACE	AIP
ABOVE FINISHED FLOOR	AFF
ABOVE FINISH GRADE	AFG
ACRYLONITRILE BUTADIENE STYRENE PIPE	ABS
AGGREGATE	AGGR
AMERICAN WATERWORKS ASSOC.	AWWA
ANCHOR BOLT	AB
ARC LENGTH	L
ASBESTOS CEMENT PIPE	ACP
ASPHALTIC CONCRETE	AC
ASPHALT	ASPH
AUXILIARY	AUX
AVENUE	AVE
BACK OF CURB	BOC
BACKFLOW PREVENTER	BFP
BALL VALVE	BV
BASE LINE	BL
BEGIN CURVE	BC
BEGIN VERTICAL CURVE	BVC
BELOW FINISHED GRADE	BFG
BENCHMARK	BM
BITUMINOUS	BITUM
BLOCKING	BLKG
BORE HOLE	BH
BOTTOM OF SLOPE	BOS
BOULEVARD	BLVD
BOUNDARY	BDRY
BUILDING	BLDG
CAST IRON	CI
CABLE TELEVISION	CTV
CASEMENT	CSMT
CAST IRON PIPE	CIP
CATCH BASIN OR CURB INLET	CB
CENTER LINE	CL ℄
CENTER TO CENTER	C-C
CHECK VALVE	CHKV
CHLORINATED POLYVINYL CHLORIDE PIPE	CPVC
CLEAN OUT, SEWER	CO
CLOSED CIRCUIT TELEVISION	CCTV
CODE OF FEDERAL REGULATIONS	CFR
COLUMN	COL
COMMUNICATION LINES	COMM
COMM/FIBER UNDERGROUND	CUG
COMM/FIBER OVERHEAD	COH
COMMUNICATION MANHOLE	COMM MH
COMMUNITY ANTENNA TV	CATV
COMPRESSOR	COMPR
CONTINUATION	CONT
CONCRETE	CONC
CONCRETE MASONRY UNIT	CMU
CONSTRUCTION	CONSTR
CONSTRUCTION JOINT	CJ
CONTROL JOINT	CLJ
CORNER	COR
CORRUGATED METAL ARCH PIPE	CMAP
CORRUGATED METAL PIPE	CMP
CUBIC FEET	CU FT
CUBIC YARD	CU YD
CULVERT	CULV
CURB & GUTTER	C&G
DEPARTMENT OF ENERGY	DOE
DETENTION	DETN
DISCHARGE	DISCH
DISCONNECT	DISC
DISTRIBUTION BOX	DBOX
DOUBLE	DBL
DOWN SPOUT	DS
DRIVE or DRIVEWAY	DR
DRAINAGE DROP INLET	DI
DUCTILE IRON PIPE	DIP
EACH WAY	EW
EASEMENT	ESMT
EAST	E
EDGE OF CONCRETE	EC
EDGE OF PAVEMENT	EP
EDGE OF SHOULDER	ES
ELECTRIC	ELEC
ELEVATION	EL
EMBANKMENT	EMBK
EMERGENCY	EMER
END CURVE	EC
END VERTICAL CURVE	EVC
ENGINEER	ENGR
EQUALLY SPACED	EQL SP
EQUIPMENT	EQUIP
EXHAUST	EXH
EXISTING	EXIST
EXISTING GRADE	EXST GR
EXPANSION JOINT	EJ
EXTINGUISHER	EXT
EYE WASH STATION	EWS

FACE OF CONCRETE OR CURB	FOC
FACTORY MUTUAL	FM
FEET	FT
FENCE	FN
FINISH FLOOR	FIN FLR
FINISH GRADE	FIN GRD
FINISH FLOOR ELEVATION	FF EL
FIRE ALARM	FA
FIRE DEPARTMENT CONNECTION	FDC
FIRE DEPARTMENT VALVE	FDV
FIRE HYDRANT	FH
FIRE PROTECTION LINE	FP
FLANGE	FLG
FLOOR DRAIN	FD
FLOW LINE	FL ℄
FLOW METER	F METER
FOOT	FT
FOOTING	FTG
FOUNDATION	FDN
FUTURE	FUT
GAGE OR GAUGE	GA
GALLONS/HOUR	GPH
GALLONS/MINUTE	GPM
GALVANIZED	GALV
GAS COMPRESSOR STATION	
GAS METER	GM
GAS PRESSURE REGULATOR	GPR
GAS VALVE	GV
GATE VALVE	GTV
GENERATOR	GEN
GLOBE VALVE	GLV
GOVERNMENT	GOVT
GRADE BREAK	GR BR
GRADE LINE	GR LN
GRATE INLET (SEE DROP INLET)	
GRATING	GRTG
GREASE TRAP	GT
GREATER CONTAINMENT DISPOSAL TEST SITE	GCDT
GUARD RAIL	GDR
GUTTER	GUT
HANDICAP	HC
HANDRAIL	HNDRL
HAZARDOUS MATERIAL	HAZ MAT
HEADWALL	HDWL
HEATING, VENTILATING AND AIR CONDITIONING	HVAC
HEIGHT	HT
HIGH DENSITY POLYETHYLENE	HDPE
HIGH LEVEL (ALARM)	HL
HIGHWAY	HWY
HORIZONTAL	HORIZ
HORSEPOWER	HP
HOSE BIBB	HB
HOSPITAL	HOSP
IDENTIFICATION NUMBER	ID NO
INCH	IN
INSIDE DIAMETER	ID
INTERSECTION	INT
INVERT ELEVATION	INV EL
ISLAND	IS
IRON PIN	IP
IRON ROD	IR
JOINT	JT
JUNCTION BOX	JBBOX
KILOMETER	km
KILOVOLT AMPERE	kVA
KILOWATT	kW
LATITUDE	LAT
LEFT	LT
LENGTH	LG
LIFT STATION (SEWER)	L STA
LIGHTING	LTG
LIGHT POLE	LP
LINEAR FEET	LF
LIQUEFIED NATURAL GAS	LNG
LIQUEFIED PETROLEUM GAS	LPG
LIQUID OXEGEN	LOX
LIQUID NITROGEN	LN2
LONGITUDE	LONG
LOW LEVEL (ALARM)	LL
LUMP SUM	LS
MAGNETIC NORTH	MN
MAINTENANCE	MAINT
MANHOLE	MH
MANUFACTURER	MFR
MATERIAL	MATL
MAXIMUM	MAX
MEAN SEA LEVEL	MSL
METER	m
MILLION GALLONS PER DAY	MGD
MINIMUM	MIN
MONUMENT	MON
MOTOR OPERATED VALVE	MOV

NATIONAL FIRE PROTECTION ACT	NFPA
NATURAL GAS LINE	G
NEVADA TEST SITE	NTS
NON RISING STEM	NRS
NORTH	N
NOT IN CONTRACT	NIC
NOT TO SCALE	NONE
NUMBER	NO
ON CENTER	OC
OUTSIDE DIAMETER	OD
OUTSIDE STEM & YOKE	OS & Y
OVERHEAD	OH
PANEL	PNL
PARKING	PRKG
PARKWAY	PKWY
PARTS PER MILLION	PPM
PAVEMENT	PVMT
POINT OF CURVE	PC
POINT OF INTERSECTION	PI
POINT OF COMPOUND CURVE	PCC
POINT OF REVERSE CURVE	PRC
POINT OF TANGENT	PT
POINT OF VERTICAL CURVE	PVC
POINT OF VERTICAL INTERSECTION	PVI
POINT OF VERTICAL TANGENT	PVT
POLYETHYLENE PLASTIC	POLY
POLYVINYL CHLORIDE	PVC
PORTLAND CEMENT CONCRETE	PCC
POST INDICATOR VALVE	PIV
POWER POLE	PP
POWER LINE OVERHEAD	POH
POWER LINE UNDERGROUND	PUG
PREFABRICTED	PREFAB
PRESSURE GAUGE	PG
PRESSURE RELIEF VALVE	PRV
PROJECT ENGINEER	PE
PROPERTY LINE	PL
PROPOSED	PROP
PULL BOX	PBOX
PUMP	P
PUMP DISCHARGE	PDISCH
PUMP SUCTION	PMPSCT
QUANTITY	QTY
RADIUS	R
RADIUS POINT	RP
RAILROAD	RR
REDUCER	RED
REFERENCE	REF
REINFORCED CONCRETE BOX	RCB
REINFORCED CONC. CULVERT	RCC
REINFORCED CONCRETE PIPE	RCP
REINFORCING STEEL BARS	REBAR
RELOCATE	RELOC
REQUIRED	REQD
REVISION	REV
RIGHT	RT
RIGHT-OF-WAY	ROW
RIGID STEEL	RDG STL
ROAD	RD
ROOM	RM
RUNWAY	RWY
SANITARY SEWER MAIN	SS
SANITARY SEWER MANHOLE	SS MH
SECTION	SECT
SEPTIC TANK	SEP TK
SHEET	SHT
SHOULDER	SHLDR
SIDEWALK	SW
SOUTH	S
SPLASH BLOCK	SB
SPECIFICATIONS	SPEC
SQUARE	SQ
SQUARE FEET	SF
SQUARE YARD	SY
STAINLESS STEEL	SST
STATION	STA
STANDARD	STD
STEAM	STM
STEEL	STL
STEEL PLATE	STL PL
STORM DRAIN PIPE	SD
STORM DRAIN MANHOLE	SDMH
STORM WATER	ST W
STREET	ST
STREET LIGHT	ST LT
STRUCTURAL	STRUCT
STRUCTURAL ENGINEER	SE
STRUCTURAL STEEL	STRUCT STL
SUBGRADE	SG
SUBSTATION	SUBSTA
SUMP PUMP	SP
SUMP TANK	SUTK
SURVEY	SURV
SYMMETRICAL	SYMM

TANGENT	TANG
TAXIWAY	TXWY
TELEPHONE	TEL
TELEPHONE MANHOLE (VAULT)	TMH
TELEPHONE POLE	TP
TEMPORARY	TEMP
TEMPORARY BENCHMARK	TBM
THICK	THK
THRUST BLOCK	TB
TO BE REMOVED	TBR
TOE OF SLOPE	TOE
TOP OF CONCRETE or CURB	TOC
TOP OF CONCRETE FOOTING	TOC FTG
TOP OF CONCRETE WALL	TOC WALL
TOP OF MANHOLE	TO MH
TOP OF SLOPE	TOP
TOP OF STEEL	TOS
TOTAL DYNAMIC HEAD	TDH
TRAFFIC SIGNAL	TS
TRAFFIC SIGNAL INTERCONNECT	TSI
TRANSFORMER	XFMR
TRANSVERSE EXPANSION JOINT	TEJ
TRENCH DRAIN	TD
TUNNEL	TNL
TYPICAL	TYP
UNDERGROUND	UGND
UNFINISHED	UNFIN
UNDERWRITERS LABORATORY	UL
UNITED STATES	US
UNLESS OTHERWISE NOTED	UON
UNPAVED ROAD	UNPV RD
UTILITY	UTIL
UTILITY POLE	UP
VACUUM	VAC
VALVE BOX	VB
VARIABLE or VARIES	VAR
VEHICLE	VEH
VERIFY	VRFY
VENTILATOR	VENT
VERTICAL	VERT
VERTICAL CURVE	VC
VESTIBULE	VEST
VITRIFIED CLAY PIPE	VCP
WASTE WATER	WW
WASTE WATER TREATMENT PLANT	WWTP
WATER	WTR
WATER MAIN LINE	W
WATER HAMMER ARRESTOR	WHA
WATER MANHOLE	WMH
WATER METER	WM
WATER VALVE	WV
WATER PROOF or WEATHER PROOF	WPRF
WEIGHT	WT
WELDED WIRE FIBRAC	WWF
WELDED WIRE MESH	WWM
WEST	W
WIDTH	WD
WITH	W/
WITHOUT	W/O
WORKING POINT	WP
YARD	YD
YARD HYDRANT	YH
YARD (DRAIN) INLET	YI
YEAR	YR

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

Reviewed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.

Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization) RM

Date: 4/1/08

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
ABBREVIATIONS

PREPARER DATE | CHECKER DATE | DERIVATIVE CLASSIFIER DATE | PROJECT ENGINEER DATE | APPROVER / USER DATE

National Security Technologies LLC
Vision • Service • Partnership
NEVADA OPERATIONS
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023 | SHEET OF | DRAWING NUMBER / WORK ORDER NUMBER 08023-G-0002 | ORIGINAL SIGNATURES ON FILE | REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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STANDARD CIVIL SYMBOLS, NOTES AND LEGEND

CIVIL SYMBOLS

DESCRIPTION	SYMBOL
EXISTING MINOR CONTOUR	
EXISTING MAJOR CONTOUR	(3934)
FINISH MINOR CONTOUR	34
FINISH MAJOR CONTOUR	35
EXISTING SPOT ELEVATION	(3934.00)
FINISH GRADE ELEVATION	3935.00 FG
EXISTING CENTER LINE	5+00 6+00
NEW CENTER LINE W/STATIONS	5+00 6+00
AREA BOUNDARY LINE	
RIGHT OF WAY / PROPERTY LINE	
LIMITS OF GRADING	
EXISTING UNPAVED ROAD	
NEW UNPAVED ROAD	
EDGE OF EXISTING PAVING	
LIMITS OF NEW PAVING	
EDGE EXISTING CONCRETE SIDEWALK	
EDGE NEW CONCRETE SIDEWALK	
EXISTING EARTH	
COMPACTED EARTH	
AGGREGATE BASE COURSE	
CONCRETE PAD	
EXISTING FLOW LINE	
NEW FLOW LINE	
EXISTING SLOPE	TOP OF SLOPE / TOE OF SLOPE
NEW SLOPE	TOP OF SLOPE / TOE OF SLOPE
RIPRAP	
COVER "SIDE SLOPE" GRADING TRANSITION ZONE	
EXISTING BUILDING OR STRUCTURE	
NEW BUILDING OR STRUCTURE	
EXISTING MOBILE/ TEMPORARY FACILITY	
BUFFER ZONE AREA BOUNDARY	
AREA BOUNDARY LINE - RWMS	
OPEN CELL/TRENCH	
COVERED CELL/TRENCH	
EXISTING STORM DRAIN PIPE W/SIZE	18" SD
NEW STORM DRAIN LINE W/SIZE	30" SD
EXISTING CULVERT SIZE & TYPE	8" RCP
NEW CULVERT SIZE & TYPE	12" RCP

DESCRIPTION	SYMBOL
SURFACE DRAINAGE FLOW DIRECTION	SLOPE%
EXISTING WING TYPE HEADWALL	
NEW WING TYPE HEADWALL	
EXISTING CURB INLET/CATCH BASIN	CB
EXISTING STORM DRAIN MANHOLE	D
EXISTING SURFACE GRATE INLET	
NEW CURB INLET/ CATCH BASIN	CB
NEW STORM DRAIN MANHOLE	D
NEW SURFACE GRATE INLET	
EXISTING ROADWAY GUARDRAIL	
NEW ROADWAY GUARDRAIL	
EXISTING 4' HIGH FENCE 2 STRAND SMOOTH WIRE	
NEW 4' HIGH FENCE 2 STRAND SMOOTH WIRE	
EXISTING 4' HIGH FENCE 3 STRAND SMOOTH WIRE	
NEW 4' HIGH FENCE 3 STRAND SMOOTH WIRE	
EXISTING 4' HIGH FENCE 3 STRAND SMOOTH WIRE WITH PLASTIC MESH	XO
NEW 4' HIGH FENCE 3 STRAND SMOOTH WIRE WITH PLASTIC MESH	XO
EXISTING 4' HIGH FENCE CHAIN LINK	XX
NEW 4' HIGH FENCE CHAIN LINK	XX
EXISTING 8' HIGH FENCE CHAIN LINK	X
NEW 8' HIGH FENCE CHAIN LINK	X
EXISTING 8' HIGH FENCE CHAIN LINK W/BARBED WIRE	
NEW 8' HIGH FENCE CHAIN LINK W/BARBED WIRE	
NEVADA STATE COORDINATE SYSTEM	N 710,000 E 700,000
CENTER LINE BEARING	N01°30'30"E
SURVEY CONTROL MONUMENT (BM)	
SURVEY TEMPORARY BENCHMARK (TBM)	
SURVEY DELTA (CENTRAL ANGLE)	
EXISTING COMMUNICATIONS POLE (NO.& TYPE)	CP
NEW COMMUNICATIONS POLE (NO.& TYPE)	CP
EXISTING COMMUNICATIONS UNDERGROUND	CUG
NEW COMMUNICATIONS UNDERGROUND	CUG
EXISTING COMMUNICATIONS UNDERGROUND	CUG (F)
NEW COMMUNICATIONS UNDERGROUND	CUG (F)
EXISTING COMMUNICATIONS SURFACE LAID	C (SL)
NEW COMMUNICATIONS SURFACE LAID	C (SL)
EXISTING COMMUNICATION VAULT/MANHOLE	C
NEW COMMUNICATION VAULT/MANHOLE	C
EXISTING COMMUNICATIONS PEDESTAL	T
NEW COMMUNICATIONS PEDESTAL	T

DESCRIPTION	SYMBOL
EXISTING POWER OVERHEAD	POH
NEW POWER OVERHEAD	POH
EXISTING POWER POLE (NO.& TYPE)	PP
NEW POWER POLE (NO.& TYPE)	PP
POLE WITH GUY ANCHOR	
EXISTING ELECTRICAL TRANSFORMER ON POLE (NO.& SIZE)	
NEW ELECTRICAL TRANSFORMER ON POLE (NO.& SIZE)	
EXISTING PAD MTD TRANSFORMER (NO.& SIZE)	T
NEW PAD MTD TRANSFORMER (NO.& SIZE)	T
EXISTING CONDUIT PULL BOX	PBOX
NEW CONDUIT PULL BOX	PBOX
EXISTING AREA LIGHTING POLE	LP
NEW AREA LIGHTING POLE (SGL ARM)	LP
NEW AREA LIGHTING POLE (DBL ARM)	LP
EXISTING ELECTRICAL VAULT/MANHOLE	E
NEW ELECTRICAL VAULT/MANHOLE	E
EXISTING POWER UNDERGROUND	PUG 3-2"C
NEW POWER UNDERGROUND	PUG 1-2"C
EXISTING POWER SURFACE LAID	P (SL)
NEW POWER SURFACE LAID	P (SL)
EXISTING WATER LINE W/SIZE	8" W
NEW WATER LINE W/SIZE	8" W
EXISTING FIRE PROTECTION MAIN W/SIZE	6" FP
NEW FIRE PROTECTION MAIN W/SIZE	6" FP
EXISTING WATER VALVE & CAP	WV
NEW WATER VALVE & CAP	WV
EXISTING WATER CHECK VALVE	CV
NEW WATER CHECK VALVE	CV
EXISTING BACK FLOW PREVENTER	
NEW BACK FLOW PREVENTER	
EXISTING WATER FLOW METER	FM
NEW WATER FLOW METER	FM
EXISTING WATER METER	WM
NEW WATER METER	WM
EXISTING WATER VAULT/MANHOLE	W
NEW WATER VAULT/MANHOLE	W

DESCRIPTION	SYMBOL
EXISTING WATER TAPPING SLEEVE	
NEW WATER TAPPING SLEEVE	
EXISTING FIRE HYDRANT	
NEW FIRE HYDRANT	
EXISTING POST INDICATOR VALVE	
NEW POST INDICATOR VALVE	
EXISTING SANITARY SEWER LINE W/SIZE	4" SS
NEW SANITARY SEWER LINE W/SIZE	4" SS
EXISTING SANITARY SEWER VAULT/ MANHOLE	S
NEW SANITARY SEWER VAULT/ MANHOLE	S
EXISTING SEWER CLEANOUT	CO
NEW SEWER CLEANOUT	CO
EXISTING GAS MAIN W/SIZE	2" G
NEW GAS MAIN W/SIZE	2" G
EXISTING GAS METER	GM
NEW GAS METER	GM
EXISTING SIGN (TRAFFIC OR INFORMATION)	
NEW SIGN (TRAFFIC OR INFORMATION)	
PIPE BOLLARDS	
EXISTING PARKING BUMPER OR WHEEL STOP	
NEW PARKING BUMPER OR WHEEL STOP	
EXISTING CONCRETE SECURITY WALL (JERSEY BARRIER)	
NEW CONCRETE SECURITY WALL (JERSEY BARRIER)	
AIRFIELD WIND SOCK, COMMUNICATIONS TOWER OR ANTENNA W/GUY WIRES	WEATHER STATION
LYSIMETER OR METEROLOROGY TOWER W/STRUCTURAL ANCHOR PADS	(TYPE) TOWER
CONCRETE (BOUNDARY) CONTROL MONUMENT	NORTH, EAST ELEV, ID *
EXISTING ENVIRONMENTAL MONITORING TUBE (ID#)	AP1 RP2
NEW ENVIRONMENTAL MONITORING TUBE (ID#)	NE1
EXISTING TDR ENVIRONMENTAL MONITORING TUBE	
EXISTING VADOSE STA (ID#) TDR ARRAY	VADOSE STA (ID #)
EXISTING GREATER CONFINEMENT DISPOSAL BOREHOLE (GCD #)	GCD

CIVIL NOTES

GENERAL CIVIL NOTES

1. WHERE CONFLICTS EXIST BETWEEN THESE STANDARDIZED NOTES AND THE DRAWINGS, THE PROJECT DRAWINGS SHALL TAKE PRECEDENCE.
2. DO NOT SCALE DRAWINGS. NUMERICAL DIMENSIONS SHALL TAKE PRECEDENCE.
3. ALL OF THE CONSTRUCTION SHOWN ON THESE PROJECT DRAWINGS IS NEW AND SHALL BE INCLUDED IN THE CONTRACT UNLESS SHOWN AS "EXIST" OR "NIC".
4. CONSTRUCTION SHALL CONFIRM ALL EXISTING DIMENSIONS AND ELEVATIONS PRIOR TO COMMENCING WORK AND SHALL REPORT ALL DISCREPANCIES TO THE PROJECT ENGINEER OR HIS/HER DESIGNATED REPRESENTATIVE BEFORE PROCEEDING WITH THE WORK.
5. ALL CONSTRUCTION INTERFERENCE SHALL BE REPORTED TO THE PROJECT ENGINEER OR HIS/HER DESIGNATED REPRESENTATIVE FOR RESOLUTION PRIOR TO PROCEEDING WITH THE WORK IN QUESTION.
6. THE LATEST EDITIONS OF REFERENCES CITED IN THESE NOTES SHALL APPLY.
7. FALL PROTECTION SHALL BE PROVIDED IN ACCORDANCE WITH 29 CFR 1926 SUBPART M-FALL PROTECTION, AND NSTec SAFETY RULE CM-0444.001-061 REV 3 DATED 8/24/07.

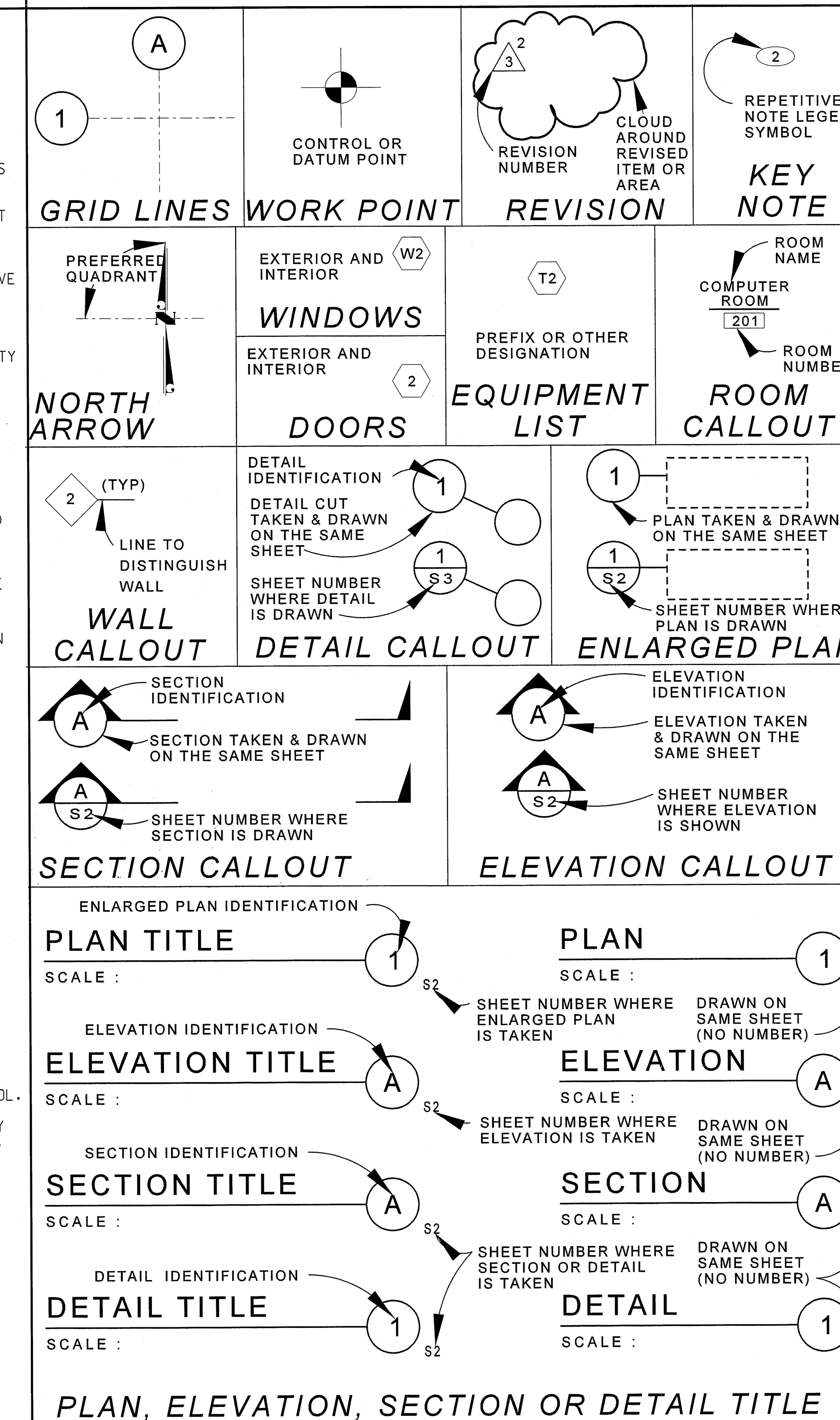
DEMOLITION NOTES

1. WHERE DEMOLITION OCCURS, SUBCONTRACTOR SHALL PROTECT EXISTING STRUCTURES, DOORS, ELECTRICAL SYSTEMS, AND MECHANICAL SYSTEMS FROM BEING DAMAGED. PROTECTION SHALL BE IN THE FORM OF DUST COVERS, BARRIERS, OR OTHER MEANS DEEMED APPROPRIATE BY THE PROJECT ENGINEER.
2. ALL DEBRIS, NON-SALVAGEABLE MATERIALS, AND EXCESS SPOILAGE SHALL BE REMOVED FROM THE JOB SITE AND DISPOSED OF AT THE NEAREST APPROVED SANITARY LANDFILL. ALL SALVAGEABLE MATERIALS NOT REQUIRED FOR THE PROJECT, AS DETERMINED BY THE STR, SHALL BE RETURNED TO PROPERTY MANAGEMENT FOR THEIR DISPOSITION.
3. ANY WASTE MATERIAL DETERMINED BY THE ENVIRONMENTAL COMPLIANCE OFFICE OR THE INDUSTRIAL HYGENE OFFICE TO BE HAZARDOUS SHALL BE DISPOSED OF IN ACCORDANCE WITH THEIR REQUIREMENTS.
4. ANY WASTE MATERIAL DETERMINED BY THE WASTE MANAGEMENT DEPARTMENT AND THE RADIOLOGICAL CONTROL ORGANIZATION TO BE RADIOLOGICALLY CONTAMINATED SHALL BE DISPOSED OF IN ACCORDANCE WITH THEIR REQUIREMENTS.
5. ALL DEMOLITION, INCLUDING EXCAVATION WORK, SHALL BE PERFORMED IN ACCORDANCE WITH OSHA REGULATION 29 CFR PART 1926 SUBPART-T DEMOLITION AND SUBPART-P EXCAVATION.
6. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND CONDITIONS PRIOR TO DEMOLITION.
7. ALL DIMENSIONS SHOWN ARE FOR ESTIMATING PURPOSES AND AS A GUIDE TO SHOW DEMOLITION EXTENTS.
8. ALL WORK SHALL BE SCHEDULED TO PROCEED IN A MANNER AS TO CAUSE MINIMUM DISTURBANCE TO PERSONNEL AND EQUIPMENT IN AND AROUND BUILDINGS AND SHALL MAINTAIN SAFE WORKING CONDITIONS AT ALL TIMES.

CIVIL NOTES

1. BASIS FOR HORIZONTAL CONTROL: NORTH AMERICAN DATUM 1927, NEVADA STATE COORDINATE SYSTEM, CENTRAL ZONE. BASIS FOR VERTICAL CONTROL: NORTH AMERICAN VERTICAL DATUM 1929, NEVADA STATE COORDINATE SYSTEM, CENTRAL ZONE. EXISTING BACKGROUND FOR ACCESS ROAD SHOWS GRADES ONLY.
2. ALL EXISTING UNDERGROUND UTILITIES WITHIN THE CONSTRUCTION SITE SHALL BE LOCATED BY MEANS OF AN ELECTRONIC METAL DETECTION DEVICE AND CLEARLY MARKED PRIOR TO COMMENCING CONSTRUCTION WORK.
3. ALL GRADE ELEVATIONS SHOWN ARE FINISH GRADES, UNLESS OTHERWISE NOTED. SUBGRADE ELEVATIONS MUST BE ESTABLISHED WHERE REQUIRED PRIOR TO FINAL GRADING BY NSTec CONSTRUCTION OR SUBCONTRACTOR.
4. EXCAVATION SAFETY PROCEDURES SHALL BE IN ACCORDANCE WITH OSHA REGULATIONS 29 CFR PART 1926 SUBPART P-EXCAVATIONS AND NSTec COMPANY DIRECTIVE CM-0444.001-021 REV 8 DATED 2/11/08.
5. TEMPORARY FENCING TO BE PLACED AROUND ALL OPEN CONSTRUCTION AREAS AS REQUIRED FOR SAFETY AND ACCESS CONTROL.
6. SURVEY DATA SHALL BE SUBMITTED TO NSTec ENGINEERING IN ASCII FILE FORMAT ALONG WITH COPIES OF FIELD SURVEY SKETCHES. DATA FILES SHALL CONTAIN SUFFICIENT DATA POINTS TO FACILITATE AS-BUILT DRAWINGS FOR THE PROJECT.

DRAFTING LEGEND



ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

REV	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
CIVIL SYMBOLS, NOTES & LEGEND

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

National Security Technologies LLC
Vision • Service • Partnership
NEVADA OPERATIONS
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1001
REVISION A

Reviewed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)
Date: 4/1/08

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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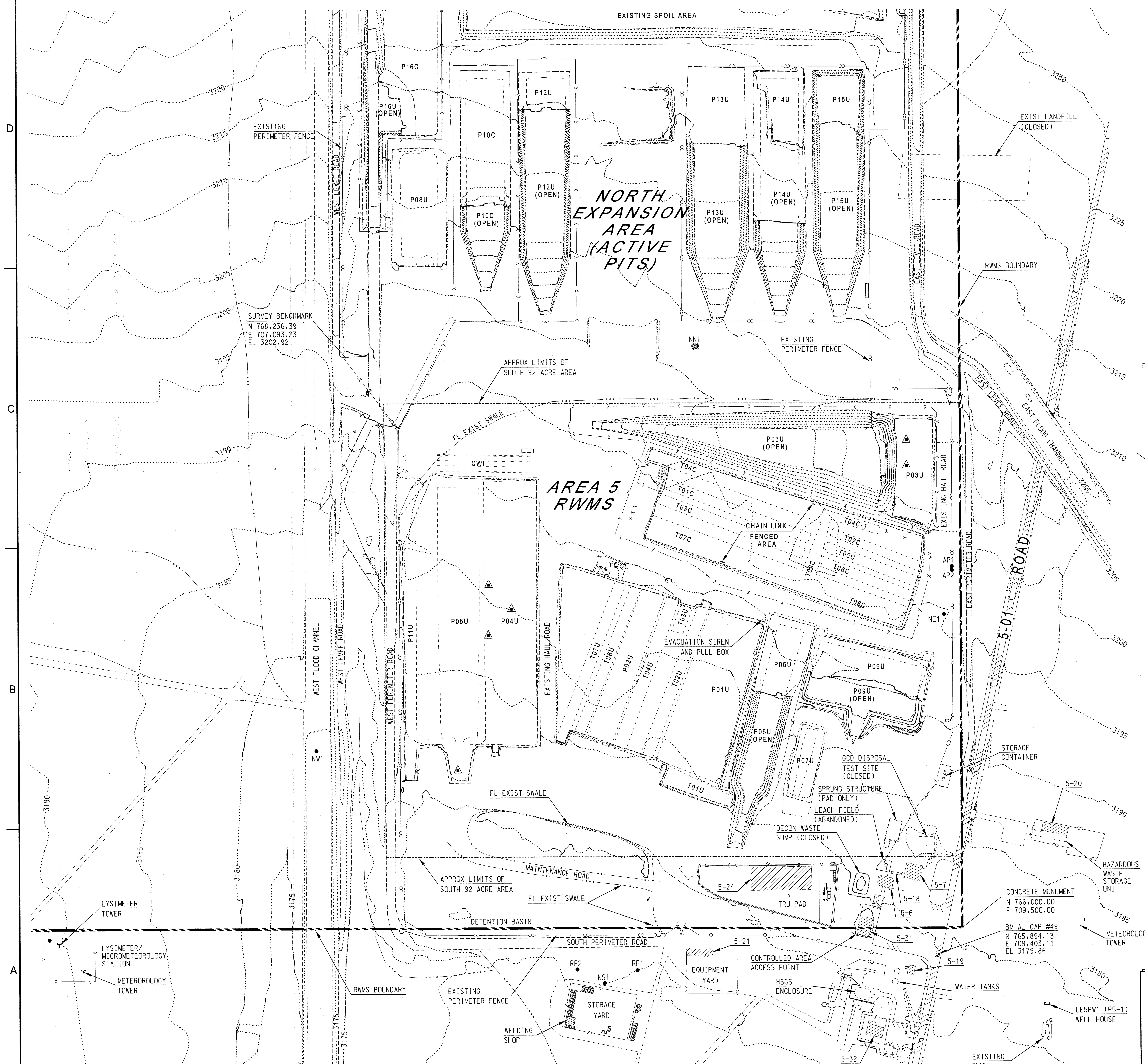
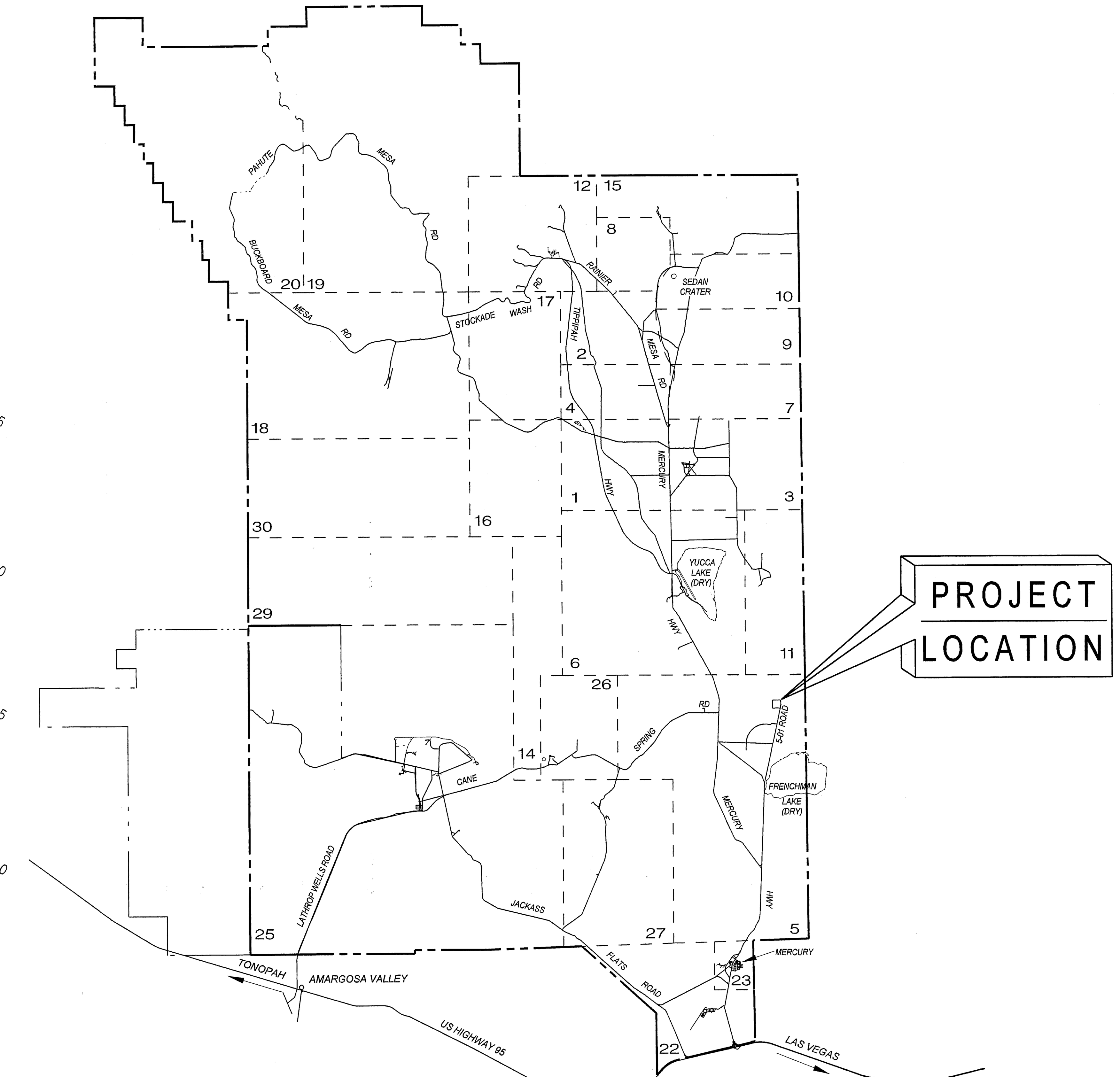
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



OVERALL LOCATION MAP

SCALE : 1" = 200'



VICINITY MAP
NEVADA TEST SITE

SCALE : NONE

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

GRAPHIC SCALE
0 100 200 400 600 FEET
1" = 200'
CONTOUR INTERVAL = 5 FEET

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

Reviewed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.

Derivative Classifier: Richard Norton, NSTec Engr (Name/Organization)

Date: 4/1/08

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
AREA 5 RWMS LOCATION MAPS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1002
REVISION A
ORIGINAL SIGNATURES ON FILE

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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DEMOLITION KEY NOTES

(1) REMOVE & RELOCATE EXISTING EVACUATION SIREN, PULL BOX AND POLE TO THE NORTH SIDE OF BLDG 5-7 AND WEST OF ELECTRICAL PULL BOX #1 AS SHOWN ON ELETRICAL DRAWING E-1001 & E-1002.

(2) REMOVE, SALVAGE AND REUSE ALL EXISTING CHAIN LINK FENCING. REINSTALL AS SHOWN ON DRAWING 08023-C-1010 AFTER FINAL COVER AND SIDE SLOPE GRADING IS ACHIEVED.

(3) REMOVE AND SALVAGE THE EXISTING SMOOTH WIRE FENCING INDICATED ON THIS SHEET. INSTALL NEW 3 STRAND SMOOTH WIRE FENCE AS SHOWN ON DRAWINGS 08023-C-1010 AND 08023-C-1011 AFTER FINAL COVER AND SIDE SLOPE GRADING IS COMPLETE.

(4) ALL EXISTING UNDERGROUND WATER, SEWER, AND COMMUNICATIONS LINES, FIXTURES AND APPURTENANCES ARE TO REMAIN IN PLACE. "DO NOT DISTURB." TAKE APPROPRIATE MEASURES AS NEEDED TO PROTECT THESE UTILITIES DURING CONSTRUCTION.

(5) REMOVE AND SALVAGE ALL EXISTING ABOVE GROUND ELECTRICAL PANELS, MONITORING DEVICES AND/OR JUNCTION BOXES WITHIN THE SOUTH 92 ACRE BOUNDARY EXCEPT AS NOTED, SEE ELETRICAL SHEET E-1001 FOR POWER CABLE AND CONDUIT DISPOSITIONS.

(6) ALL EXISTING MONITORING TUBES (INCLUDING AP1 AND AP2) SHALL BE CUT OFF 12" BELOW EXISTING GRADE AND BACKFILLED WITH SAND OR SUITABLE COMMON BACKFILL MATERIAL PRIOR TO PLACEMENT OF ANY FINAL COVER CAP SOIL. ALL EXISTING GCD BOREHOLES SHALL BE FILLED WITH SUITABLE COMMON BACKFILL MATERIAL PRIOR TO PLACEMENT OF ANY FINAL COVER SOIL.

(7) THE EXISTING EAST-TO-WEST DRAINAGE SWALE, NORTH OF PIT P03U, IS TO BE REGRADED TO INTERSECT THE NEW CMP CULVERTS SHOWN ON DRAWING 08023-C-1005. SEE DRAWING 08023-C-3002 FOR DITCH DETAILS.

(8) PRIOR TO COMMENCING ANY CONSTRUCTION,CONTACT AREA 5 RWMS OPERATIONS MANAGEMENT FOR DISPOSITION AND INSTRUCTIONS CONCERNING ANY REMAINING ABOVE GROUND STORAGE CONTAINERS (i.e. CC-49 THRU CC-55, LOCATED INSIDE THE EXISTING CLASSIFIED AREA SECURITY FENCE.

(9) REMOVE ALL EXISTING CONCRETE MONUMENTS EXCEPT AS NOTED AT THE GCD TEST PIT. SALVAGE AND REUSE FOR COVER CAP MONUMENTS IF APPROVED BY THE PROJECT ENGINEER. SEE DRAWING 08023-C-1012 FOR NEW MONUMENT FABRICATION AND MARKING DETAILS.

(10) REMOVE EXISTING DRAIN CULVERT AT THE SOUTH MAINTENANCE ROAD. SEE DRAWING 08023-C-1005 FOR NEW CULVERT AND DRAINAGE SWALE DETAILS.

(11) THE EXISTING SOUTH MAINTENANCE ROAD AND DETENTION BASIN AREA ARE TO BE REGRADED AS SHOWN ON DRAWINGS 08023-C-1005 & C-1009.

(12) EXISTING TDR MONITORING CABINETS ARE TO BE RAISED AND REINSTALLED ON SURFACE OF NEW CLOSURE COVER. NEW SENSOR CABLES ARE TO BE SPICED WITH EXISTING CABLE AND CONNECTED TO RELOCATED CABINET.

Reviwed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.

Derivative Classifier: [signature] (Name/Organization)

Date: 4/1/08

GS

GRAPHIC SCALE

0 50 100 200 300 FEET

1" = 100'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES

EXISTING SITE & DEMOLITION PLAN

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

National Security Technologies LLC
Vision • Service • Partnership
NEVADA OPERATIONS
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER 08023-C-1003
REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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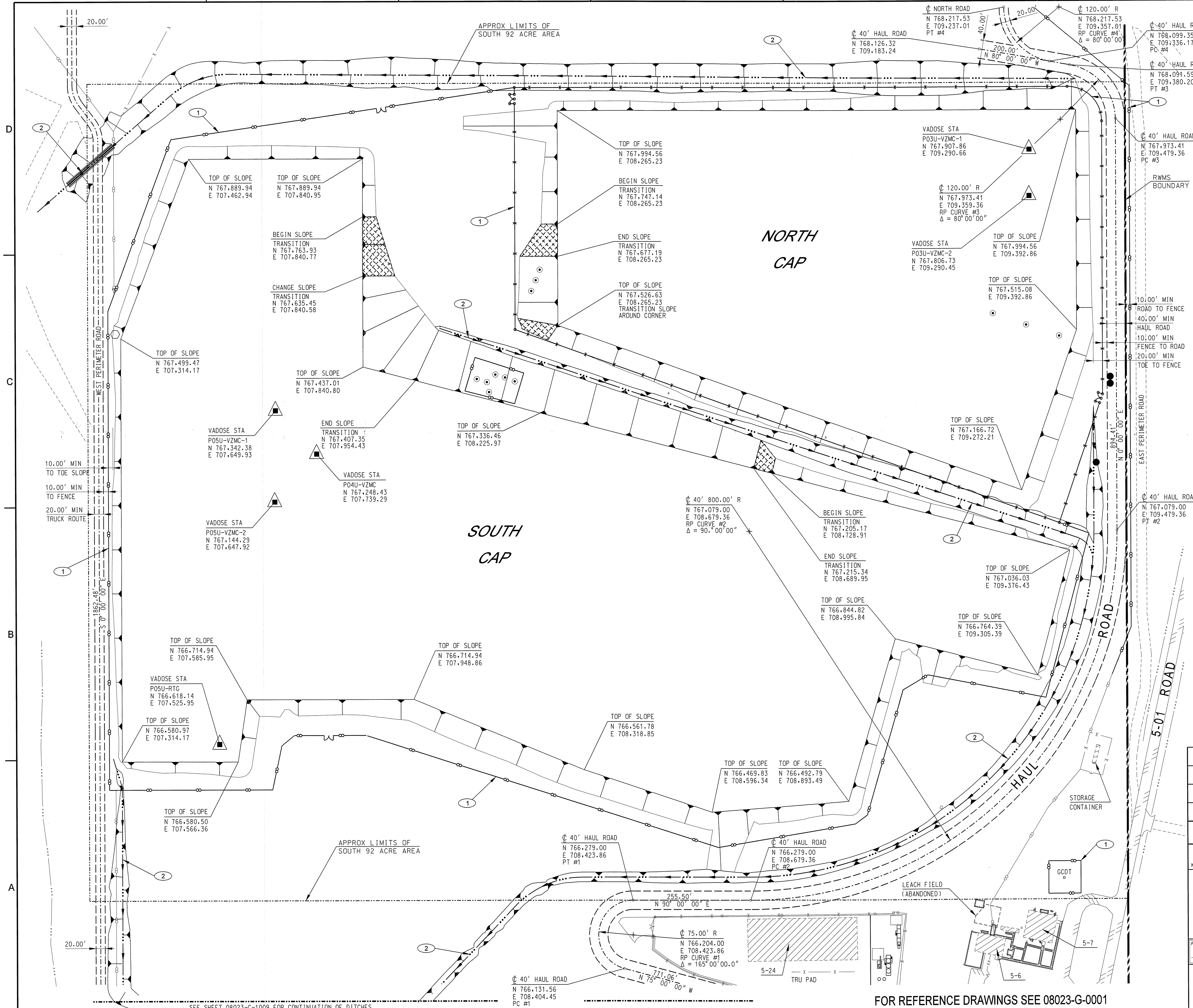
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION

KEY NOTES

1. SEE SHEET 08023-C-1010 FOR LOCATION OF NEW FENCING.
2. SEE SHEET 08023-C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR LOCATION OF NEW DITCH FLOW LINES.
3. SEE SHEET 08023-C-1005 FOR ELEVATIONS AT SLOPE TRANSITION POINTS.



ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

Reviwed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec EngR (Name/Organization)
Date: 4/1/08

GS

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA
NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
NEW SITE & HORIZONTAL CONTROL PLAN

PREPARER DATE | CHECKER DATE | DERIVATIVE CLASSIFIER DATE | PROJECT ENGINEER DATE | APPROVER/USER DATE

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ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1004
REVISION: A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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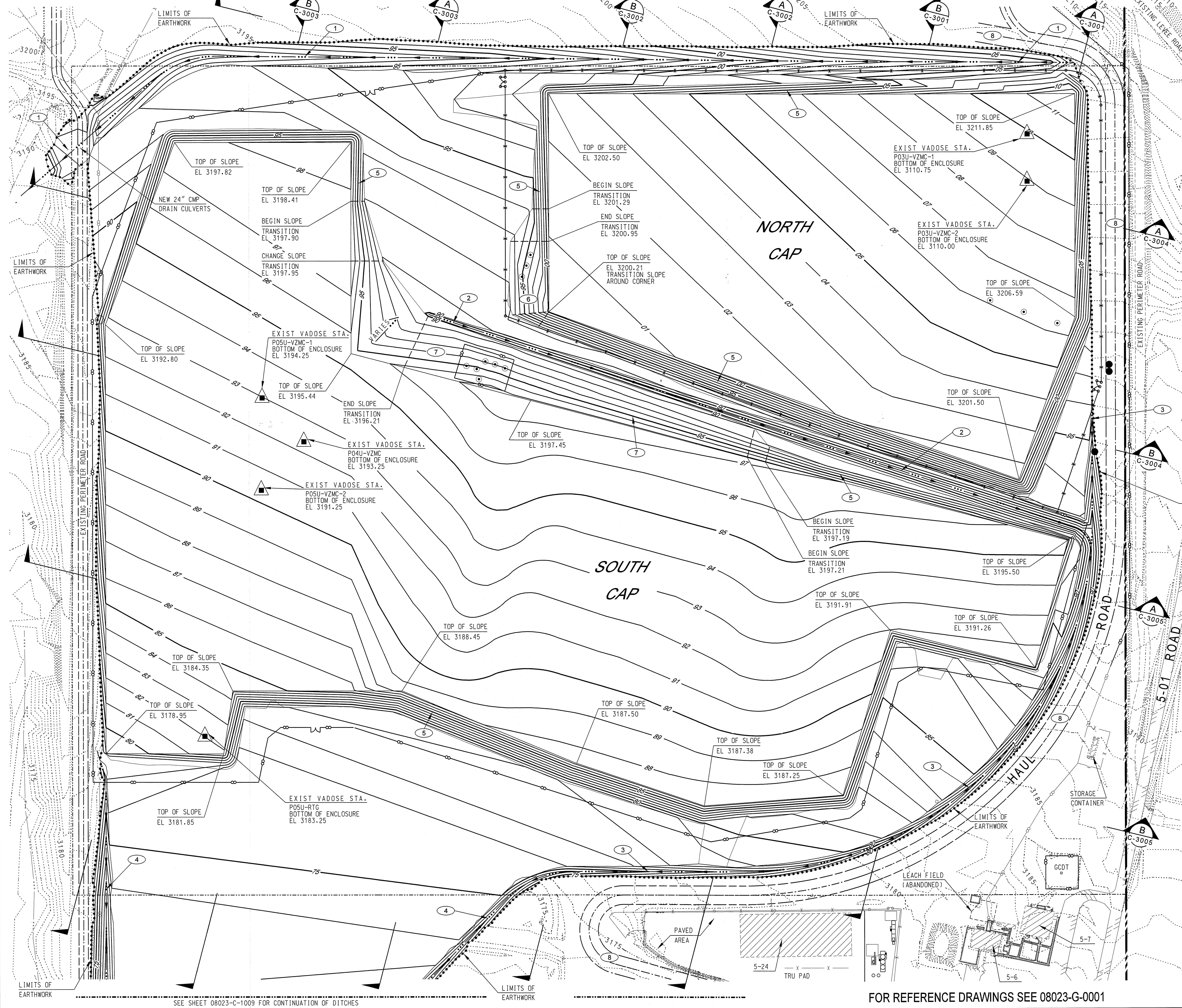

KEY NOTES

1. SEE DRAWING 08023-C-1006 FOR NORTH DRAINAGE DITCH GRADING DETAILS.
2. SEE DRAWING 08023-C-1007 FOR CENTER DRAINAGE DITCH GRADING DETAILS.
3. SEE DRAWING 08023-C-1008 FOR EAST DRAINAGE DITCH GRADING DETAILS.
4. SEE DRAWING 08023-C-1009 FOR SOUTH DRAINAGE DITCH GRADING DETAILS.
5. THE TYPICAL COVER CAP SIDE SLOPE IS 5:1 UNLESS OTHERWISE NOTED.
6. THE NORTH COVER CAP SIDE SLOPE AT GCD's SHALL BE 10:1.
7. THE NORTHERN FACE OF THE SOUTH COVER CAP SIDE SLOPE (AT THE GCD's) SHALL EXTEND TO THE TOP SLOPE OF THE NEW CENTER DITCH.
8. A NEW 40' WIDE UNPAVED HAUL ROAD IS TO BE GRADED LEVEL TO MATCH THE EXISTING TERRAIN AS SHOWN. SET ℄ AND SHOULDER ELEVATIONS SUCH THAT THE NEW TRAVEL SURFACE PROVIDES POSITIVE DRAINAGE AWAY FROM BLDGS S18C, 5-7, 5-6 & 5-24, AND TOWARDS THE NEW DITCHES. CONSTRUCTION SHALL SUBMIT ALL FINISHED ROAD GRADES TO THE NSTec PROJECT ENGINEER FOR APPROVAL PRIOR TO PERFORMING FINAL GRADING.

ESTIMATED QUANTITIES

DESCRIPTION	UNIT	QUANITY *
NORTH CLOSURE COVER		
VOLUME REQUIRED TO MATCH EXISTING GRADE PIT P03U	CY	192,270 **
BALANCE OF VOLUME FOR NORTH CAP FINAL COVER	CY	105,245
FILL REQUIRED (ASSUMING NO NEW WASTE)		297,515
SOUTH CLOSURE COVER		
DESCRIPTION	UNIT	QUANITY *
VOLUME REQUIRED TO MATCH EXISTING GRADE PIT P06U	CY	43,063 **
PIT P09U	CY	20,373 **
BALANCE OF VOLUME FOR SOUTH CAP FINAL COVER	CY	228,103
FILL REQUIRED (ASSUMING NO NEW WASTE)		291,539
DITCH WORK & LEVELING OUTSIDE COVER CAPS		
DESCRIPTION	UNIT	QUANITY *
FILL REQUIRED FOR DITCHES & REGRADED AREAS	CY	27,322
CUT FOR DITCHES & REGRADED AREAS	CY	-19,159
NET FILL FOR DITCHES & REGRADED AREAS OUTSIDE COVER CAPS	CY	8,163
TOTAL PROJECT		
TOTAL FILL REQUIRED (ASSUMING NO NEW WASTE)	CY	597,217*

* NO COMPACTION OR CUT AND FILL FACTORS ARE APPLIED TO PROVIDED QUANTITIES. QUANTITIES PROVIDED ARE FOR NSTec ESTIMATING PURPOSES ONLY.

** TOTAL REMAINING VOLUME CALCULATIONS ARE BASED ON FY06 SURVEY DATA AND ASSUME NO NEW WASTE IS PLACED IN PITS.

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This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec Engr.
(Name/Organization)
Date: 4/1/08

GS

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'
CONTOUR INTERVAL = 1 FOOT

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
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NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES

NEW CLOSURE COVER GRADING PLAN

PREPARER / DATE — CHECKER / DATE — DERIVATIVE CLASSIFIER / DATE — PROJECT ENGINEER / DATE — APPROVER / USER / DATE

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ENGINEERING NO. 08023
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DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1005
REVISION: A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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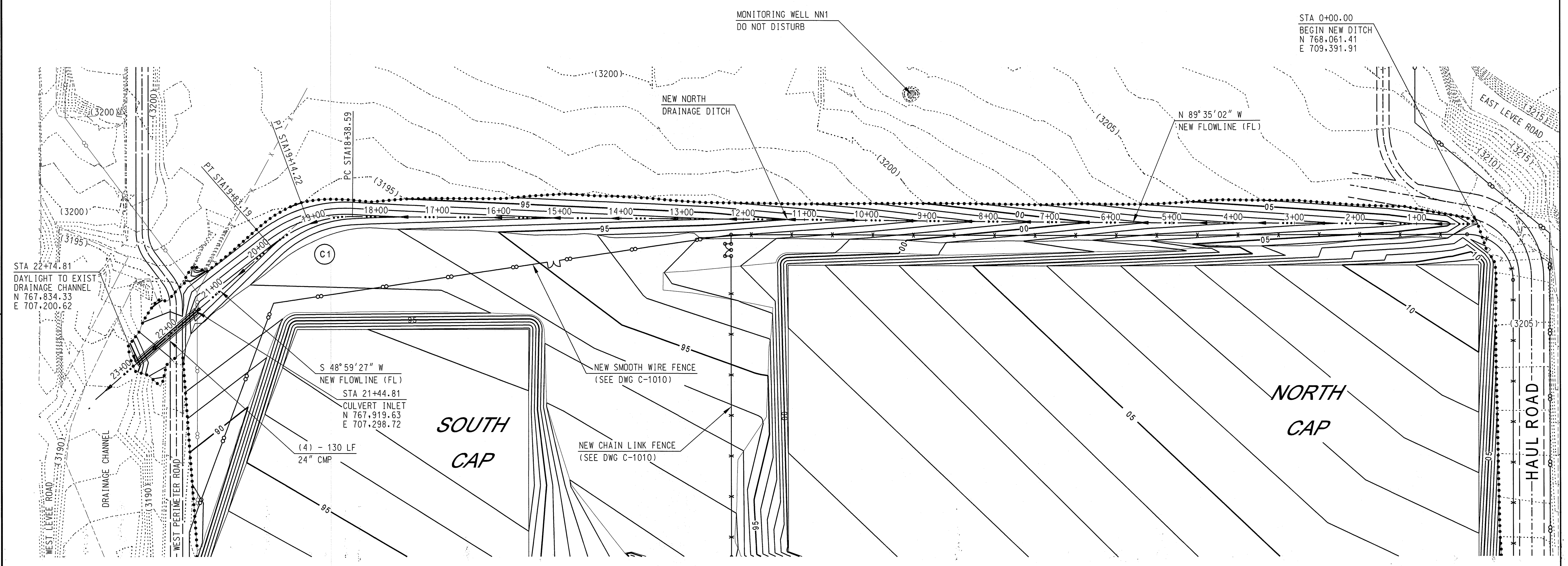
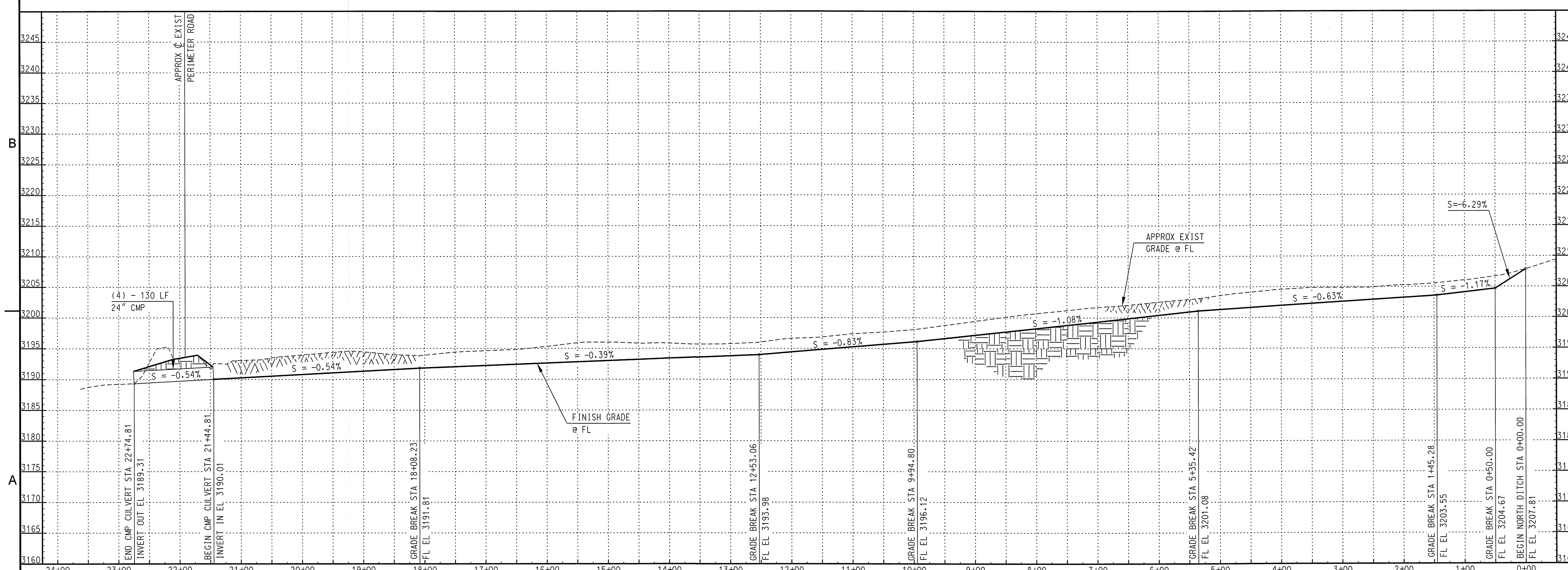


PLAN

SCALE: 1"= 100'



PROFILE

SCALE: HORIZ 1"= 100', VERT 1"= 10'

FOR REFERENCE DRAWINGS SEE 08023-G-0001

NORTH DRAINAGE HORIZONTAL CURVE DATA

NO	RP	PC	PT	R	Δ	L	T
C1	N 767,874.76 E 707,551.91	N 768,074.76 E 707,553.36	N 768,025.68 E 707,420.68	200.00'	41° 25' 31"	144.60'	75.62'

NOTES

1. FOR COMPACTION SPECIFICATIONS SEE DRAWING C-3001.
2. INSTALL CORRUGATED METAL PIPE (CMP) IN ACCORDANCE WITH NEVADA DEPARTMENT OF TRANSPORTATION (NDOT) STANDARD CONSTRUCTION PLANS R-1.1.1, R-1.1.5, R-1.1.6, R-1.3.1.2, AND R-2.8.1.

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Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)

Date: 4/1/08

GRAPHIC SCALE 0 10 20 30 FEET 1" = 10'

GS

GRAPHIC SCALE 0 50 100 200 300 FEET 1" = 100'

(CONTOUR INTERVAL = 1 FOOT)

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

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NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES

NORTH DRAINAGE PLAN & PROFILE

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER/USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
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ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1006
REVISION A

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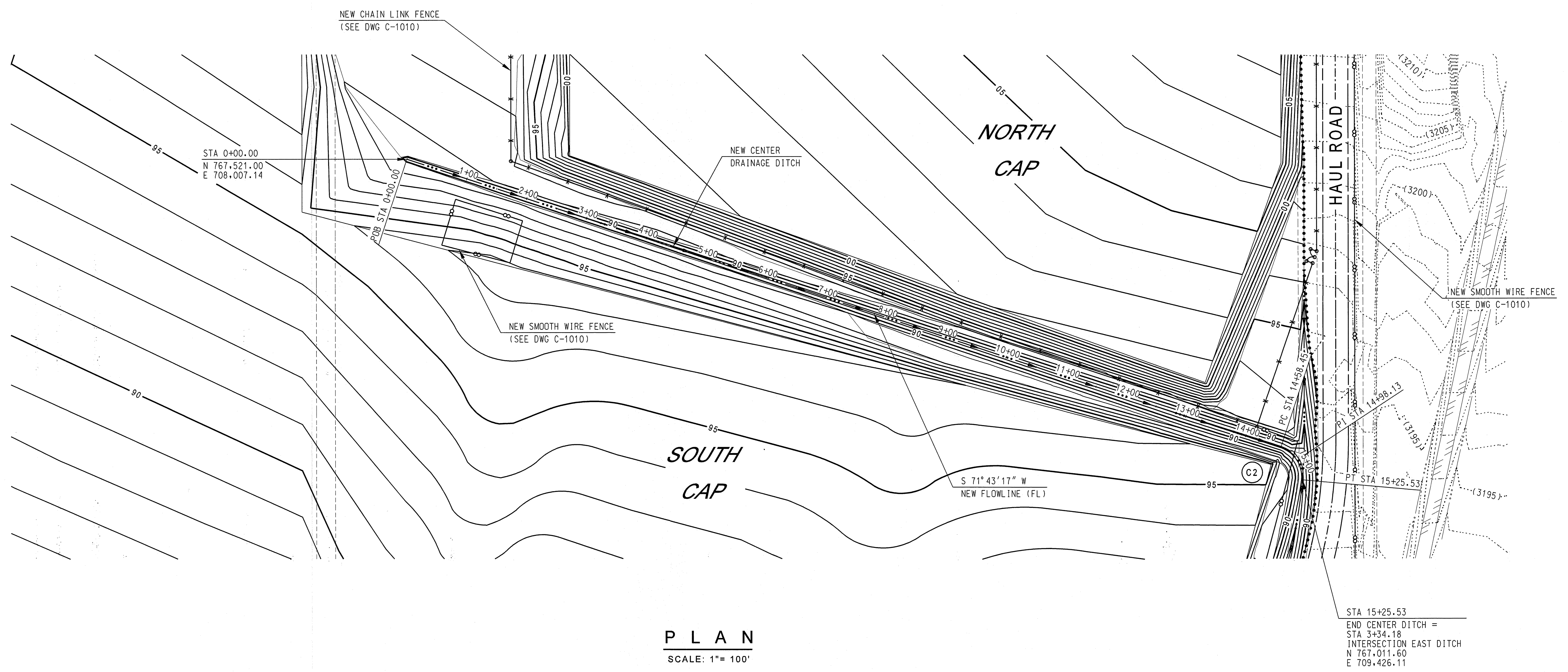
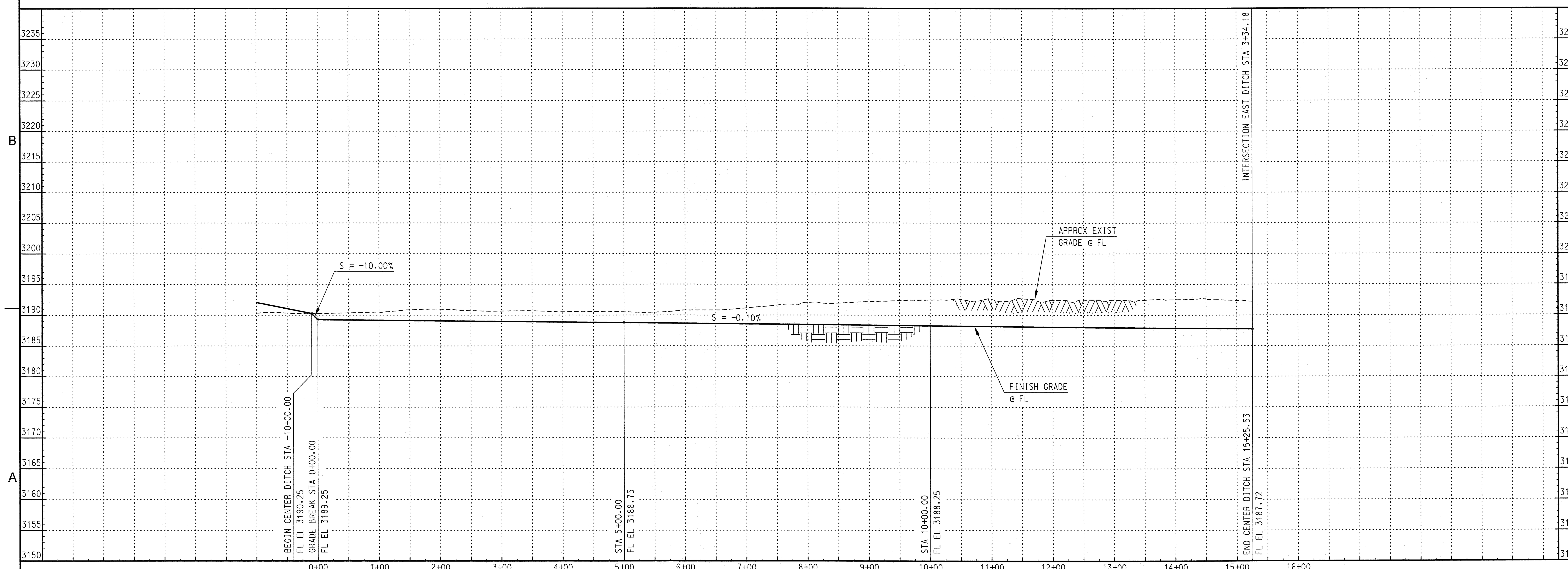
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



PLAN
SCALE: 1"= 100'



PROFILE
SCALE: HORIZ 1"= 100', VERT 1"= 10'

FOR REFERENCE DRAWINGS SEE 08023-G-0001

CENTER DRAINAGE HORIZONTAL CURVE DATA

NO	RP	PC	PT	R	Δ	L	T
C2	N 767,016.10 E 709,376.31	N 767,063.57 E 709,392.00	N 767,011.60 E 709,426.11	50.00	76° 52' 37"	67.09'	39.68'

NOTES

1. FOR COMPACTION SPECIFICATIONS SEE DRAWING C-3001.

ISSUED FOR 90% DESIGN REVIEW
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Reviwed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)
Date: 4/1/08

GRAPHIC SCALE
0 10 20 30 FEET
1" = 10'

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'
(CONTOUR INTERVAL = 1 FOOT)

GS

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
CENTER DRAINAGE PLAN & PROFILE

PREPARER / DATE — CHECKER / DATE — DERIVATIVE CLASSIFIER / DATE — PROJECT ENGINEER / DATE — APPROVER/USER / DATE

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ENGINEERING NO. 08023
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DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1007
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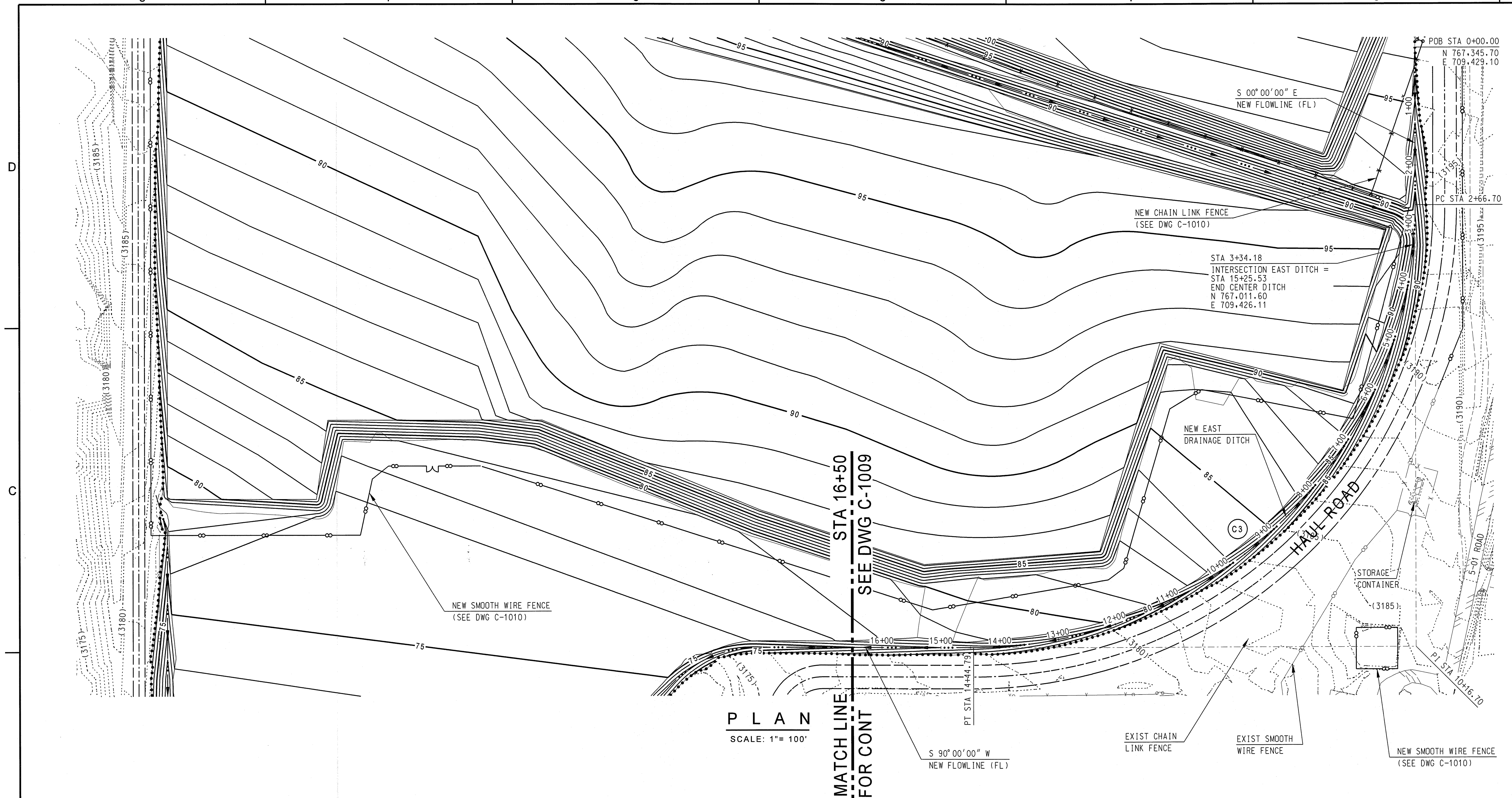
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



P L A N

SCALE: 1"= 100'

EAST DRAINAGE HORIZONTAL CURVE DATA							
NO	RP	PC	PT	R	Δ	L	T
C3	N 767,079.00 E 708,679.10	N 767,079.00 E 709,429.10	N 766,329.00 E 708,679.10	750.00'	90° 00' 00"	1178.10'	750.00

NOTES

1. FOR COMPACTION SPECIFICATIONS SEE DRAWING C-3001.

ISSUED FOR 90% DESIGN REVIEW
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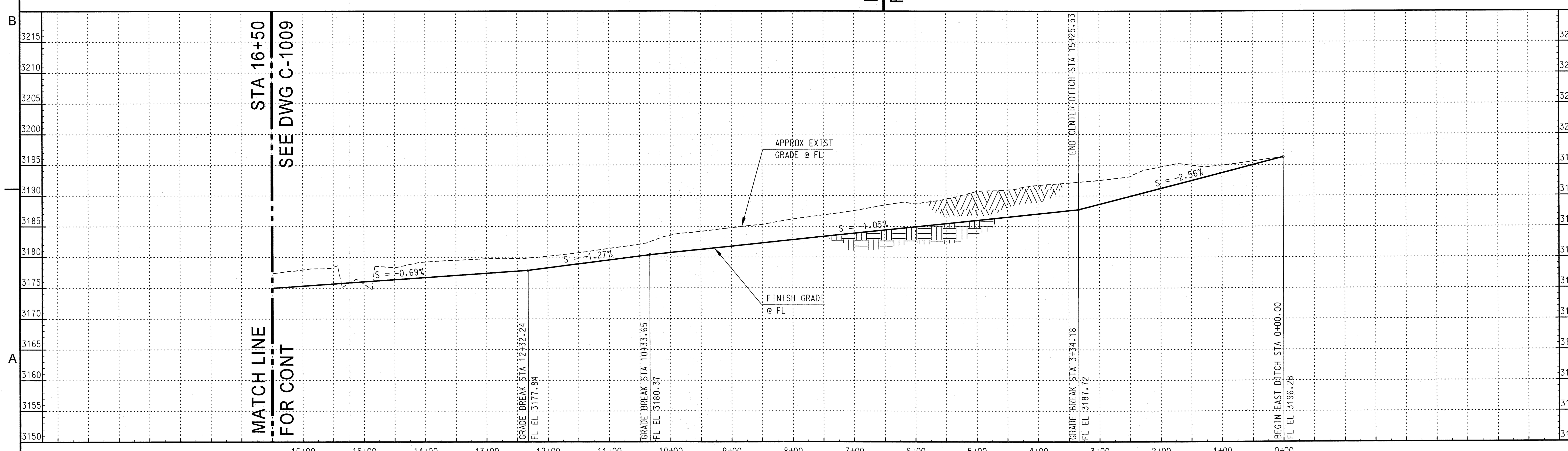
Reviewed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.
Derivative Classifier: Richard Melton, NSTec Engr RM (Name/Organization)
Date: 4/1/08

GRAPHIC SCALE
0 10 20 30 FEET
1" = 10'

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'
(CONTOUR INTERVAL = 1 FOOT)

GS



P R O F I L E

SCALE: HORIZ 1"= 100', VERT 1"= 10'

FOR REFERENCE DRAWINGS SEE 08023-G-0001

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
EAST DRAINAGE PLAN & PROFILE

PREPARER DATE | CHECKER DATE | DERIVATIVE CLASSIFIER DATE | PROJECT ENGINEER DATE | APPROVER / USER DATE

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DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1008
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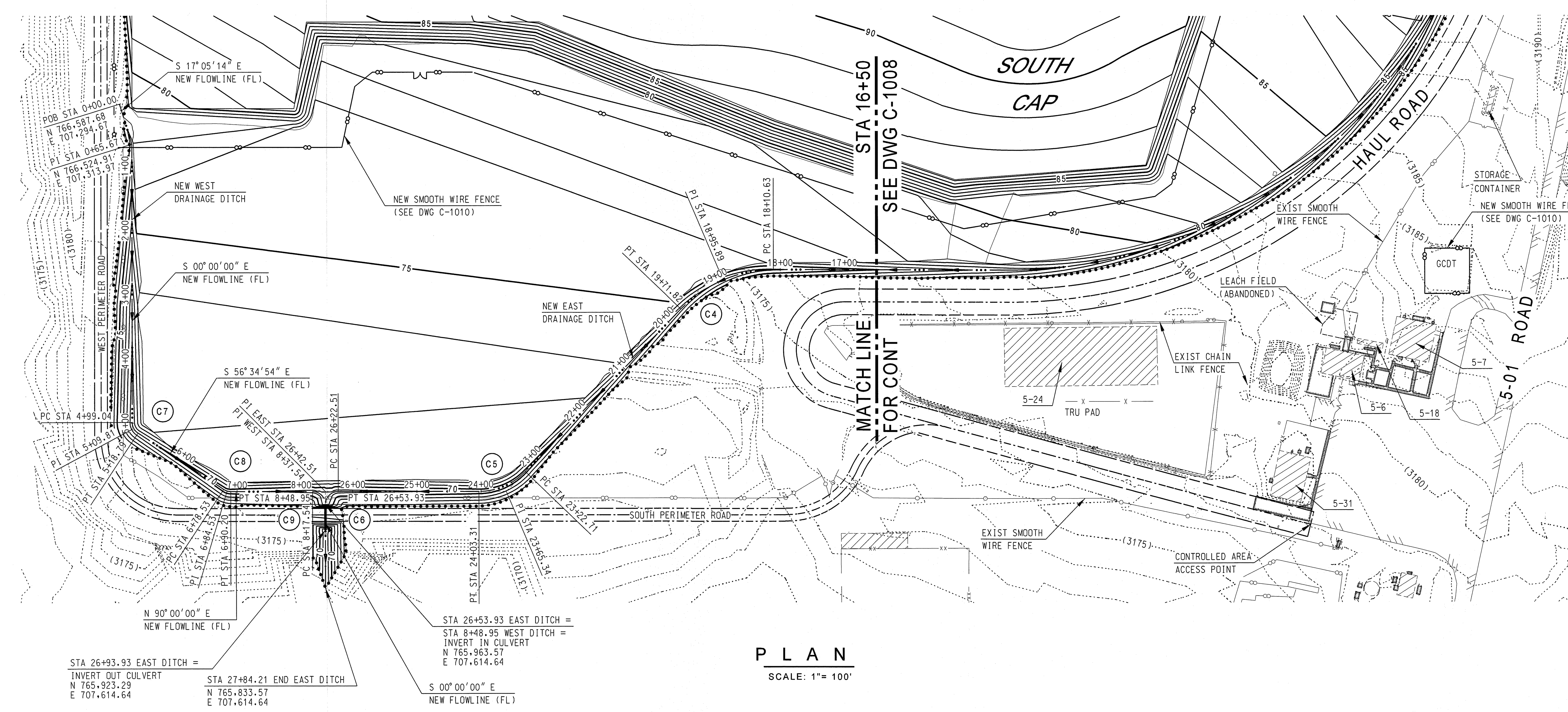
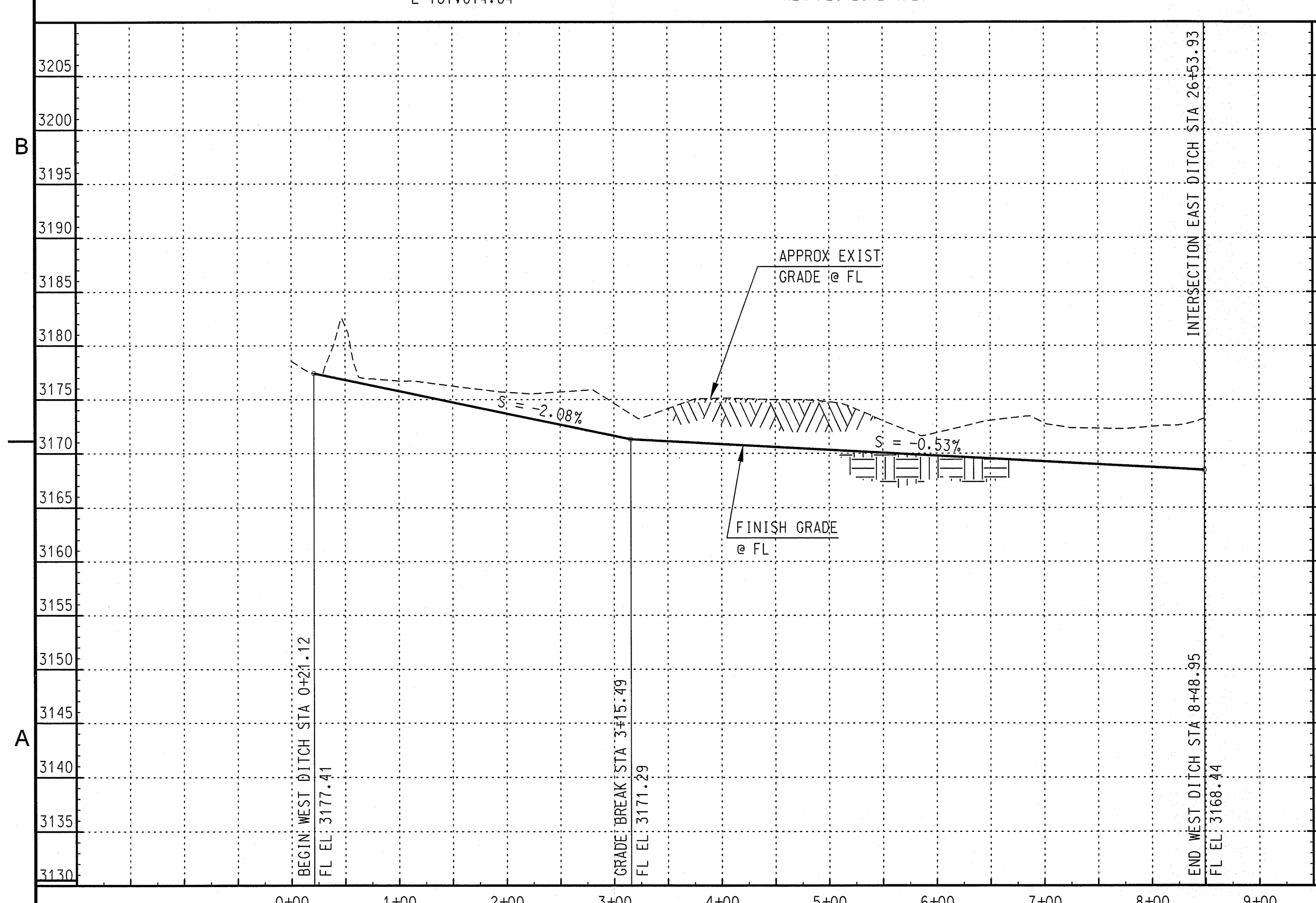
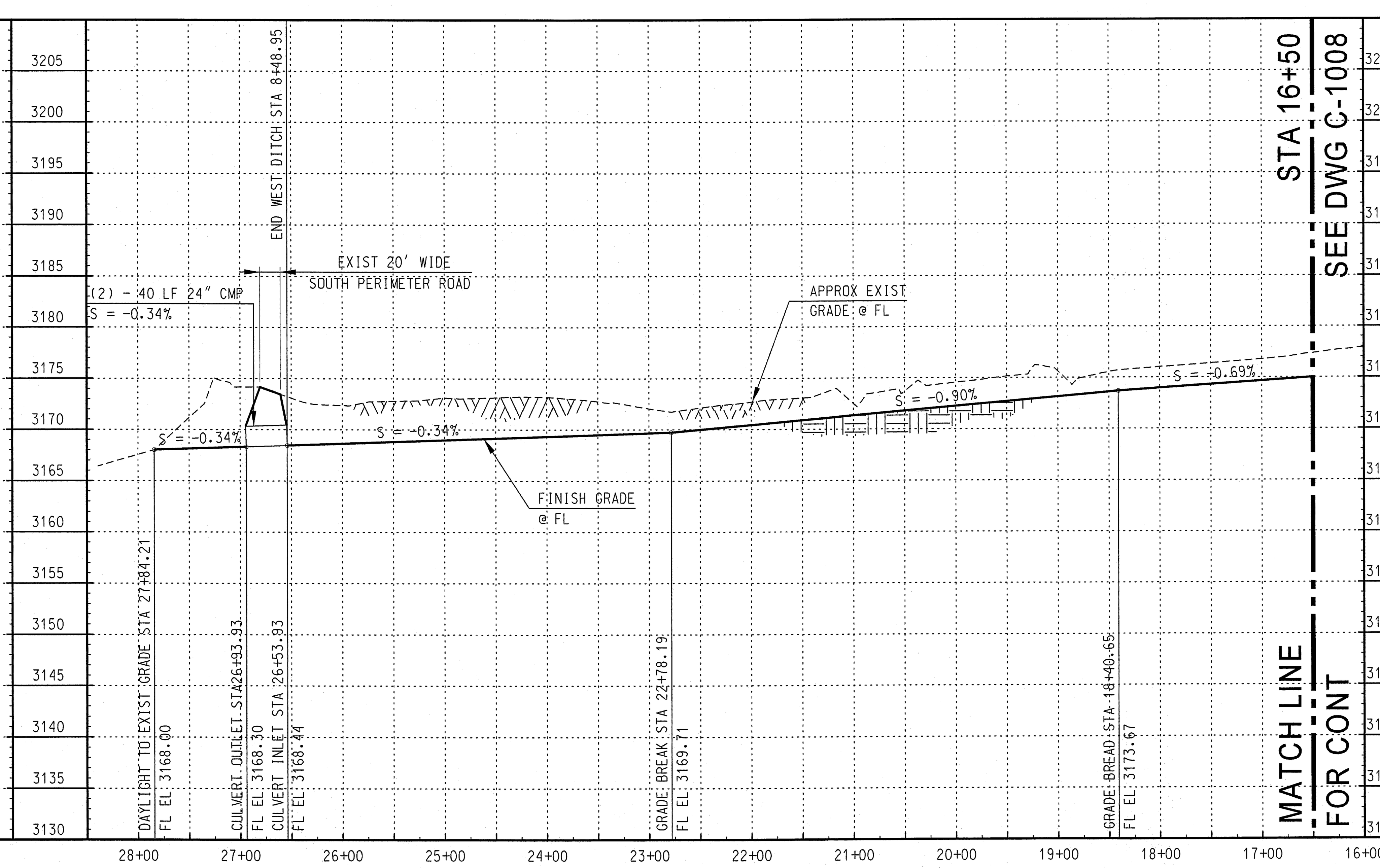
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



PLAN
SCALE: 1"= 100'



PROFILE (B)
SCALE: HORIZ 1"= 100', VERT 1"= 10'



PROFILE (A)
SCALE: HORIZ 1"= 100', VERT 1"= 10'

FOR REFERENCE DRAWINGS SEE 08023-G-0001

SOUTH DRAINAGE HORIZONTAL CURVE DATA

NO	RP	PC	PT	R	Δ	L	T
C4	N 766,129.00 E 708,313.26	N 766,329.00 E 708,313.26	N 766,267.49 E 708,168.97	200.00'	46°10'36"	161.19'	85.26'
C5	N 766,083.57 E 707,853.85	N 766,014.32 E 707,925.99	N 765,983.57 E 707,853.85	100.00'	46°10'36"	80.59'	42.63'
C6	N 765,963.57 E 707,634.64	N 765,983.57 E 707,634.64	N 765,963.57 E 707,614.64	20.00'	90°00'00"	31.42'	20.00'
C7	N 766,091.54 E 707,333.97	N 766,091.54 E 707,313.97	N 766,074.85 E 707,322.95	20.00'	56°34'54"	19.75'	10.76'
C8	N 766,003.57 E 707,467.30	N 765,986.87 E 707,456.28	N 765,983.57 E 707,467.30	20.00'	33°25'06"	11.67'	6.00'
C9	N 765,963.57 E 707,594.64	N 765,983.57 E 707,594.64	N 765,963.57 E 707,614.64	20.00'	90°00'00"	31.42'	20.00'

NOTES

1. FOR COMPACTION SPECIFICATIONS SEE DRAWING C-3001.
2. INSTALL CORRUGATED METAL PIPE (CMP) IN ACCORDANCE WITH NEVADA DEPARTMENT OF TRANSPORTATION (NDOT) STANDARD CONSTRUCTION PLANS R-1.1.1, R-1.1.5, R-1.1.6, R-1.3.1.2, AND R-2.8.1.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

Reviewed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec Eng RM
(Name/Organization)
Date: 4/1/08

GRAPHIC SCALE
0 10 20 30 FEET
1" = 10'

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'
(CONTOUR INTERVAL = 1 FOOT)

GS

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA
NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
SOUTH DRAINAGE PLAN & PROFILE

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1009
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ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION

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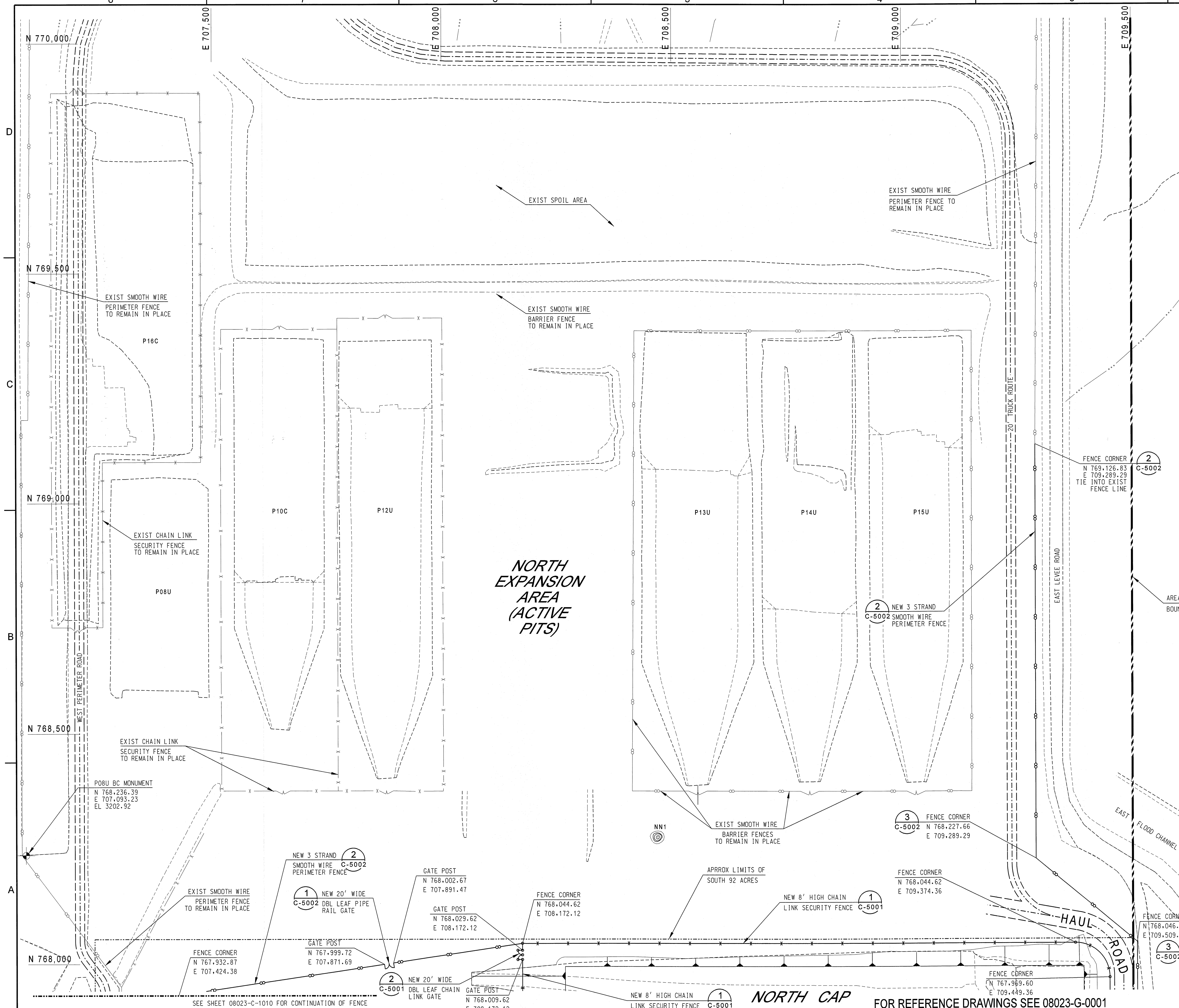
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



FOR REFERENCE DRAWINGS SEE 08023-G-0001

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This review does not constitute clearance for public release.
Derivative Classifier: RM Richard Morton, NSTec Engr (Name/Organization)
Date: 4/1/08

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NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
NEW FENCING PLAN (NORTH)

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1011
REVISION A

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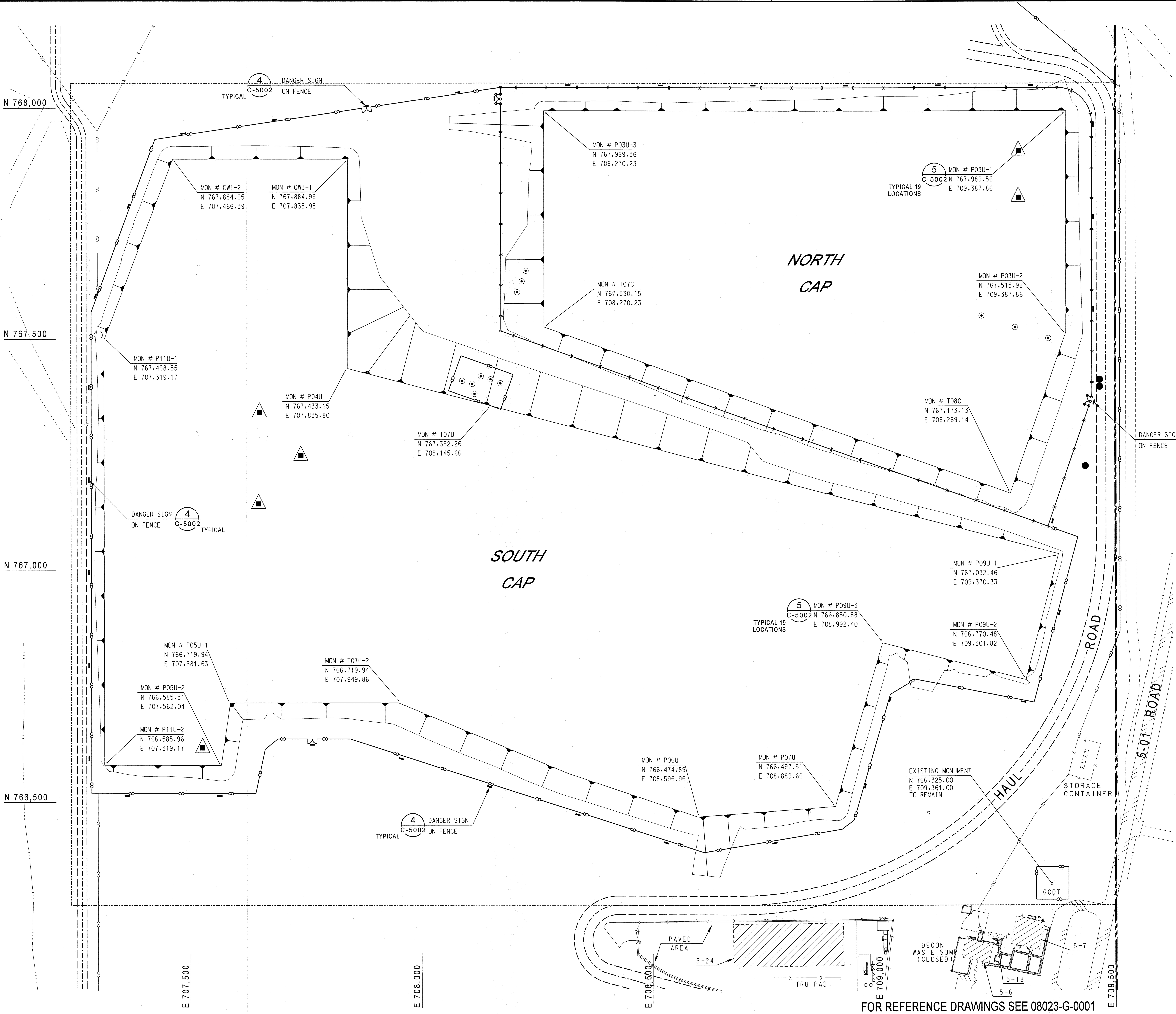
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



NOTES

1. SEE DRAWING 08023-C-5002 DETAIL 5 FOR MONUMENT FABRICATION AND MARKING DETAILS.
2. SEE DRAWING 08023-C-5002 DETAIL 4 FOR SIGN FABRICATION DETAILS AND SPACING INSTRUCTIONS.

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This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)
Date: 4/1/08

GS

GRAPHIC SCALE
0 50 100 200 300 FEET
1" = 100'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

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NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
NEW MONUMENT & SIGNAGE PLAN

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-1012
REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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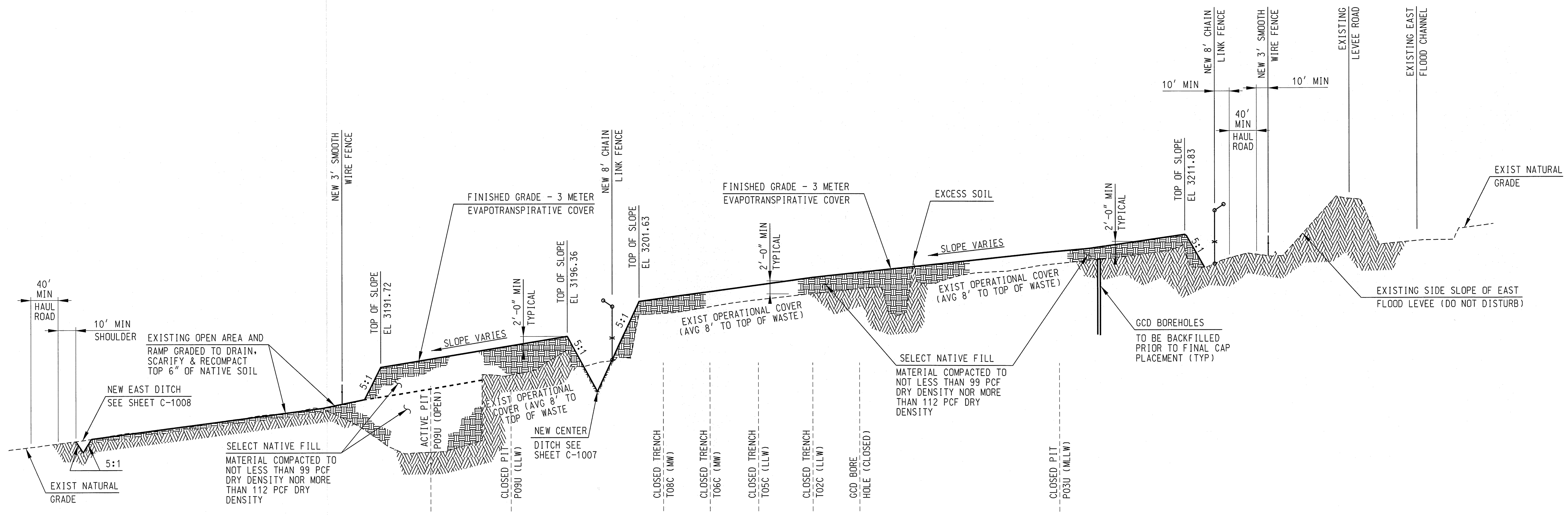
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



SECTION (SOUTH TO NORTH) (A) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

NOTES

1. SEE DRAWINGS C-1010 & C-1011 FOR FENCE HORIZONTAL LOCATIONS.
2. SEE DRAWINGS C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR DITCH FLOWLINE & HORIZONTAL LOCATIONS.

SOIL BACKFILL NOTES

1. PRIOR TO PLACING FILL AS COVER MATERIAL WITHIN THE RWMS, THE EXISTING SOILS IN AREAS TOO RECEIVE COVER FILL SHALL BE SCARIFIED TO A DEPTH OF 6 INCHES. THE SCARIFIED SOILS SHALL THEN BE MOISTURE CONDITIONED AND COMPACTED TO NOT LESS THAN 99 PCF DRY DENSITY NOR MORE THAN 112 PCF DRY DENSITY.
2. AN IN-SITU DENSITY MEASUREMENT PER SHALL BE TAKEN FOR EVERY 1,000 CUBIC YARDS OF COVER MATERIALS PLACED. DENSITY TESTING WILL BE CONDUCTED USING EITHER THE SAND CONE METHOD - D1556 OR THE NUCLEAR GAUGE METHOD - D6938.
3. BORROW SOILS ARE ACCEPTABLE FOR USE AS COVER MATERIALS, AND SHALL BE TESTED FOR ACCEPTANCE EVERY 5,000 CUBIC YARDS. TESTS SHALL INCLUDE THE FOLLOWING:
   1. GRAIN SIZE DISTRIBUTION BY ASTM METHOD D-422-63 (02)
   2. ATTERBERG LIMITS, ASTM METHOD D-4318-00
   3. MAXIMUM DENSITY OPTIMUM MOISTURE CONTENT, ASTM METHOD D-1557
4. COVER MATERIALS SHALL BE PLACED IN LIFTS A MAXIMUM OF 12 INCHES IN COMPACTED THICKNESS, MOISTURE CONDITIONED AND COMPACTED. LIFT THICKNESS MAY NEED TO BE REDUCED BASED UPON THE SIZE AND EFFECTIVENESS OF THE COMPACTION EQUIPMENT UTILIZED. NO ORGANIC, FROZEN OR DECOMPOSABLE MATERIALS SHOULD BE PLACED IN THE FILL, AND COBBLE/BOULDER SIZED MATERIALS LARGER THAN 3 INCHES SHOULD NOT BE PLACED WITHIN COMPACTED FILLS. COVER SOILS SHALL BE UNIFORMLY GRADED WITH NO GREATER THAN 20 PERCENT PASSING THE #200 SIEVE.
5. COMPACTION TESTING SHALL BE PERFORMED UPON COMPLETION OF EXISTING GROUND SURFACE PREPARATIONS AND WITHIN THE COMPACTED COVER MATERIALS EVERY LIFT UNTIL FINISH GRADE IS ACHIEVED. A TESTING FREQUENCY OF ONE COMPACTION TEST PER 1,000 CUBIC YARDS MATERIAL PLACED SHALL BE ADHERED TO DURING COVER CONSTRUCTION.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

Reviewed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.

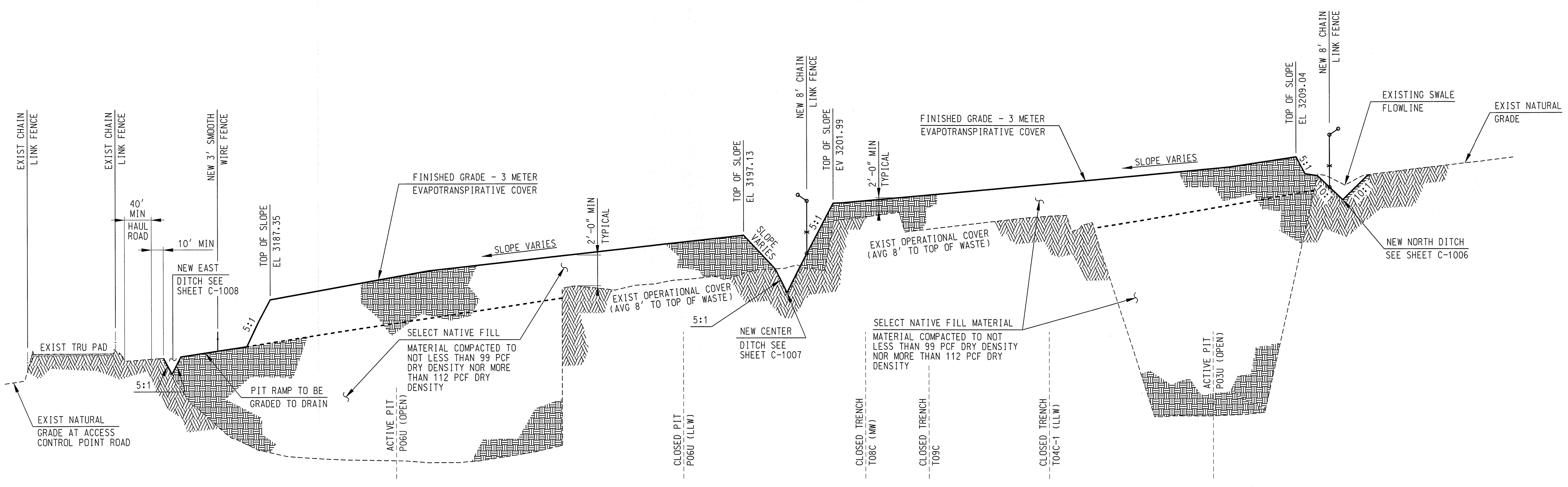
Derivative Classifier: Richard M. Morton, NSTec Eng (Name/Organization)

Date: 4/1/08

GRAPHIC SCALE: 0 10 20 30 FEET — 1" = 10'

GRAPHIC SCALE: 0 50 100 200 300 FEET — 1" = 100'

GS



SECTION (SOUTH TO NORTH) (B) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

FOR REFERENCE DRAWINGS SEE 08023-G-0001

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05

RADIOACTIVE WASTE MANAGEMENT SITE

FINAL CLOSURE COVER DESIGN

SOUTH 92 ACRES

CLOSURE CAP GRADING SECTIONS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

National Security Technologies LLC
Vision • Service • Partnership
NEVADA OPERATIONS
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023 — SHEET OF — ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-3001

REVISION A

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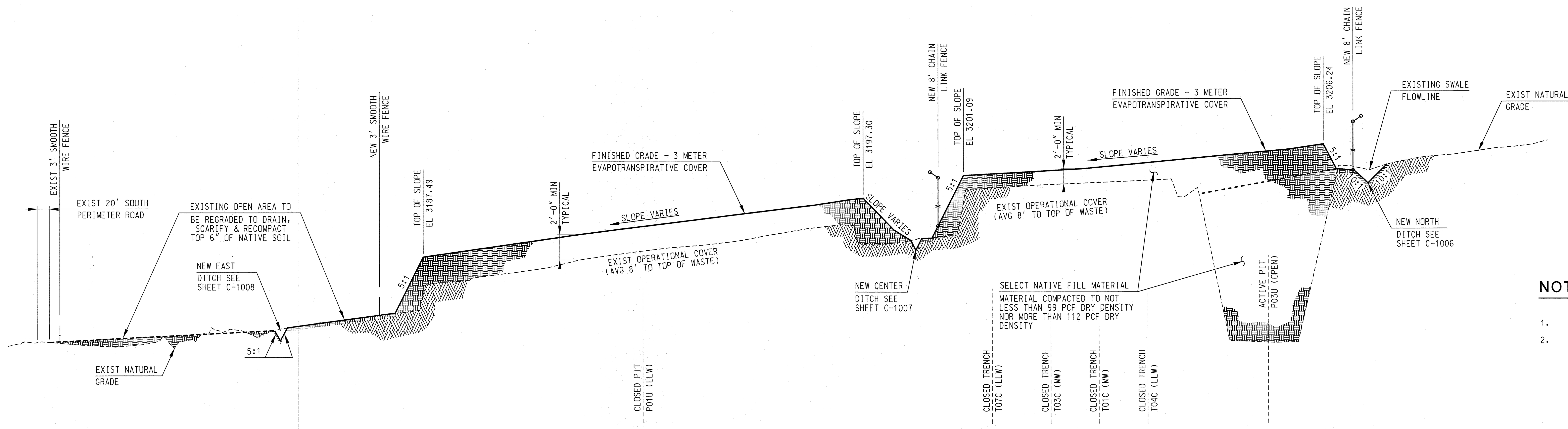

SECTION (SOUTH TO NORTH)

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

A C-1005

NOTES

1. SEE DRAWINGS C-1010 AND C-1011 FOR FENCE HORIZONTAL LOCATIONS.
2. SEE DRAWINGS C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR DITCH FLOWLINE & HORIZONTAL LOCATIONS.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

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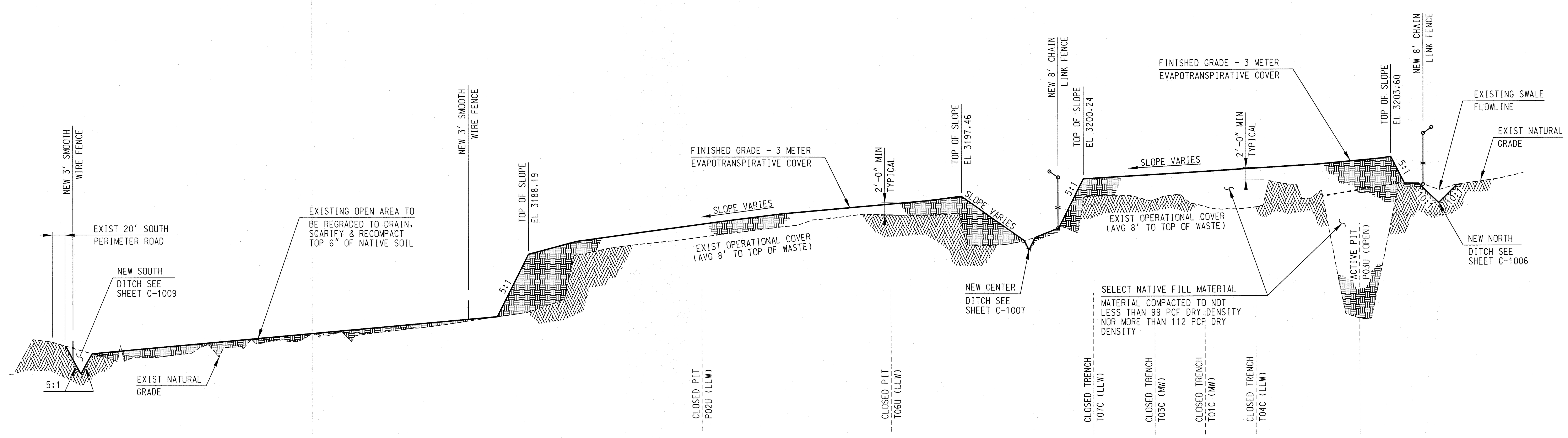
Derivative Classifier: Richard Morton, NSTec EnvP (Name/Organization)

Date: 4/1/08

GS

GRAPHIC SCALE: 0 10 20 30 FEET, 1" = 10'

GRAPHIC SCALE: 0 50 100 200 300 FEET, 1" = 100'



SECTION (SOUTH TO NORTH)

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

B C-1005

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

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FINAL CLOSURE COVER DESIGN

SOUTH 92 ACRES

CLOSURE CAP GRADING SECTIONS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023 — SHEET OF — ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-3002 — REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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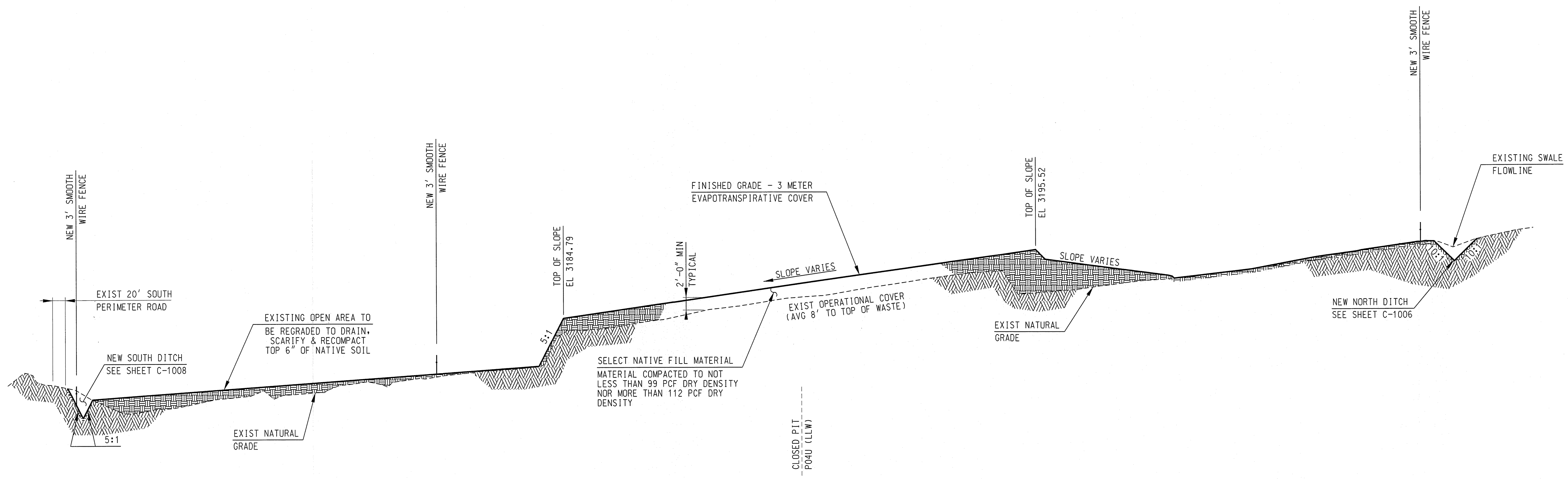
NOTES

1. SEE DRAWINGS C-1010 AND C-1011 FOR FENCE HORIZONTAL LOCATIONS.
2. SEE DRAWINGS C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR DITCH FLOWLINE & HORIZONTAL LOCATIONS.



SECTION (SOUTH TO NORTH) (A) C-1005

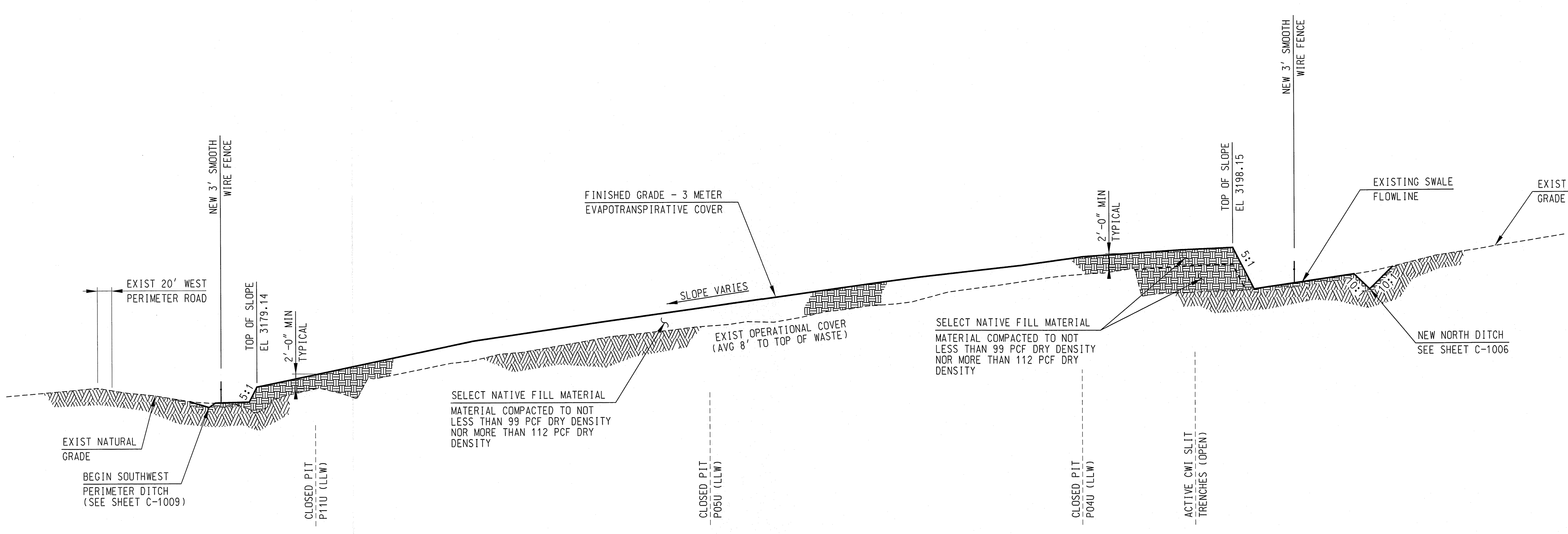
SCALE: HORIZ. 1" = 100' VERT. 1" = 10'

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

Reviwed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.

Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)

Date: 4/1/08



SECTION (SOUTH TO NORTH) (B) C-1005

SCALE: HORIZ. 1" = 100' VERT. 1" = 10'

GS

GRAPHIC SCALE: 0 10 20 30 FEET; 1" = 10'

GRAPHIC SCALE: 0 50 100 200 300 FEET; 1" = 100'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

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CLOSURE CAP GRADING SECTIONS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023; SHEET OF; ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-3003

REVISION: A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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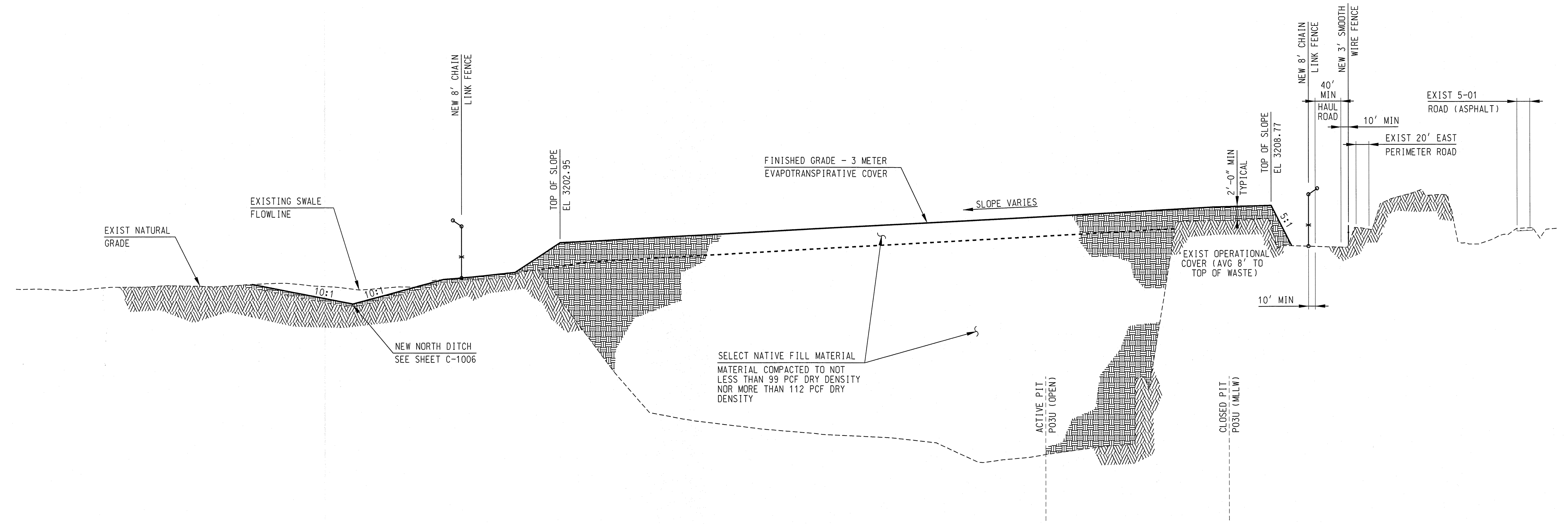

SECTION (WEST TO EAST) (A) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

NOTES

1. SEE DRAWINGS C-1010 AND C-1011 FOR FENCE HORIZONTAL LOCATIONS.
2. SEE DRAWINGS C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR DITCH FLOWLINE & HORIZONTAL LOCATIONS.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

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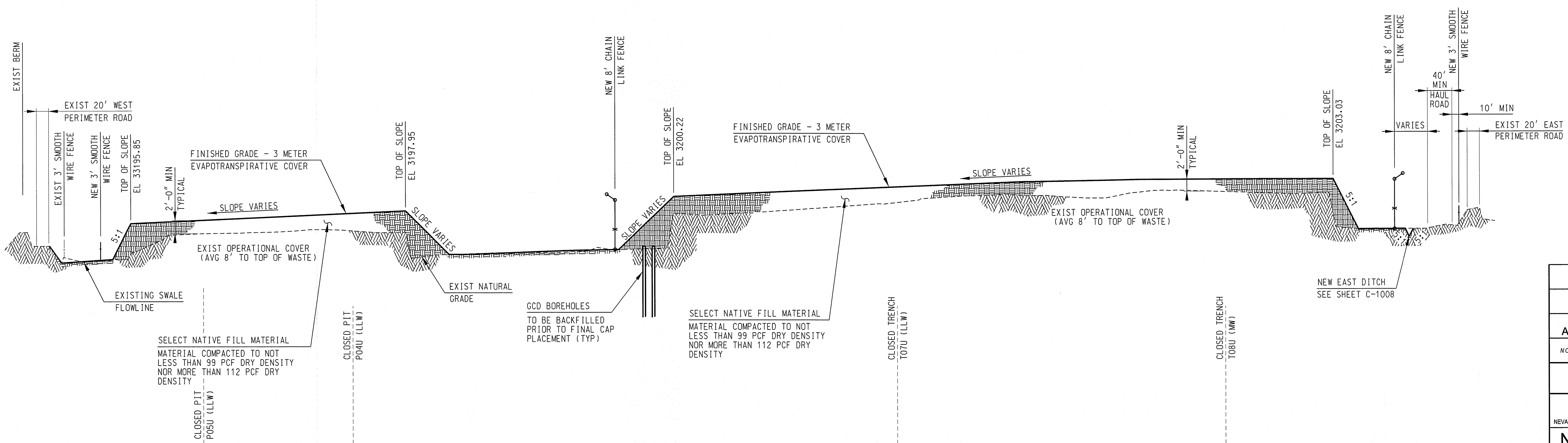
Derivative Classifier: Richard Morton, NSTec Engr (Name/Organization)

Date: 4/1/08



GRAPHIC SCALE 0 10 20 30 FEET 1" = 10'

GRAPHIC SCALE 0 50 100 200 300 FEET 1" = 100'

GS

SECTION (WEST TO EAST) (B) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
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FINAL CLOSURE COVER DESIGN
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CLOSURE CAP GRADING SECTIONS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023 | SHEET OF | ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-3004
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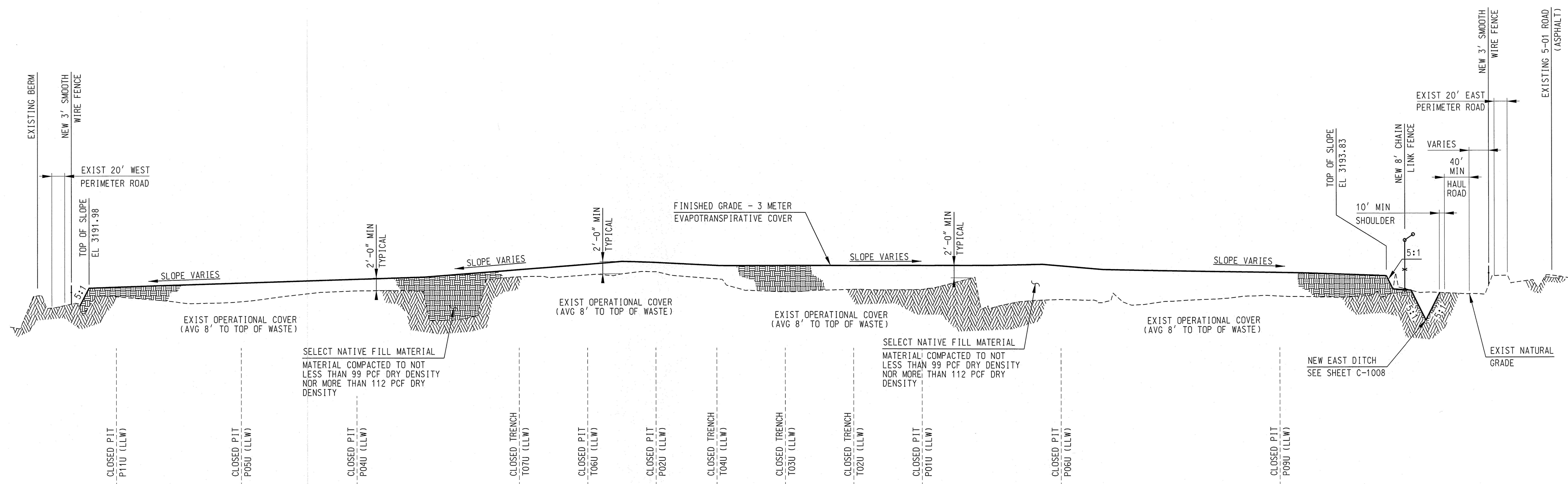

SECTION (WEST TO EAST) (A) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

NOTES

1. SEE DRAWINGS C-1010 AND C-1011 FOR FENCE HORIZONTAL LOCATIONS.
2. SEE DRAWINGS C-1006 (NORTH), C-1007 (CENTER), C-1008 (EAST) AND C-1009 (SOUTH) FOR DITCH FLOWLINE & HORIZONTAL LOCATIONS.

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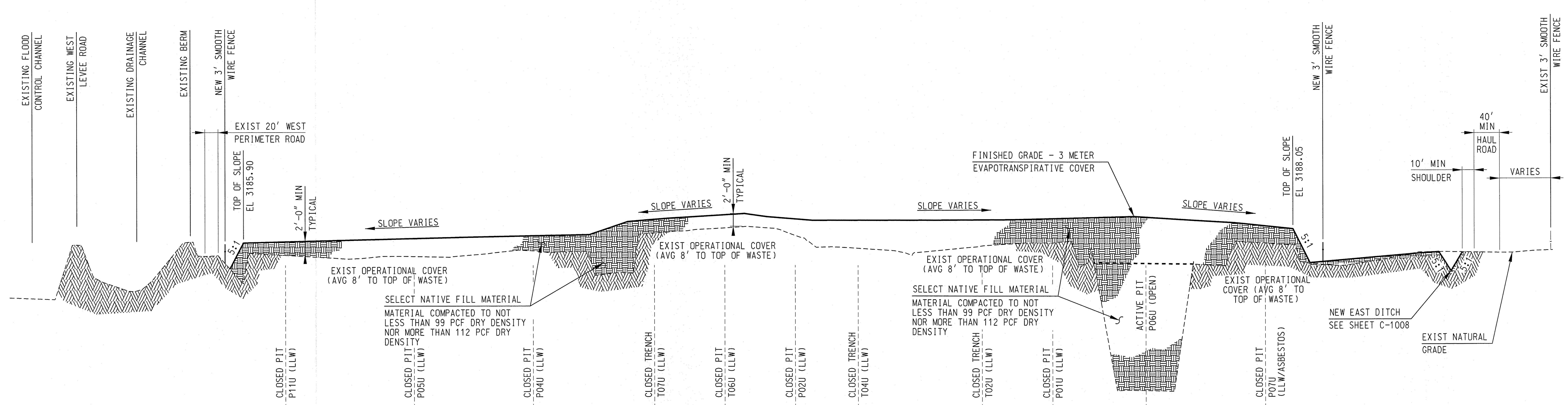
Date: 4/1/08

GRAPHIC SCALE 0 10 20 30 FEET 1" = 10'

GRAPHIC SCALE 0 50 100 200 300 FEET 1" = 100'

GS



SECTION (WEST TO EAST) (B) C-1005

SCALE : HORIZ. 1" = 100' VERT. 1" = 10'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
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FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
CLOSURE CAP GRADING SECTIONS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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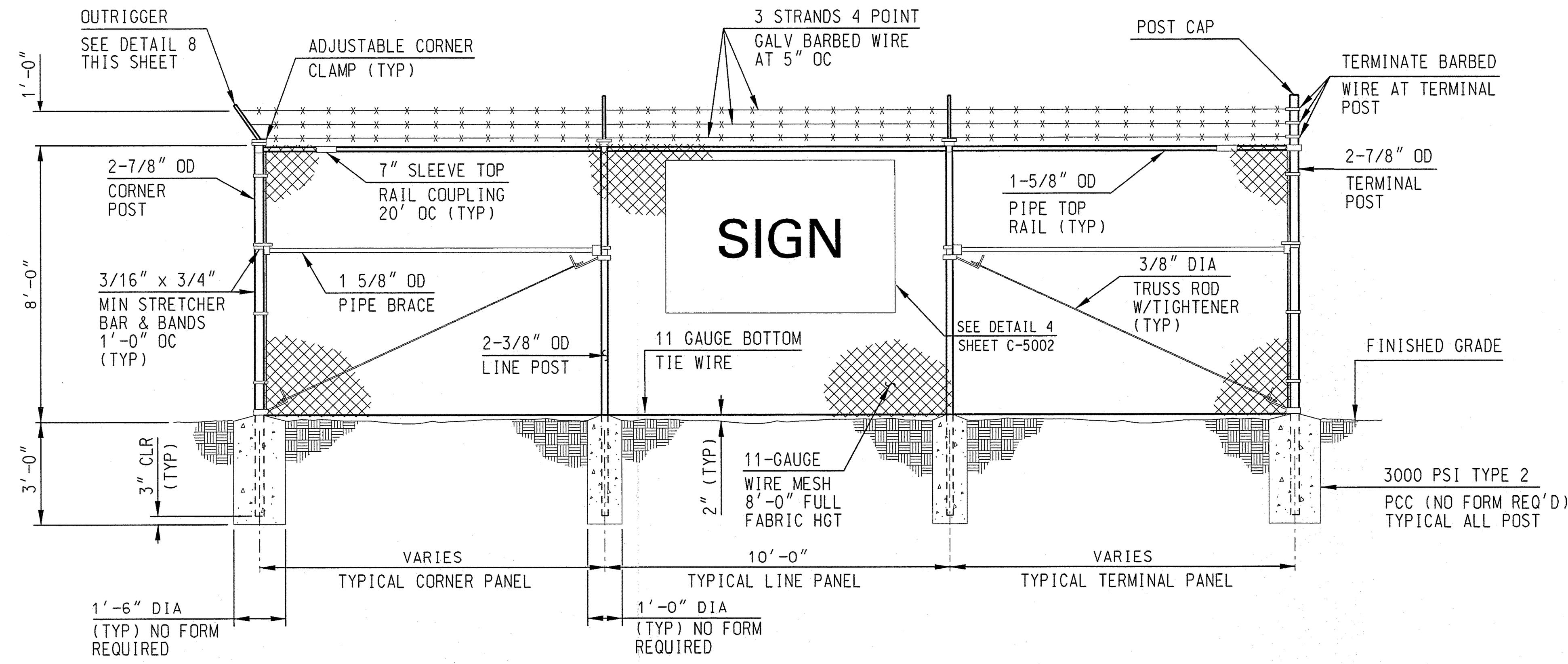
ENGINEERING NO. 08023 — SHEET OF — ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-3005
REVISION: A

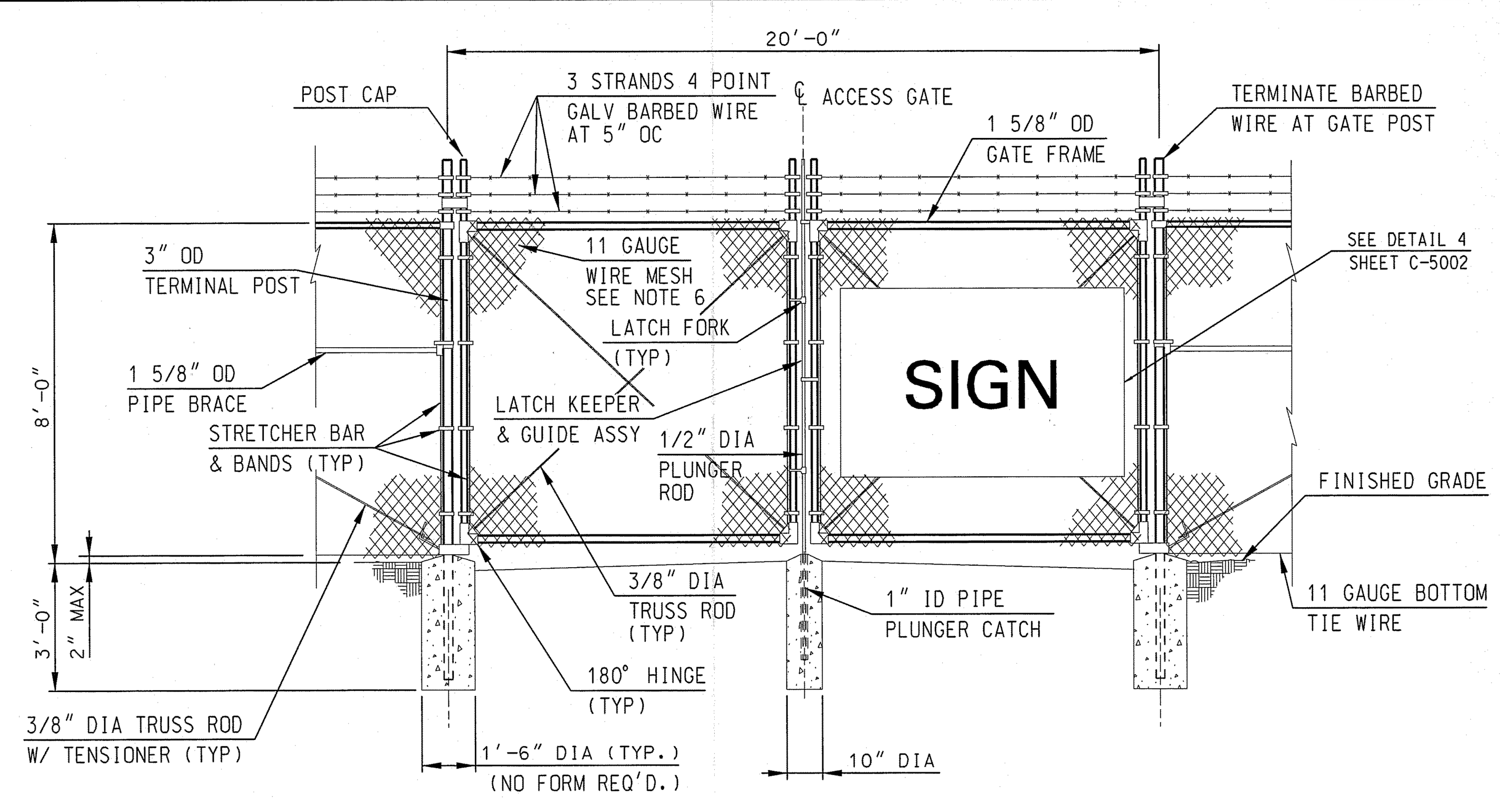
FOR REFERENCE DRAWINGS SEE 08023-G-0001



SECURITY FENCE (1)

SCALE: NONE

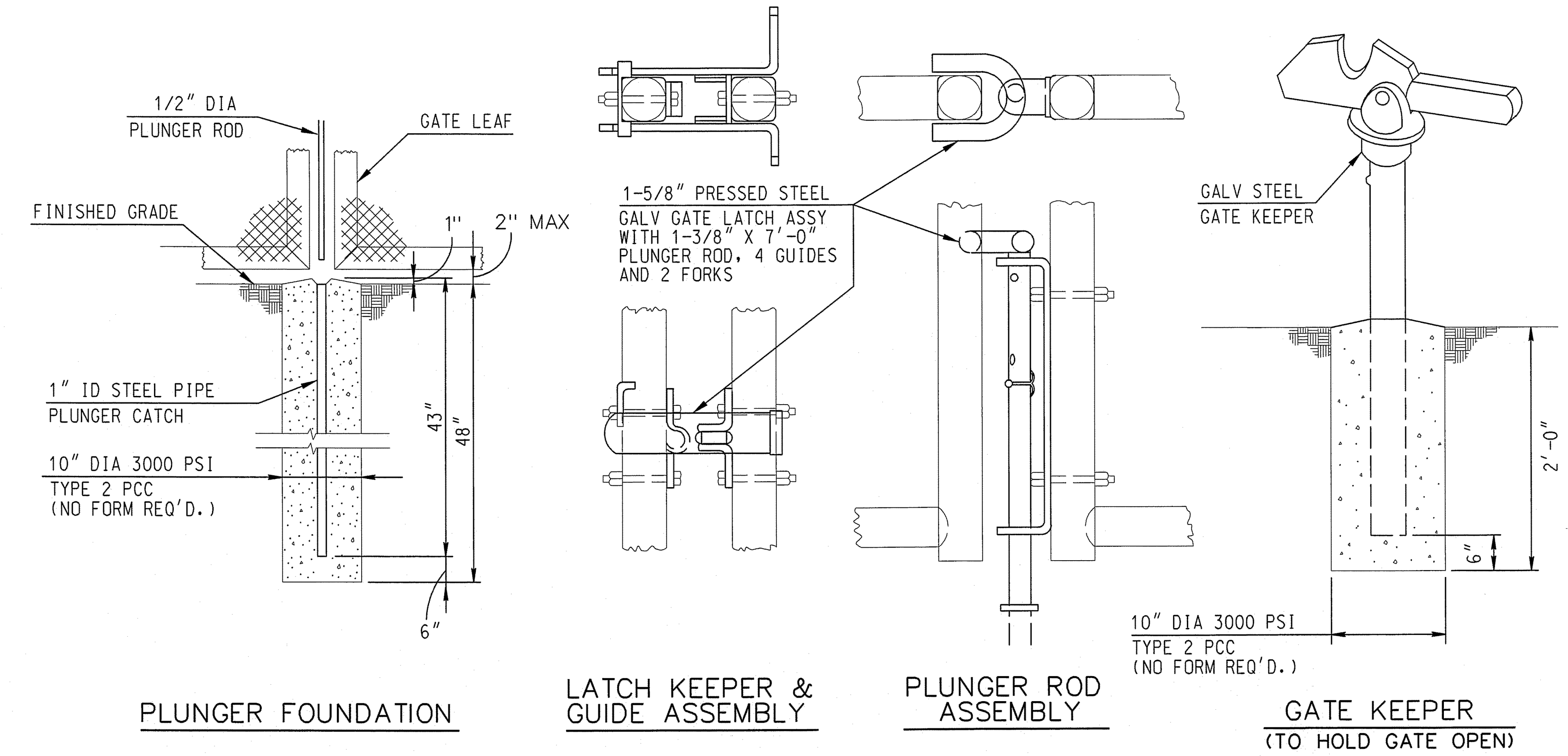
C-1010,C-1011



20'-0" DOUBLE SWING GATE (2)

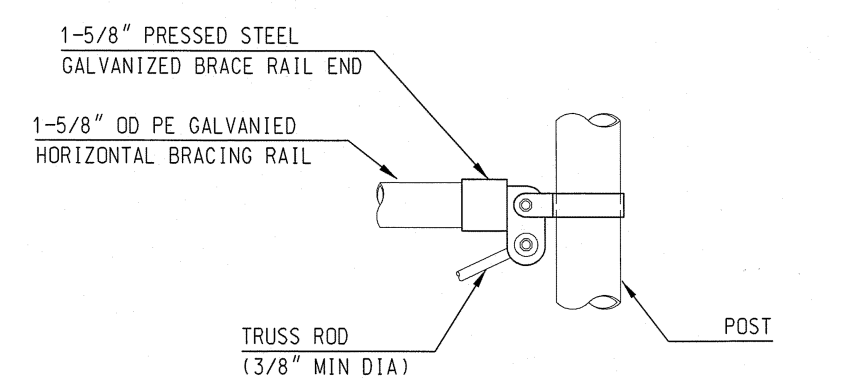
SCALE: NONE

C-1010, C-1011



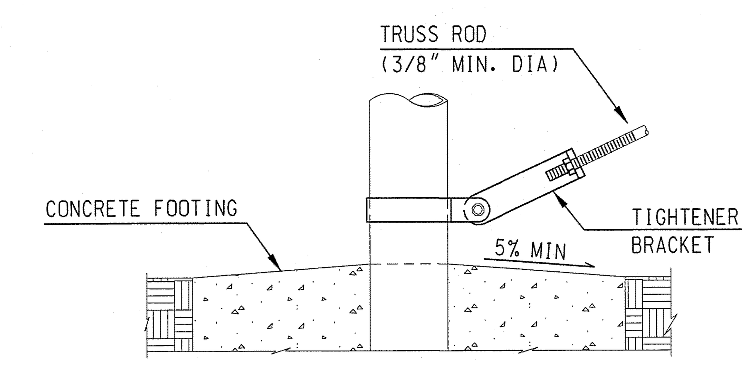
SWING GATE DETAILS (3)

SCALE: NONE



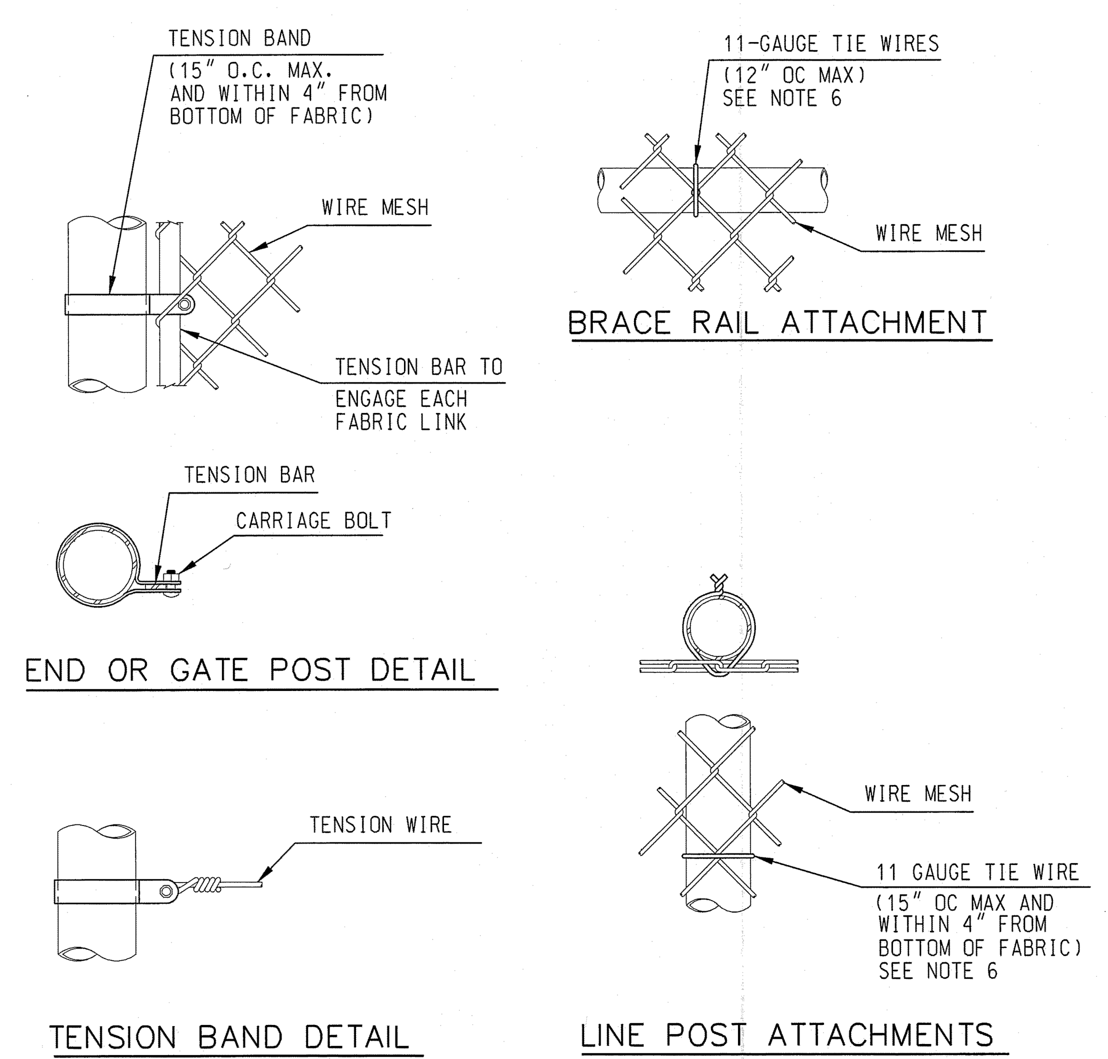
BRACE RAIL CLAMP DETAIL (5)

SCALE: NONE



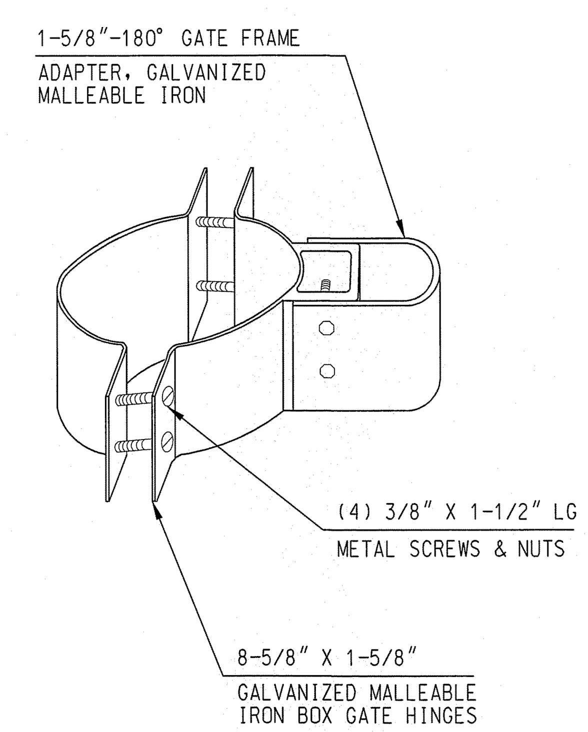
TRUSS ROD AND BAND (5)

SCALE: NONE



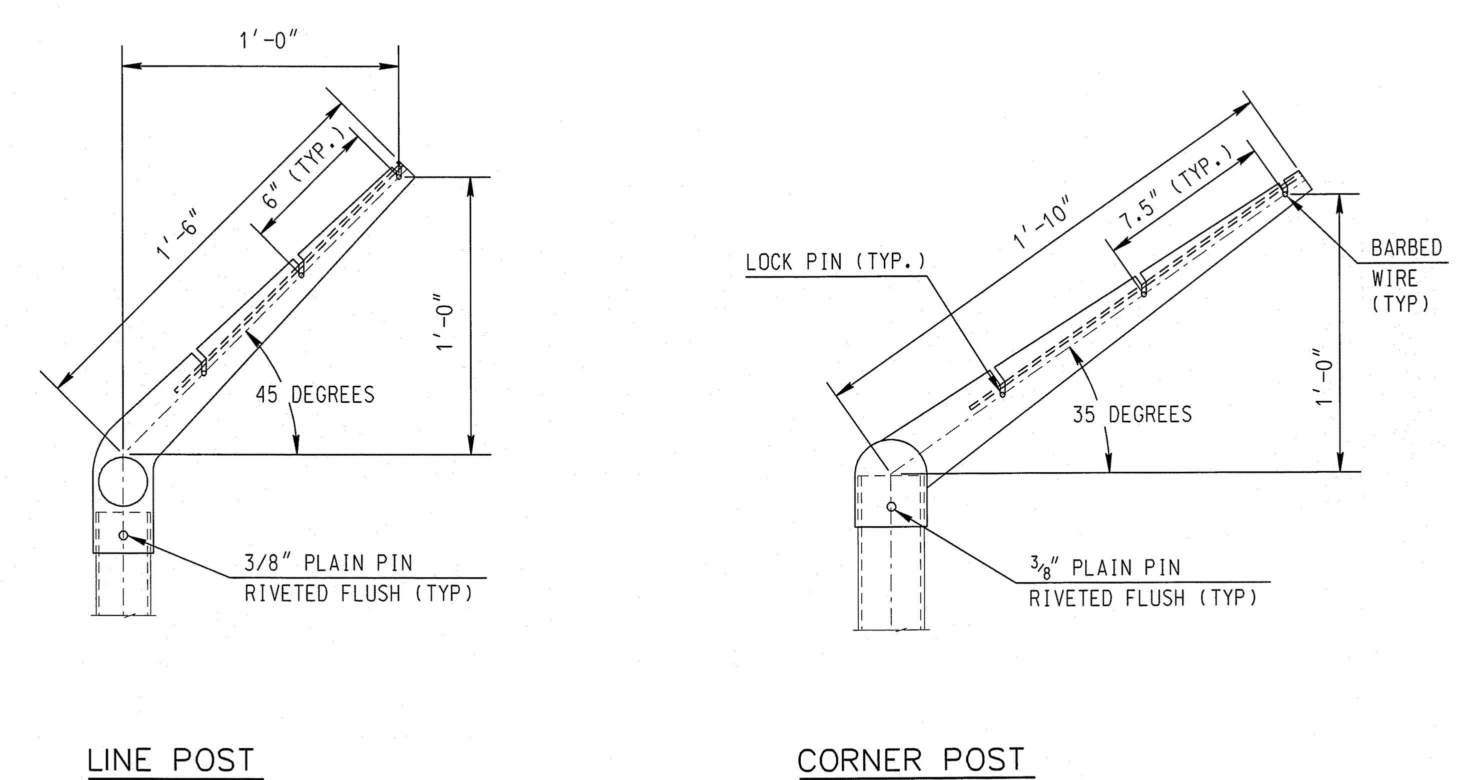
TYPICAL FASTENING DETAILS (6)

SCALE: NONE



STANDARD 180 DEGREE HINGE (7)

SCALE: NONE



OUTRIGGER EXTENSION ARM DETAILS (8)

SCALE: NONE

FOR REFERENCE DRAWINGS SEE 08023-G-0001

FENCE NOTES

1. ALL SECURITY FENCING AND ACCESS GATES SHALL MEET THE REQUIREMENTS OF DOE M 470.4-2, SECTION A, AS A MINIMUM. ALL FENCING COMPONENTS SHALL BE GALVANIZED.
2. WIRE MESH FENCE AND GATES SHALL CONSIST OF 2 SQUARE INCH OR SMALLER MESH, NUMBER 11 AMERICAN WIRE GAUGE OR HEAVIER GALV. STEEL MATERIALS. FENCE AND GATES SHALL BE TOPPED WITH THREE OR MORE STRANDS OF BARBED WIRE ON SINGLE OUTRIGGERS, FACING OUTWARD, AWAY FROM THE STRUCTURE BEING PROTECTED.
3. CONNECTION DETAILS SHOWN ON THIS SHEET SHALL COMPLY WITH ASTM F626 AS A MINIMUM. IN ADDTION, ALL CHAIN LINK FENCING PROVIDED SHALL COMPLY WITH THE MINIMUM MATERIAL AND INSTALLATION REQUIREMENTS SPECIFIED IN THE CHAIN LINK MANUFACTURERS INSTITUTE'S PRODUCT MANUAL (LATEST EDITION).
4. SWING GATES SHALL COME COMPLETE WITH PLUNGER ROD, LATCHE KEEPER AND LOCKABLE CLOSURE HARDWARE. GATE FRAMES MAY BE CONSTRUCTED USING WELDED HORIZONTAL BRACES IN LIEU OF TRUSS RODS FOR GATE BRACING. ALL FENCE AND GATE HARDWARE SHALL BE INSTALLED USING A METHOD TO PREVENT TAMPERING AND/OR REMOVAL (e.g. BY BRAZING, PEENING, OR WELDING). SECURITY PADLOCKS ARE TO BE PROVIDED BY OTHERS (NIC).
5. FENCE POST, BRACING, BOLTING AND OTHER STRUCTURAL MEMBERS SHALL BE LOCATED ON THE SECURE SIDE (INSIDE) AND THE WIRE FABRIC SHALL BE PLACED ON THE OPPOSITE SIDE (OUTSIDE) OF THE SECURE AREA. WHERE THE GALVANIZED FINISH HAS BEEN REMOVED OR DAMAGED DURING INSTALLATION, ALL POST, BRACING AND OTHER STRUCTURAL MEMBERS SHALL BE COATED WITH ZINC-ENRICHED PAINT AFTER FINAL INSTALLATION.
6. PER DOE M 470.4-2, ALL WIRE TIES USED TO FASTEN FENCE FABRIC TO THE POLES SHALL BE OF AN EQUAL TENSILE STRENGTH TO THAT OF THE FENCE FABRIC.
7. FOR ALL LINE POST, CORNER POSTS AND GATE POSTS, PROVIDE AN APPROVED PRE-MIXED PORTLAND CEMENT CONCRETE HAVING A COMPRESSIVE STRENGTH OF 3,000 PSI AT 28 DAYS IN ACCORDANCE WITH ACI 318 (2005).
8. FINISH CONCRETE FOOTINGS BY NEATLY SHAPING AT THE FINISH GRADE LINE TO PROVIDE SHEDDING OF WATER AWAY FROM POST.
9. DURING CONSTRUCTION, TEMPORARY FENCING SHALL BE INSTALLED TO COMPLY WITH SITE-SPECIFIC PROTECTION GOALS AND OPERATIONAL REQUIREMENTS AS DIRECTED BY RWMS OPERATIONS MANAGEMENT.
10. PROVIDE "DANGER SIGNS" AS SPECIFIED IN DETAIL 4, SHEET C-5002. MOUNT ONE SIGN AT EACH GATE AND ALONG ALL PERIMETER FENCE RUNS AS SHOWN IN DETAIL 2 THIS SHEET. LOCATE SIGNS ON THE PERIMETER FENCE AT THE APPROXIMATE. LOCATIONS SHOWN ON DWG C-1010, WITH A MAXIMUM OF 200' SPACING BETWEEN SIGNS.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

Reviwed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.
Derivative Classifier: Richard Morton, NSTec/Engr (Name/Organization)
Date: 4/1/08

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 30% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05

RADIOACTIVE WASTE MANAGEMENT SITE

FINAL CLOSURE COVER DESIGN

SOUTH 92 ACRES

CHAIN LINK FENCING DETAILS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023 — SHEET OF — ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-5001

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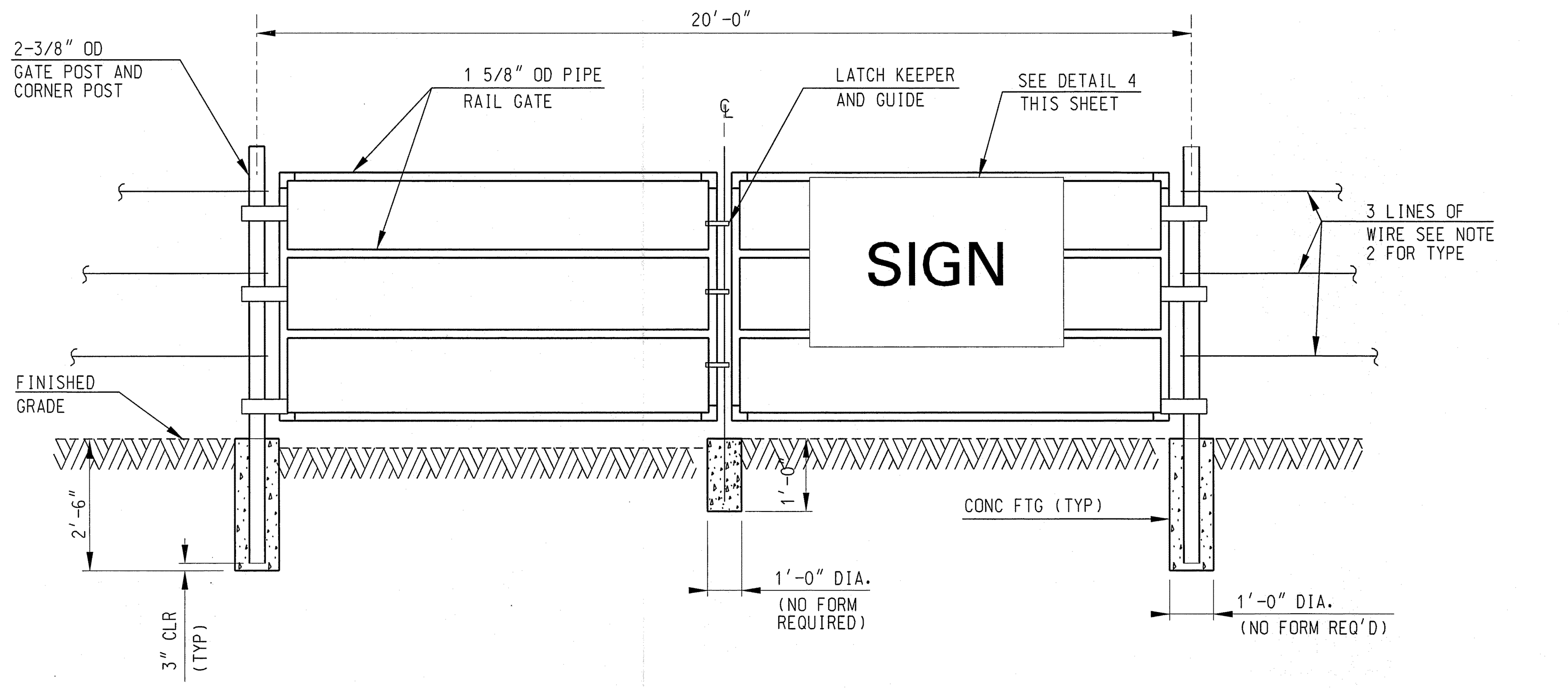
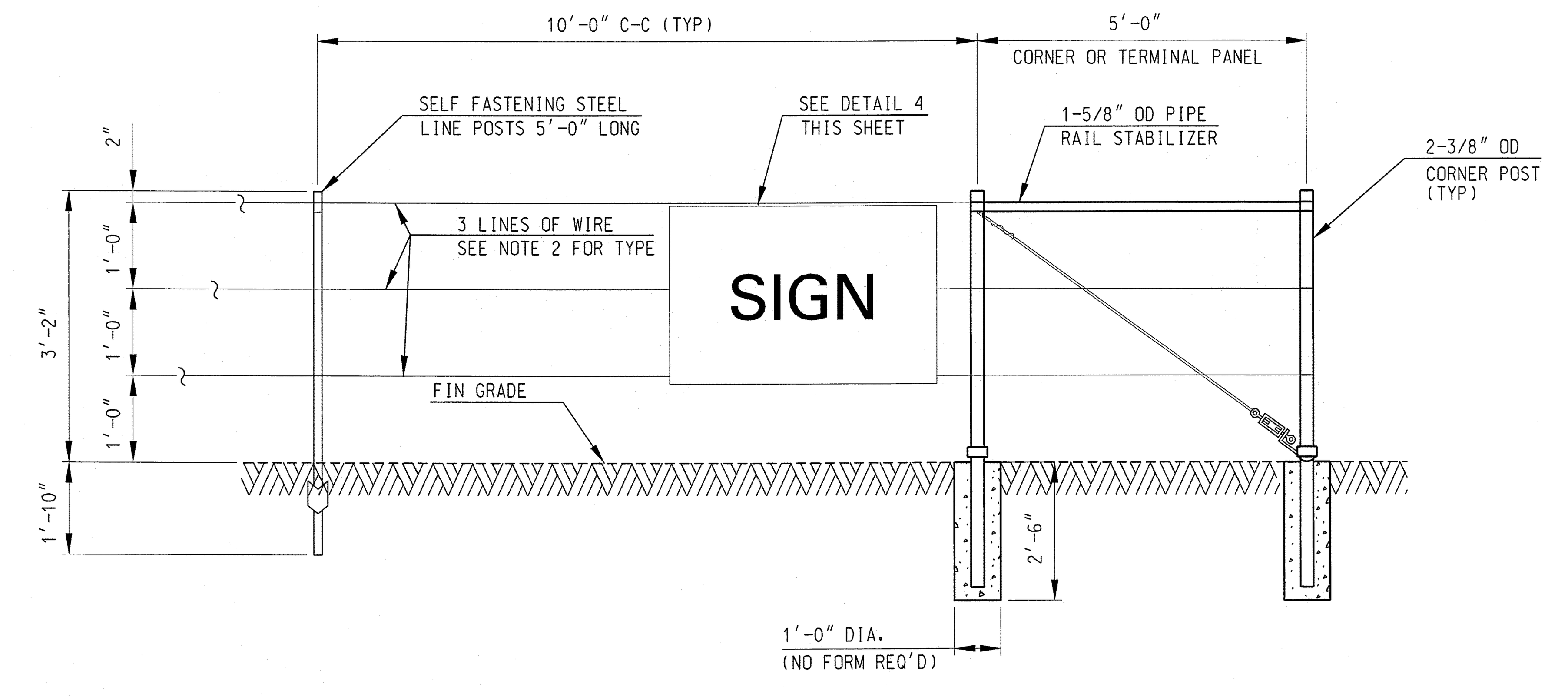
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



20'-0" DOUBLE LEAF GATE ASSEMBLY (1)

SCALE: NONE

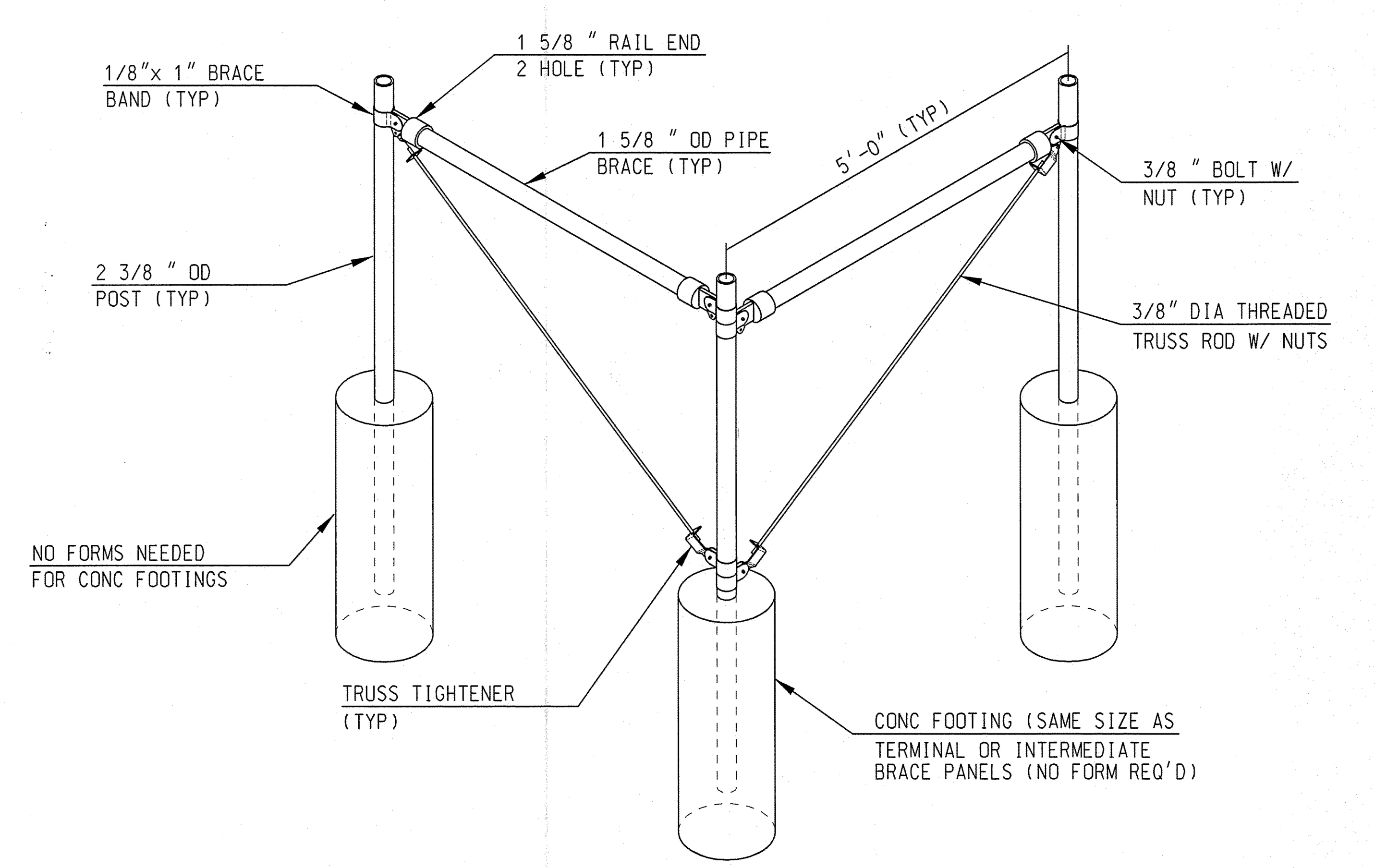
C-1010, C-1011



3 WIRE (3' HIGH) FENCE DETAIL (2)

SCALE: NONE

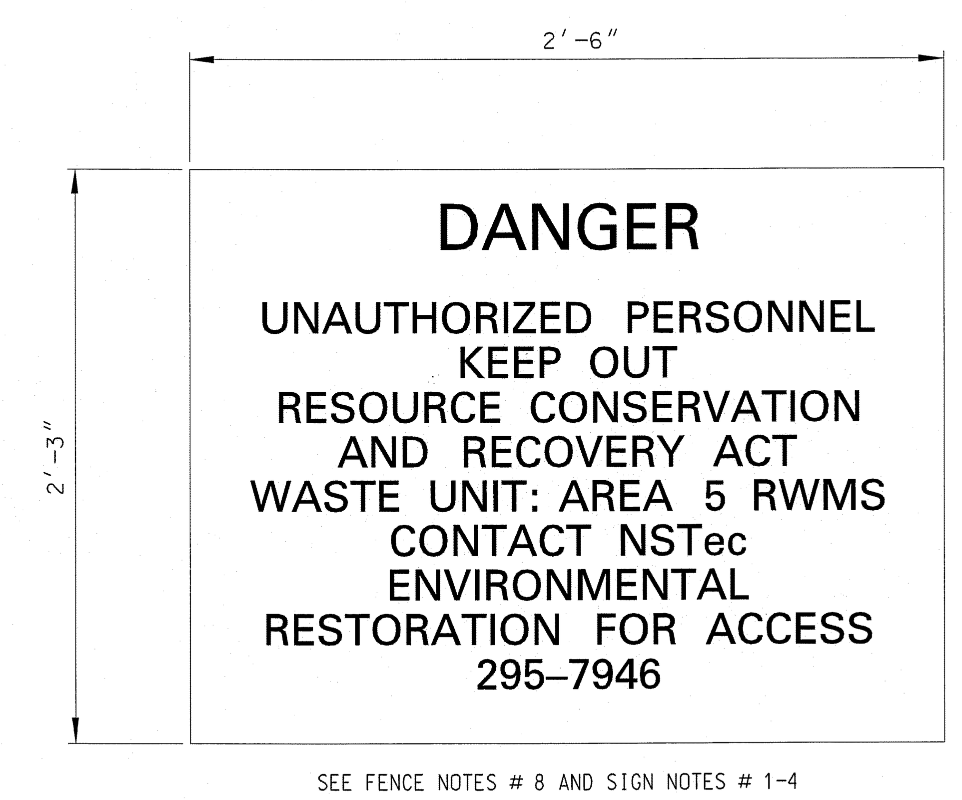
C-1010, C1011



3-POST CORNER PANEL ASSEMBLY (3)

SCALE: NONE

C-1010, C-1011

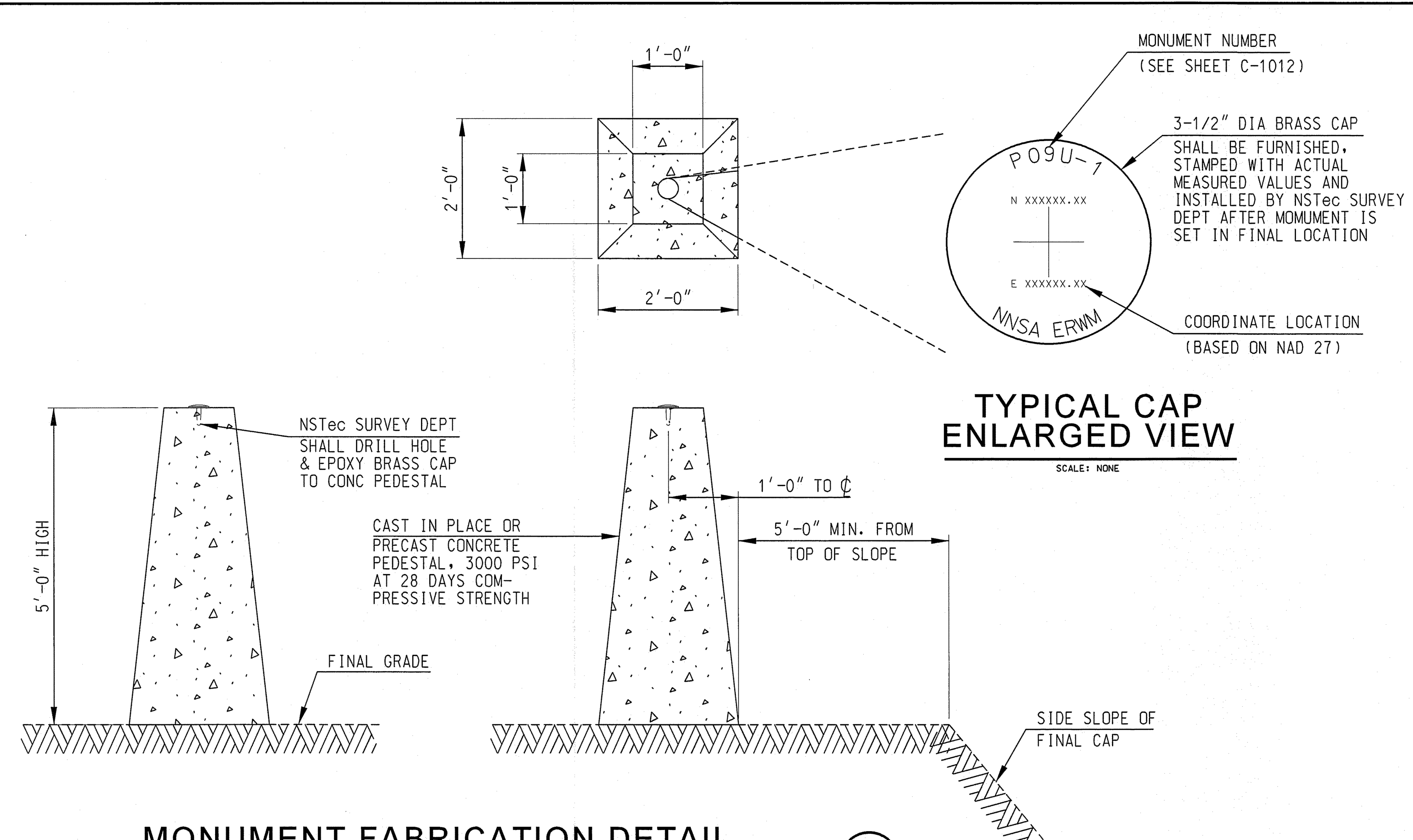


SEE FENCE NOTES # 8 AND SIGN NOTES # 1–4

SIGN DETAIL (4)

SCALE: NONE

C-1012, C-5001



MONUMENT FABRICATION DETAIL (5)

SCALE: NONE

C-1012

FENCE NOTES

1. DURING CONSTRUCTION, TEMPORARY FENCING SHALL BE INSTALLED TO COMPLY WITH SITE-SPECIFIC PROTECTION GOALS AND OPERATIONAL REQUIREMENTS AS DIRECTED BY RWMS OPERATIONS MANAGEMENT.
2. PROVIDE VINYL OR POLYMER COATED, STEEL SMOOTH WIRE. MINIMUM WIRE SIZE SHALL BE 12-1/2 GAUGE. WIRE COATINGS SHALL COMPLY WITH ASTM F668 (2007)AND A854 (2003).
3. PROVIDE DRIVE-TYPE SELF FASTENING GALVANIZED STEEL LINE POST, AND 2-3/8" OD GALVANIZED STEEL CORNER/END POST AS INDICATED ON THE PLANS. PROVIDE 1-5/8" OD GALVANIZED PIPE RAIL DOUBLE LEAF GATE. GALVANIZED COATINGS FOR POSTS SHALL CONFORM TO ASTM A123 (2002).
4. FOR ALL 3 POST CORNERS, END POST AND GATE POSTS, PROVIDE AN APPROVED PRE-MIXED PORTLAND CEMENT CONCRETE HAVING A COMPRESSIVE STRENGTH OF 3,000 PSI AT 28 DAYS IN ACCORDANCE WITH. ACI 318 (2005).
5. FINISH CONCRETE FOOTINGS BY NEATLY SHAPING AT THE FINISH GRADE LINE TO PROVIDE SHEDDING OF WATER AWAY FROM POST.
6. SMOOTH WIRE SHALL BE FASTENED AS REQUIRED BY THE TYPE OF POST USED. TIE WIRES SHALL BE 11 GUAGE MINIMUM. SECURE WIRE TO LINE POSTS AND PULL AROUND CORNER POST WITH ENOUGH TENSION TO AVIOD SAGGING.
7. GATE HINGES SHALL HAVE TIGHT, NON-REMOVABLE PINS. LATCHES SHALL BE PROVIDED WITH A MEANS FOR PADLOCKING GATES.
8. PROVIDE "DANGER SIGNS" AS SPECIFIED IN DETAIL 4, THIS SHEET. MOUNT ONE SIGN AT EACH GATE AND ALONG ALL PERIMETER FENCE RUNS AS SHOWN IN DETAIL 2 THIS SHEET. LOCATE SIGNS ON THE PERIMETER FENCE AT THE APPROXIMATE. LOCATIONS SHOWN ON DRAWING C-1010, WITH A MAXIMUM OF 200' SPACING BETWEEN SIGNS.

SIGN NOTES

1. THESE NOTES APPLY TO "DANGER SIGNS" MOUNTED ON THE PERIMETER FENCE ONLY.
2. SIGN SHALL BE WHITE WITH BLACK LETTERING.
3. MINIMUM LETTER/WORD HEIGHT IS:

   DANGER = 3" (76MM)
   ALL OTHER = 1-1/2" (38MM)
4. SIGN STOCK THICKNESS SHALL BE 16 GAUGE/0.635" OR GREATER.

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

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Derivative Classifier: Richard Morton, NSTec Eng. (Name/Organization)

Date: 4/1/08

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05

RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES

SMOOTH WIRE FENCING DETAILS

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER/USER
DATE	DATE	DATE	DATE	DATE

D. DURHAM — J. SOROLA

National Security Technologies LLC
Vision • Service • Partnership
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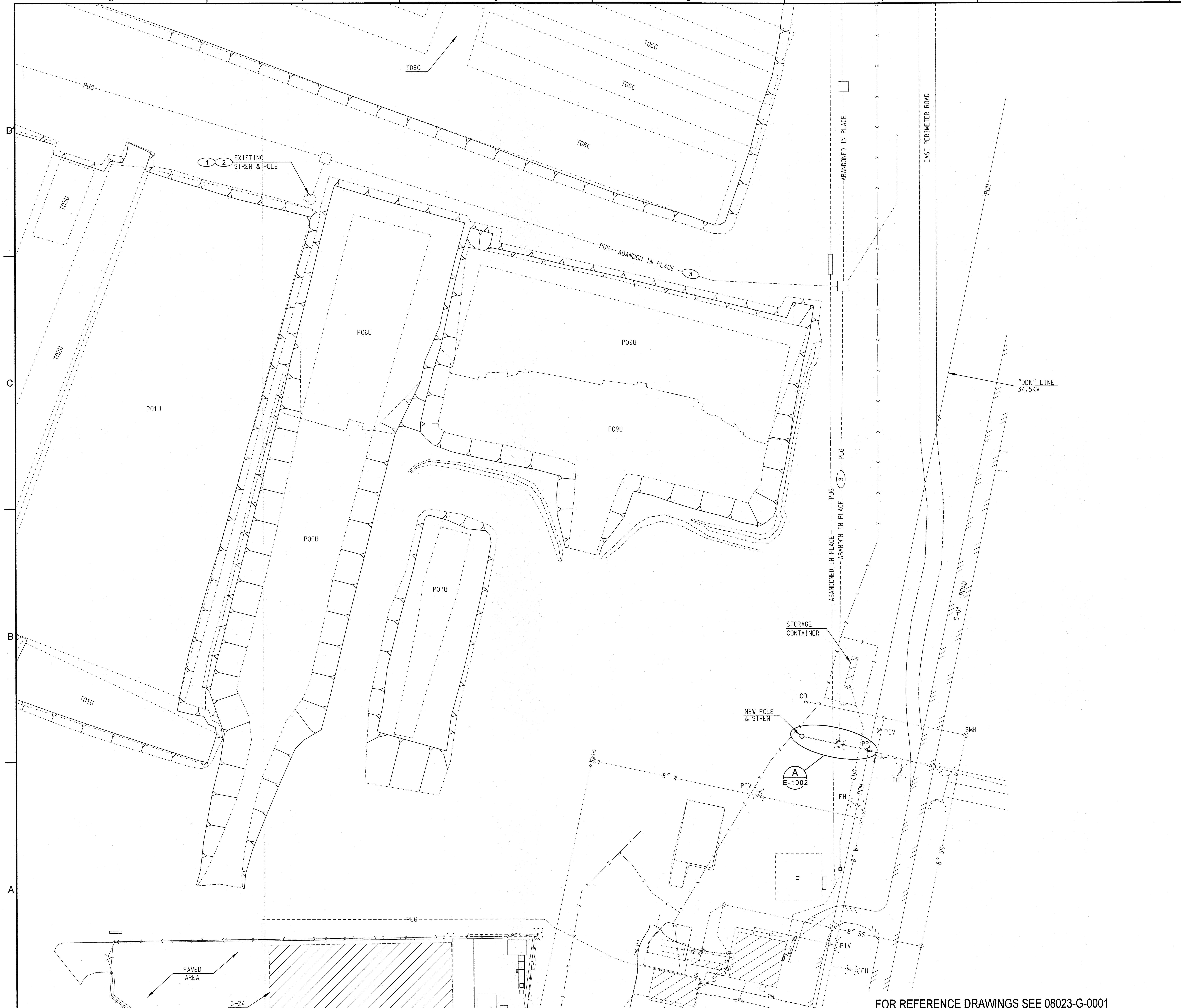
P.O. BOX 98521 LAS VEGAS, NV 89193-8521

ENGINEERING NO. 08023
SHEET OF
ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-C-5002

REVISION: A

FOR REFERENCE DRAWINGS SEE 08023-G-0001



NOTES

1. REMOVE AND SALVAGE ALL EXISTING ABOVE GROUND ELECTRICAL PANELS, MONITORING DEVICES AND/OR JUNCTION BOXES WITHIN THE SOUTH 92 ACRE BOUNDARY. ALL UNDERGROUND POWER LINES ARE TO BE ABANDONED IN PLACE, EXCEPT AS NOTED. PULL BOXES AND/OR MAN HOLES NOT BEING USED ARE TO BE FILLED IN WITH NATIVE SOIL AND ABANDONED IN PLACE.

KEY NOTES

(1) REMOVE POLE AND EXISTING EQUIPMENT. RELOCATE EXISTING EVACUATION SIREN, DISCONNECT SWITCH, CONTROL BOX AND ASSOCIATED EQUIPMENT TO WEST OF THE ELECTRICAL PULL BOX #1. SEE SHEET 08023-E-1002 FOR DETAILS.

(2) FROM THE EXISTING SIREN AND POLE, GOLD-DIKE THE 5 CONTROL WIRES TO FIND THE PATH TO WHERE THEY ARE BEING FED FROM (THE SOURCE). AFTER FINDING THE PATH TO THE SOURCE, CONSULT THE PROJECT ENGINEER AND THE ELECTRICAL DESIGN ENGINEERING TO FIND THE BEST LOCATION TO CUT AND SPLICE NEW CONTROL WIRES INTO THE EXISTING CONTROL WIRES (MATCH EXISTING SIZE, TYPE WIRE AND TERMINATIONM POINTS ON CONTROLLER).

(3) REMOVE POWER CABLE AFTER NEW POLE/SIREN IS IN PLACE. CONDUIT AND PULL BOX WILL BE ABANDON IN PLACE

ISSUED FOR 90% DESIGN REVIEW NOT FOR CONSTRUCTION

Reviwed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.

Derivative Classifier: Richard Morton NSTec Emp. (Name/Organization)

Date: 4/1/08

GS

GRAPHIC SCALE

0 30 60 120 180 FEET

1" = 60'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER / USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05

RADIOACTIVE WASTE MANAGEMENT SITE

FINAL CLOSURE COVER DESIGN

SOUTH 92 ACRES

ELECTRICAL SITE PLAN

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
SHEET 1 OF 1
ORIGINAL SIGNATURES ON FILE

DRAWING NUMBER / WORK ORDER NUMBER: 08023-E-1001

REVISION: A

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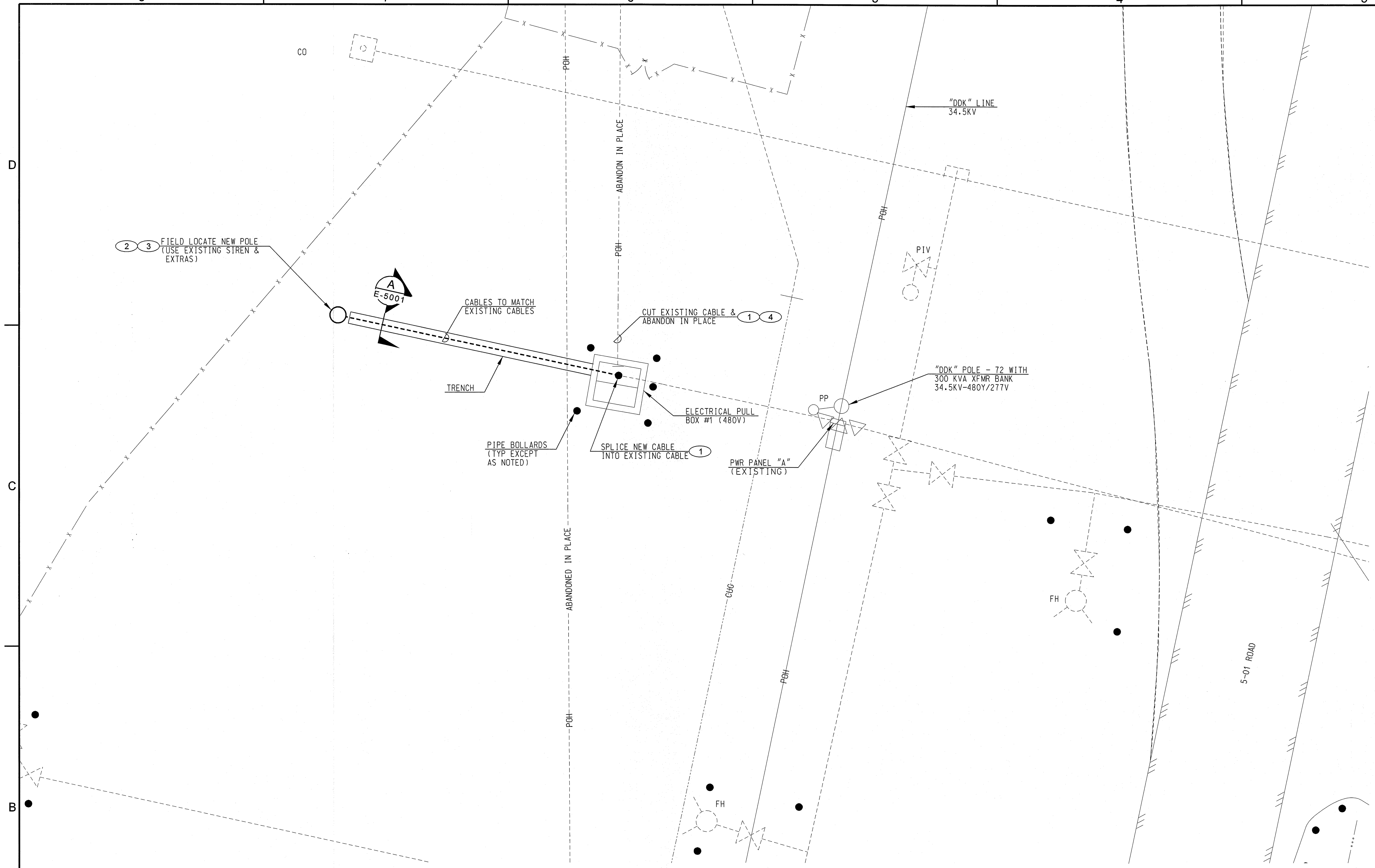

ELECTRICAL PLAN (A / E-1001)

SCALE: 1" = 10'-0"

KEY NOTES

1. AFTER LOTO AND DE-ENERGIZING SYSTEM (CKT 9, PWR PNL 'A'), CUT EXISTING POWER CABLES AND SPLICE IN NEW POWER CABLES GOING TO NEW SIREN POLE (MATCH EXISTING CABLE SIZE AND TYPE).
2. FIELD LOCATE 70FT (MIN) CLASS 3 (MIN) POLE (REUSING EXISTING SIREN, CONTROL BOX, DISCONNECT SWITCH, ETC.).
3. CONSULT THE PROJECT ENGINEER AND THE ELECTRICAL DESIGN ENGINEER ON THE BEST LOCATION TO CUT THE EXISTING CONTROL CABLES AND SPLICE NEW CONTROL CABLES INTO THE EXISTING ONES AND THEN CONNECT THE NEW CONTROL CABLES INTO THE CONTROL BOX RE-LOCATED ONTO THE NEW POLE. THESE NEW CONTROL CABLES WILL BE PLACED IN A TRENCH FROM THE SPLICE TO THE NEW POLE (TRENCH WILL BE OF SIMULAR DESIGN AS DETAIL "B" ON DWG 08023-E-5001).
4. UNDERGROUND POWER CABLES TO BE REMOVED AFTER SPLICING OF NEW CABLE INTO CABLE THAT IS TO REMAIN. CONDUIT IS TO BE ABANDON IN PLACE.

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NOT FOR CONSTRUCTION

Reviwed and determined to be UNCLASSIFIED.
This review does not constitute clearance for public release.

Derivative Classifier: Richard Norton, NSTec Engr (Name/Organization)

Date: 4/1/08

GS

GRAPHIC SCALE 0 10 20 30 FEET
1" = 10'

NO	DATE	REVISIONS	PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJ ENGR	APPROVER/USER
A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05
RADIOACTIVE WASTE MANAGEMENT SITE
FINAL CLOSURE COVER DESIGN
SOUTH 92 ACRES
ELECTRICAL PLAN

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
SHEET 1 OF 1
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER: 08023-E-1002
REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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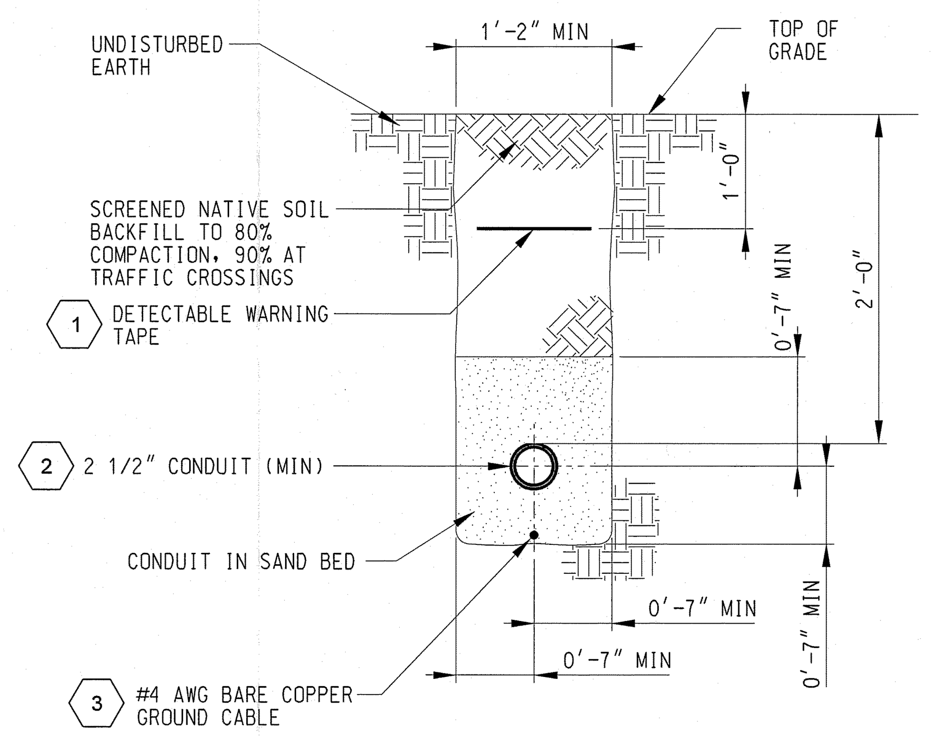
ENGINEERING DESIGN IN PROGRESS - NOT FOR CONSTRUCTION



TRENCH DETAIL

SCALE : NONE

A E-1002

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

GS

Reviwed and determined to be UNCLASSIFIED. This review does not constitute clearance for public release.

Derivative Classifier: Richard Melton, NSTec Engr (Name/Organization)

Date: 4/1/08

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A		ISSUED FOR 90% REVIEW					

NATIONAL NUCLEAR SECURITY ADMINISTRATION

NEVADA SITE OFFICE — LAS VEGAS, NEVADA

NEVADA TEST SITE — AREA 05

RADIOACTIVE WASTE MANAGEMENT SITE

FINAL CLOSURE COVER DESIGN

SOUTH 92 ACRES

TRENCH DETAIL

PREPARER	CHECKER	DERIVATIVE CLASSIFIER	PROJECT ENGINEER	APPROVER / USER
DATE	DATE	DATE	DATE	DATE

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ENGINEERING NO. 08023
SHEET 1 OF 1
ORIGINAL SIGNATURES ON FILE
DRAWING NUMBER / WORK ORDER NUMBER 08023-E-5001
REVISION A

FOR REFERENCE DRAWINGS SEE 08023-G-0001

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APPENDIX B

DESIGN CALCULATIONS

08023-CAL-C-001	Area 5 RWMS 92-Acre Area WEQ
08023-CAL-C-002	Area 5 RWMS Internal Drainage
08023-CAL-C-003	Area 5 RWMS Water Erosion

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1. **Calculation No.:**	2. **Revision No.:**	3. **Date:**	4. **Project No.:**	5. **Pages**
08023-CAL- C - 001	0	3-18-08	08023	9

6. **Calculation Title:**	7. **Project Title:**
Area 5 ~~RMWS~~ RWMS 92-Acre Area WEQ	Area 5 Closure Plan for the 92 Acre Area

8. **Calculation Type:** (BAN 4/1/08)	9. **Quality Grade**	10. **Performance Category**	11. Superseded by Calculation No.: N/A 12. Supersedes Calculation No.: N/A
☐ Preliminary ☒ Final ☐ Voided/ Superseded	☐ QG-1 ☒ QG-3 ☐ QG-2 ☐ QG-4	☒ PC-1 ☐ PC-2 ☐ PC-3	

Original and Revised Calculation/Analysis Approval (Signature/Date)

13.	Revision A	Revision	Revision
14. **Preparer:**	Lloyd Desotell		3-18-08 Date
15. **Checker:**	Vefa Yucel		3/18/08 Date
16. **Peer Reviewer:**	N/A		Date
17. **Discipline Section Supervisor:**	Richard Greenwold		4-1-08 Date

Affected Documents

Document No.	Document Title	Revision No	Responsible Discipline Lead Initials

Record of Revision

Revision No.	Reason for Revision
0	Original

Attachments

Attachment No.	Title	Total Pages
A.	Wind erodibility groups and wind erodibility index	1
B.	Agronomy Technical Note 69 – Wind Erosion Equation	4
C.	(E) * Soil Loss From Wind Erosion in Tons per Acre per Year	4
	Total Calculation Page Count	18

1 Introduction

This calculation was generated to estimate the magnitude of soil loss due to wind erosion for the proposed final landfill closure cover for the Area 5 RWMS 92-acre area. The cover will be constructed of a single layer of native alluvium and seeded with native vegetation. The site is located within the Area 5 Radioactive Waste Management Site (RWMS). Annual soil loss estimates are made using the Wind Erosion Equation (WEQ).

2 Basis

Calculations are performed to support landfill closure design.

2.1 Design Inputs

- Soil particle size data were obtained from boreholes drilled in Area 5 (Shott et al 1998).
- Wind speed, temperature and precipitation data required to calculate the local climate factor (C) were obtained from Soule, 2006. These data are from the Well 5B meteorological station located approximately 3.5 miles from the proposed location. Values used in calculations are based on averages of over 17 years of data.
- Unsheltered distances and surface slopes for the closure cover surface and cover sideslopes were obtained from design drawings completed by the Civil Engineering Design group.

2.2 Criteria

Compute annual average soil loss due to wind erosion.

2.3 Assumptions

- The final cover slope is less than 3%.
- Cover sideslopes will vary between 10-20%.
- The finished grade of the cover will be approximately 6 ft above existing grade.

3 References

Coduto, D. Geotechnical Engineering: Principles and Practices. Prentice-Hall Inc Upper Saddle River, New Jersey, 1999.

Natural Resources Conservation Service (NRCS). National Agronomy Manual, 190-V-NAM, 3rd

Edition October 2002.

National Security Technologies (NSTec), LLC. Nevada Test Site 2006 Waste Management Monitoring Report Area 3 and Area 5 Radioactive Waste Management Sites, June 2007.

Soule, D. 2006. Climatology of the Nevada Test Site. SORD Technical Memorandum SORD 2006-3, Air Resources Laboratory, Silver Spring, Maryland 165pp.

Shott GJ, Barker LE, Rawlinson SE, Sully MJ, and BA Moore. Performance assessment for the Area 5 Radioactive Waste Management Site, Nye County, Nevada. Las Vegas, NV: Bechtel Nevada, DOE/NV/11718—176; 1998.

Turner FB and DC Randall. Net production by shrubs and winter annuals in Southern Nevada. Journal of Arid Environments (1989) **17**, 23-36.

Microsoft Excel 2002 SP3

U.S. Department of Agriculture, Soil conservation Service, Western Technical Services Center – Portland Oregeon. Agronomy Technical Note 69 – Wind Erosion Equation (Annual Method) on Rangeland May 2004.

Webb, R. H., M. B. Murov, T. C. Esque, D. E. Boyer, L. A. DeFalco, D. F. Haines, D. Oldershaw, S. J. Scoles, K. A. Thomas, J. B. Blainey, and P. A. Medica. 2003. *Perennial Vegetation Data from Permanent Plots on the Nevada Test Site, Nye County, Nevada*. Open-File Report 03-336, U.S. Geological Survey, Tuscon, AZ

Personal communication with project plant ecologist David Anderson.

Personal communication with Mike Sporcic, Wind Erosion Specialist, Natural Resources Conservation Service, National Technology Support Center-Central .

4 Methods

- Wind erosion loss is calculated using the Wind Erosion Equation (WEQ).

5 Results and Conclusions

The calculated annual soil loss is for the cover and sideslopes due to wind erosion is presented below.

Surface	Wind Erosion (tons/acre/year)
Cover sideslopes	194 (10H:1V), 162 (5H:1V)
Cover	115

Important limitations of this method should be recognized when interpreting these results. Limitations include the equation does not account for deposition of incoming soil particles or the changes in the soil surface over time which may reduce the amount of erosion. This is of particular importance at the project site due to the high percentage of coarse fragments (~ 25%) present in the site soils. Therefore these calculations should be considered very conservative. Additionally, little erosion has been observed at the U-3ax/bl landfill at the Nevada Test Site which was constructed in 2001 and has similar climatic, soil and vegetation conditions.

6 Calculations and Analyses

The Wind Erosion Equation (WEQ) (NRCS, 2002) was used to calculate potential wind erosion.

$$E = f\,(IKCLV)$$

where:

E = estimated average annual soil loss (tons/acre)
f = indicates the relationships that are not straight-line mathematical functions
I = soil erodibility index
K = soil surface roughness
C = climatic factor
L = the unsheltered distance (feet)
V = the vegetative cover (small grain equivalent residue in pounds per acre)

Soil Grain-Size Data - Mean Percent Passing Indicated Size

3/4 in	3/8 in	#4	#6	#10	#16	#40	#70	#140	#200
19.0 mm	9.52 mm	4.75 mm	3.35 mm	2.0 mm	1.18 mm	0.425 mm	0.212 mm	0.106 mm	0.075 mm
96.0%	91.3%	85.1%	80.3%	74.7%	65.5%	51.3%	31.8%	12.9%	8.4%

(Shott et al, 1998)

Soil Grain Size Data (minus 2.0 mm fraction only)

#10	#16	#40	#70	#140	#200
2.0 mm	1.18 mm	0.425 mm	0.212 mm	0.106 mm	0.075 mm
100%	91.7	68.7	42.6	17.3	11.2

The United States Department of Agriculture (USDA) soil classification system is used to determine the Soil Erodibility Index (p 502-22, NRCS 2002) for the WEQ. The USDA classification system does not include coarse (>2.0 mm) fragments in the classification procedure (Coduto, 1999). The USDA size range for silt is 0.05 – 0.002 mm. The smallest sieve size data available is minus 0.075mm. For the purpose of determining soil texture, the minus #200 percentage is assumed to be silt. Hydrometer analysis indicates the minus #200 fraction is primarily silt rather than clay (Shott et al 1998). Using the presented soil grain-size data (the minus 2mm fraction only), and the NRCS soil texture calculator http://soils.usda.gov/technical/aids/investigations/texture/ , the soil texture is classified as coarse sand.

From footnote 5 (p 502-22 NRCS 2002) – the soil erodibility index (I) for coarse sand is 160 ton/acre/yr.

The soil roughness coefficient (K) is a function of ridge (Krd) and random roughness (Krr).

K =Krd * Krr

The cover will be constructed without ridges, therefore Krd = 1. The random roughness factor Krr for I factors greater than 134 is equal to 1. Therefore K = 1

The climatic factor (C) equation is expressed as :

$$C = 34.48 \times \frac{V^3}{(PE)^2}$$

where:
C = annual climatic factor
V = average annual wind velocity (mi/hour)
PE = precipitation-effectiveness index of Thornthwaite
34.48 = constant use to adjust to local values to a common base (Garden City, Kansas)

$$PE = \sum_{Jan}^{Dec} 115 \times \left[\frac{P}{T - 10} \right]^{10/9}$$

where:
PE = the annual precipitation effectiveness index
P = average monthly precipitation (in) (minimum of 0.5)
T = average monthly temperature (F)

W5B meteorological data

Month	Average precipitation (in)	Average temperature (F)
January	0.61	39.7
February	0.68	44.7
March	0.54	50.7
April	0.32	57.2
May	0.26	66.5
June	0.16	74.9
July	0.47	81.7
August	0.47	80.0
September	0.36	71.5
October	0.23	60.0
November	0.36	46.6
December	0.45	38.9

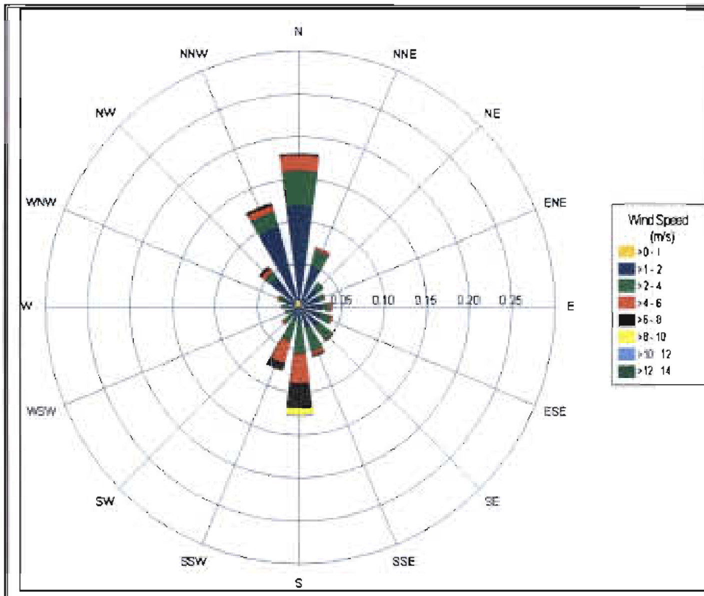
Soule, 2006 pages 9 and 38

V = 6.4 mi/hr (Soule 2006 p 21)

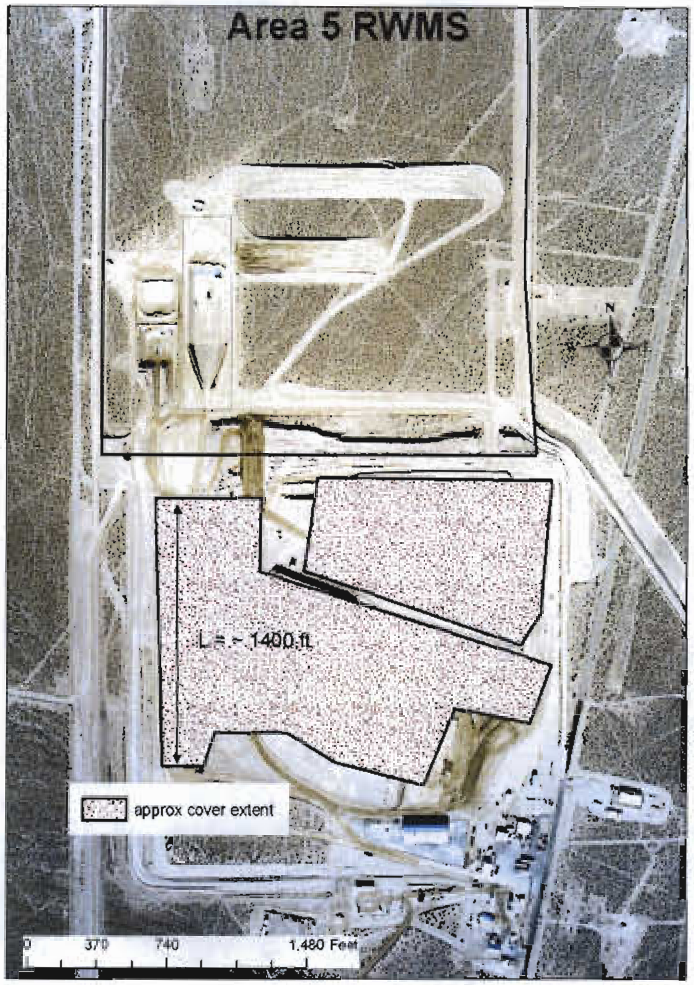
The calculated climatic factor (C) = 87

The prevailing wind erosion direction is estimated from the annual wind rose presented in NSTec (2007). These data are collected from the meteorological tower located on-site.

From the estimated extent of the closure cover, L = 1400 ft. The estimated soil loss is relatively insensitive to unsheltered distance as L approaches 1000 ft.



2006 Wind Rose (NSTec, 2007)



Approximate 92-acre closure cover

The vegetative cover factor (in small grain equivalent) was estimated using the aboveground net production (ANP) equations (eqs 3 and 4) presented in Turner and Randall (1989). W5B precipitation data was used.

For annuals

$$\log(ANP) = 1.976\log(PPTSM - 26.2) - 2.746$$

where:
PPTSM is the precipitation from September through March in millimeters.
ANP in grams/m^2

For perennials

$$ANP = 0.297(PPTOS) - 6.12$$

where:
PPTOS is the precipitation from October through September in millimeters.
ANP in grams/m^2

Annual net production

Annuals ANP (pounds/acre)	Perrenials ANP (pounds/acre)
45	275.9

Annual net production values (ANP) must be converted in small grain equivalent (sge) values for use in the WEQ. The sge is calculated using the below equation. The coefficients for the sge equations were taken from the WEQ Annual Method West spreadsheet obtained from Mike Sporcic wind erosion specialist from the NRCS.

$$sge = a * (species\, lbs / acre)^b$$

Perrenial small grain equivalents

Total lbs/acre (perennial)	**275.9**				
species	**% abundance**	**lbs / acre**	**a**	**b**	**sge**
Low sagebrush	47	129.65	0.078687	1.643208	233.16
Greasewood	14	38.62	0.014532	1.828419	11.58
Tall/low rabbitbrush	1	2.76	0.026389	1.775753	0.16
shadscale	4	11.03	0.040087	1.663769	2.18
Creosote bush	33	91.03	0.049122	1.569699	58.43
Winterfat	1	2.76	0.077278	1.566006	0.38
				total	**305.89**

Percent abundance values were taken from Webb et al, 2003 with interpretation from David Anderson (project plant ecologist) to categorize into species presented in Agronomy Technical Note 69.

The annuals species found at the project site are not listed in Agronomy Technical Note 69, annuals are therefore assumed to have a 1:1 ratio of ANP to small grain equivalent (sge).

The vegetative factor (V) for use in the WEQ is 350 (the sum of the annuals and perennial sge's).

Using the calculated WEQ parameters and interpolation of tables in Attachment C, the calculated wind erosion for the final closure cover is 115 tons/acre/yr.

Sideslopes
With the exception of the unsheltered length and the erodidibility index, the WEQ parameters for the sideslopes are the same as those calculated for the cover.

Due to the greater than 3% slope of the cover sideslopes, a knoll erodibility adjustment is applied to the I factor (NRCS, 2002, p 502). From Table 502- (NRCS, 2002) the Knoll erodibility factor is 3.6 for slope changes >= 10%, this results in an I factor of 576 for the sideslopes. Tabulated values for the climatic factor (C) do not exceed 310, therefore an I value of 310 is assumed for the sideslope erosion calculation. The top of the cover is assumed to be completed approximately 6 ft above grade.

WEQ parameter summary

Surface	I (tons/acre/yr)	K	C	L (ft)	V (sge lbs/acre)	E (tons/acre/yr)
Closure cover	160	1.0	87	1400	350	115
10H:1V sideslopes	310	1.0	87	60	350	194
5H:1V sideslopes	310	1.0	87	30	350	162

Assuming a 1.6 g/cm^3 bulk density of cover material, the calculation indicates over 30 years the cover will have eroded 1.6 ft.

Attachment A

Wind erodibility groups and wind erodibility index

Exhibit 502–2 Wind erodibility groups and wind erodibility index

Soil texture [1]	EWE texture wetness factor [2]	Predominant soil texture class of surface layer	Wind Erodibility Group (WEG) [3]	Soil Erodibility Index (I) (ton/ac/yr) [4, 5]	Soil Erodibility Index (I) for irrigated soils (ton/ac/yr) [4]
C	1	Very fine sand, fine sand, sand, or coarse sand	1	310 [4] 250 220 180 160	310 250 220 160 134
C	1	Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, sapric organic soil materials, and all horizons that meet andic [6] soil properties as per Criteria 2 in Soil Taxonomy, regardless of the fine earth texture	2	134	104
C	1	Very fine sandy loam, fine sandy loam, sandy loam, coarse sandy loam, and noncalcareous silt loam with 35 to 50% very fine sand and <10% clay	3	86	56
F	3	Clay, silty clay, non-calcareous clay loam, or silty clay loam with more than 35% clay	4	86	56
M	2	Calcareous [7] loam and silt loam or calcareous clay loam and silty clay loam	4L	86	56
M	2	Non-calcareous loam and silt loam with more than 20% clay (but does not meet WEG 3 criteria), or sandy clay loam, sandy clay, and hemic organic soil materials	5	56	38
M	2	Non-calcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay or silty clay loam with less than 35% clay	6	48	21
M	2	Silt and fibric organic soil material	7	38	21
—	—	Soils not susceptible to wind erosion because of surface rock and pararock fragments or wetness	8	—	—

1/ Soil texture, C = Coarse; M = Medium; F = Fine

2/ Texture wetness factor for adjustment of Erosive Wind Energy (EWE) for the period (Irrigated fields only).

3/ For all WEGs except sand and loamy sand textures, if percent rock and pararock fragments (>2mm) by volume is 15-35, reduce I value by one group with more favorable rating. If percent rock and pararock fragments by volume is 35-60, reduce I value by two favorable groups except for sands and loamy sand textures which are reduced by one group with more favorable rating. If percent rock and pararock fragments by volume is more than 60, use I value of zero for all textures except sands and loamy sand textures which are reduced by three groups with more favorable rating.

4/ The wind erodibility index is based on the relationship of dry soil aggregates greater than 0.84 millimeters to potential soil erosion. Value for irrigated soils is applicable throughout the year. Values for irrigated soils determined by Dr. E.L. Skidmore, USDA, ARS, Wind Erosion Research Unit, Manhattan, Kansas.

5/ The I factor for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an I value of 220 as an average figure.

6/ Vitrandic, Vitritorrandic, and Vitrxerandic Subgroups with ashy textural modifiers move one group with less favorable rating.

7/ Calcareous is a strongly or violently effervescent reaction of the fine-earth fraction to cold dilute (IN) HCL.

Preparer: UD 3-18-08

Checker: UY 3/18/08

Attachment B

Agonomy Technical Note 69 – Wind Erosion Equation

Agronomy Technical Note 69 - Wind Erosion Equation (Annual Method) on Rangeland

NM-NRCS May, 2004 Mike Sporcic, State Agronomist

This note is to be used to estimate annual wind erosion annual method using the WEQ NAM part 502 method where native vegetation is in the field. It is **not** to be **used for RMS planning on rangeland**. It can be used when sodbusting land to estimate a before erosion rate and can be used to see if current vegetation meets T.

TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE
West Technical Services Center - Portland Oregon

June 1981

A GUIDE FOR CONVERTING RANGELAND VEGETATION TO SMALL GRAIN EQUIVALENTS

This technical note is to be used as a supplement to the National Resources Inventory (NRI 1981-82) instruction Section N, Wind Erosion, Data.

In using the wind erosion equation (WEE) to determine the soil loss by wind on rangelands, the vegetative cover must be converted to small grain equivalents. When western rangelands are properly managed, vegetation is generally adequate to control wind erosion. Areas receiving 12 inches or more of average annual precipitation and those range sites producing more than 1,000 pounds of average annual air dry vegetation per acre generally will not have a wind erosion problem if they are properly managed.

Natural plant communities produce various proportions of grass, forbs, and shrubs. A variety of species complement each other and, when properly managed, generally curtail wind erosion. In areas of less than 12 inches average annual precipitation and where vegetation is not properly managed, wind erosion can become a serious problem.

Vegetative communities in the western states which may require the use of the WEE are the Great Basin sagebrush areas, saltbush-greasewood, creosote bush, cactus-shrub, grama-tobosa-creosote bush, and other areas which have sparse plant cover and have not been properly managed.

To use the following table, estimate the total vegetation produced per acre and, determine the percent composition by species, then convert to flat small grain equivalent. Mixtures of species generally have a combined effect greater than the sum of the individual effects (see reference). As a rule of thumb, 75 to 125 pounds of plant growth can be expected for each inch of water available in the soil even though the site may be in a low ecological condition. If a conversion is needed for a plant not listed on the table, use a similar species.

The figures in the table are based on the current total production of leaves and twig growth. The Woody materials (trunks, branches, and stems) are not included in the table. Wood material of deciduous species such as shimery oak and mesquite may have a significant effect on wind erosion, depending density and height. Fallen leaves provide some mulch cover which provides some protection from wind erosion. Until we have better data, use a direct ratio for litter to flat small grain; i.e. 200 pounds of litter equals 200 pounds small grain residue.

The effect of rock fragments (stones and desert pavement) is provided for in the "I" factor of the equation.

Other than those grass plants indicated, the conversion equivalents are estimates by the author and are intended to be used to attain an approximation of potential wind erosion under average conditions. Field testing and research are needed to improve these estimates so that the conversion guide will be more reliable. As field use is made of this table, suggestions for improvement should be sent to the range conservationist at the technical service center.

Prepared by Donald H. Fulton, Range Conservationist, West TSC, Portland Oregon.

Preparer: UO 3-18-08 Checker: UY 3/18/08

Guide for Converting Range Vegetation to Equivalent Quantity of Flat Small Grain Residue

Pounds per acre of Range Vegetation

	Grass Plants	50	100	200	300	400	500	600	700	800	900	1000
1	*Buffalograss, burrograss Inland saltgrass	320	720	1630	2630							
2	*Big bluestem	45	110	280	480	705	950	1215	1495	1785	2090	2410
3	*Western wheatgrass, creeping wildrye & sideoats grama	155	245	775	1240	1740	2260	2795	3345			
4	*Little bluestem	45	110	285	495	735	995	1280	1580	1900	2230	2575
5	*Blue grams, threadleaf sedge & perennial threeawn	110	235	490	760	1040	1325	1610	1905			
6	Galleta & tobosa	150	300	800	1200	1700	2600					
7	Bottlebrush squirreltail, needleandthread, & thurber needlegrass	70	150	300	600	800	1200					
8	Alkali sacaton	60	150	400	800	1400	2200	2800	3600			
9	Bluebunch wheatgrasa	50	120	300	550	850	1150	1500	1900	2300	2600	3000
10	Idaho fescue	100	200	400	900	1500	2300					
11	Indian ricegrass	100	175	300	600	900	1400					
12	Crested wheatgrass	130	300	600	900	1300	1800	2400	3100	4000		
13	Cheatgrass	100	200	300	600	800	1000	1200	1600	2000	2500	3000

*Lyles Leon and Bruce E. Allison, "Range Grasses and Their Small Grain Equivalents for Wind Erosion Control," Journal of Range Management, Vol. 33 No. 2, March 1980, pp. 143-146.

NOTE: Other grass species equivalents were estimated by comparing the growth characteristics with the tested species.

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Checker: [signature] 3/18/08

Pounds per acre of Range Vegetation [1/]

	Forbs	**50**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
1	Perennial forbs	50	100	300	500							
2	Annual forbs	50	100	200	300	500	800	1000				
	Shrubs											
1	Big sagebrush	30	70	300	750	1100	1500	2000	2600	3200	4000	
2	Low sagebrush	50	150	450	900	1600	2200	2900	3600			
3	Greasewood & 4-wing saltbush	20	60	250	450	800	1250	1800	2400	3000		
4	Tall and low rabbitbrush	30	70	350	800	1200	1700	2200	2800	3400		
5	Shadscale	30	70	300	500	850	1300					
6	Creosote bush	20	70	250	400	600	800	1000				
7	Mesquite	20	80	200	300	500	700	800	1000	1500	2000	3000
8	Juniper	40	90	180	300	450	800	950	1300	2000	2700	36050
9	Cholla 2/	0	50	100	250	350	500	700	950	1300		
10	Yucca 2/	0	70	150	250	400	600	750	000	1400	1800	
11	Winterfat	40	100	300	500	800	1400	1800	2300	3000		
12	Litter 3/	50	100	200	300	400	509	600	700	300	900	1000

[1/] Total leaf and twig growth-air dry weight. Woody production not included in these weight figures,
[2/] Include all leaf and fibrous material.
[3/] Litter should, include leaves, twigs and seems up to 1/2 inch in diameter.
For deciduous shrub" estimate foliage production at time of wind erosion hazard.
The forb and shrub small grain equivalents are personal judgment only. No research data is available to support these figures.

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Checker: [signature] 3/18/08

Examples of determining "v" for use in the wind erosion equation.

Range site: Loamy – 8-10" p.z. fair condition

Bluebunch wheatgrass	-	50#/acre	=	80
Cheatgrass	-	100#/acre	=	200
Annual forbs	-	50#/acre	=	50
Big sagebrush	-	500#/acre	=	1500
Litter	-	300#/acre	=	300
		v	=	2130

Range site: Basalt hills 2-7"" p.z. fair condition

Perennial threeawn	-	20#/acre	=	28	
Sixweeks grama	-	80#/acre	=	160	(use cheatgrass)
Annual forbs	-	20#/acre	=	20	
Creosote bush*	-	250#/acre	=	325	
Litter	-	50#/acre	=	50	
		v	=	583	

*current and accumulated production

Range site: Loamy 12-16" p.z. [1/] poor condition

Cheatgrass	-	300#/acre	=	600
Big sagebrush	-	700#/acre	=	2600
Litter	-	400#/acre	=	400
		v	=	3600

[1/] Little if any wind erosion should occur on this site.

Preparer: [signature] 3-12-08

Checker: [signature] 3/18/08

Attachment C

(E)* Soil Loss From Wind Erosion in Tons per Acre per Year

prepared by: 3-18-08

checked by: 3/18/08

SUBPART G - EXHIBITS

502.60(a)

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 80
I = 160

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
8000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
6000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
4000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
3000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
2000	128.0	113.9	94.9	76.3	50.4	33.3	19.2	11.4	6.9	3.4	1.8	0.1	
1000	124.3	110.5	91.8	73.5	48.4	31.6	18.1	10.6	6.4	3.1	1.6	0.1	
800	121.3	107.8	89.4	71.3	46.7	30.4	17.3	10.1	6.0	2.9	1.5	0.1	
600	117.9	104.6	86.6	68.8	44.8	28.9	16.3	9.4	5.6	2.7	1.3	0.1	
400	111.5	98.7	81.3	64.2	41.3	26.2	14.6	8.3	4.9	2.3	1.1	0.1	
300	107.6	95.1	78.1	61.4	39.3	24.7	13.6	7.7	4.5	2.1	1.0	0.1	
200	98.7	85.9	70.9	55.1	34.7	21.3	11.5	6.3	3.6	1.6	0.7	0.1	
150	91.3	80.1	65.0	50.0	31.0	18.6	9.9	5.3	3.0	1.3	0.4		
100	84.1	73.5	59.2	45.1	27.5	16.1	8.4	4.4	2.4	1.0	0.3		
80	78.3	63.3	54.7	41.3	24.9	14.3	7.3	3.7	2.0	0.8			
60	71.0	61.7	49.0	36.6	21.6	12.1	6.0	3.0	1.6	0.6			
50	65.6	55.9	44.8	33.1	19.3	10.5	5.1	2.5	1.3	0.5			
40	60.1	51.9	40.7	29.7	17.0	9.1	4.3	2.1	1.0				
30	53.8	46.2	35.9	25.8	14.5	7.5	3.5	1.6	0.8				
20	44.3	37.8	28.9	20.3	11.0	5.4	2.4	1.0	0.3				
10	31.3	26.3	19.5	13.1	6.7	3.0	1.2	0.4					

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 80
I = 160

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
8000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
6000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
4000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
3000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
2000	115.2	102.1	84.3	66.8	43.3	27.8	15.6	8.9	5.3	2.5	1.2	0.1	
1000	111.0	98.2	80.9	63.8	41.1	26.0	14.5	8.2	4.8	2.2	1.1	0.1	
800	109.2	96.6	79.4	62.5	40.1	25.3	14.0	7.9	4.6	2.1	1.0	0.1	
600	105.5	93.2	76.4	59.9	38.2	23.9	13.1	7.3	4.3	1.9	0.9	0.1	
400	100.1	88.2	72.0	56.1	35.4	21.8	11.8	6.5	3.7	1.7	0.8	0.1	
300	95.4	83.9	68.2	52.8	33.0	20.0	10.8	5.8	3.3	1.4	0.7	0.1	
200	86.6	75.8	61.2	46.8	28.7	17.0	8.9	4.7	2.6	1.1	0.3		
150	79.1	69.0	55.3	41.8	25.2	14.5	7.4	3.8	2.1	0.8			
100	72.8	63.3	50.3	37.7	22.4	12.6	6.3	3.2	1.7	0.6			
80	67.7	58.7	46.4	34.4	20.2	11.1	5.5	2.7	1.4	0.5			
60	59.8	51.6	40.4	29.5	16.9	9.0	4.3	2.0	1.0				
50	55.7	47.9	37.3	27.0	15.2	7.9	3.7	1.7	0.9				
40	51.6	44.2	34.2	24.5	13.6	7.0	3.2	1.4	0.7				
30	45.0	38.4	29.4	20.7	11.2	5.5	2.4	1.1	0.3				
20	36.3	30.7	23.1	15.8	8.2	3.8	1.6	0.5					
10	24.6	20.5	14.9	9.7	4.7	2.0	0.7						

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Preparer: UN 3-18-08

Checker: VY 3/18/08

SUBPART G - EXHIBITS

502.60(a)

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 90

SURFACE - K =1.00

I = 160

(L) UNSHELTERED DISTANCE IN FEET	(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE												
	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
8000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
6000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
4000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
3000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
2000	144.0	128.8	108.4	88.3	59.8	40.8	24.2	14.8	9.3	4.8	2.6	0.2	
1000	140.7	125.7	105.5	85.8	57.8	39.2	23.1	14.1	8.8	4.5	2.4	0.2	
800	137.9	123.1	103.2	83.7	56.2	37.8	22.2	13.4	8.3	4.2	2.2	0.2	
600	134.3	119.8	100.2	81.0	54.1	36.2	21.1	12.7	7.8	3.9	2.1	0.2	
400	127.0	113.0	94.1	75.5	49.9	32.9	18.9	11.2	6.8	3.3	1.7	0.1	
300	121.9	108.2	89.8	71.7	47.0	30.6	17.4	10.2	6.1	3.0	1.5	0.1	
200	110.6	97.9	80.6	63.6	40.9	25.9	14.4	8.2	4.8	2.2	1.1	0.1	
150	103.8	91.6	75.0	58.7	37.3	23.2	12.7	7.1	4.1	1.9	0.9	0.1	
100	96.9	85.2	69.4	53.8	33.8	20.6	11.1	6.0	3.4	1.5	0.7	0.1	
80	90.6	79.5	64.4	49.5	30.6	18.3	9.7	5.2	2.9	1.2	0.4		
60	81.7	71.4	57.3	43.5	26.4	15.3	7.9	4.1	2.2	0.9	0.3		
50	76.4	66.5	53.1	40.0	24.0	13.7	6.9	3.5	1.9	0.7			
40	71.4	62.0	49.3	36.8	21.8	12.2	6.1	3.0	1.6	0.6			
30	63.0	54.5	42.8	31.5	18.2	9.8	4.7	2.3	1.2				
20	53.0	45.5	35.2	25.3	14.2	7.3	3.4	1.5	0.8				
10	37.8	32.0	24.2	16.6	8.8	4.1	1.7	0.6					

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 90

SURFACE - K =0.90

I = 160

(L) UNSHELTERED DISTANCE IN FEET	(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE												
	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
8000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
6000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
4000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
3000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
2000	129.6	115.4	96.3	77.4	51.4	34.0	19.7	11.7	7.1	3.5	1.8	0.2	
1000	124.8	111.0	92.2	73.9	48.6	31.9	18.3	10.7	6.5	3.2	1.6	0.1	
800	122.5	108.8	90.3	72.2	47.3	30.9	17.6	10.3	6.2	3.0	1.5	0.1	
600	117.5	104.2	86.2	68.5	44.6	28.7	16.2	9.4	5.6	2.7	1.3	0.1	
400	110.7	97.9	80.6	63.6	40.9	25.9	14.4	8.2	4.8	2.2	1.1	0.1	
300	106.3	93.9	77.1	60.5	38.6	24.2	13.3	7.5	4.3	2.0	1.0	0.1	
200	98.1	86.4	70.4	54.7	34.4	21.1	11.4	6.2	3.6	1.6	0.7	0.1	
150	90.2	79.1	64.1	49.2	30.5	18.2	9.6	5.1	2.9	1.2	0.4		
100	82.5	72.1	57.9	44.0	26.8	15.6	8.1	4.2	2.3	0.9	0.3		
80	77.2	67.3	53.8	40.6	24.4	13.9	7.1	3.6	1.9	0.7			
60	69.9	60.7	48.1	35.8	21.1	11.7	5.8	2.9	1.5	0.6			
50	64.4	55.7	43.9	32.3	18.8	10.2	4.9	2.4	1.2				
40	59.1	51.0	39.9	29.1	16.6	8.8	4.2	2.0	1.0				
30	52.8	45.3	35.1	25.2	14.1	7.2	3.3	1.5	0.8				
20	43.3	36.8	28.1	19.7	10.6	5.1	2.3	1.0	0.3				
10	30.8	25.9	19.2	12.9	6.5	2.9	1.2	0.4					

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Preparer: UQ 3-18-08

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SUBPART G - EXHIBITS

502.60(a)

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 80
I = 310

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
8000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
6000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
4000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
3000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
2000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
1000	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
800	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
600	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
400	248.0	227.1	199.7	174.4	131.4	104.6	70.9	51.0	36.4	23.6	15.5	4.1	2.8
300	245.5	224.7	197.4	172.2	129.5	102.8	69.5	49.8	35.5	22.9	15.0	4.0	2.7
200	238.0	217.5	190.7	165.6	123.8	97.4	65.3	46.4	32.8	20.9	13.5	3.5	2.4
150	230.5	210.4	183.9	159.1	118.1	92.1	61.3	43.2	30.3	19.0	12.2	3.1	2.1
100	223.0	203.2	177.2	152.7	112.6	87.0	57.5	40.0	27.8	17.3	10.9	2.8	1.8
80	215.5	196.1	170.5	146.3	107.2	82.0	53.7	37.0	25.6	15.6	9.7	2.4	1.6
60	203.0	184.3	159.4	135.7	98.3	73.9	47.7	32.3	22.0	13.1	8.0	1.9	1.3
50	193.6	175.4	151.2	127.9	91.8	68.1	43.5	29.0	19.5	11.4	6.8	1.6	1.0
40	185.8	168.0	144.3	121.5	86.4	63.4	40.1	26.4	17.6	10.1	6.0	1.4	0.7
30	170.5	153.6	131.0	109.1	76.3	54.6	33.8	21.8	14.2	7.9	4.5	1.0	0.5
20	148.7	133.2	112.3	91.9	62.6	43.1	25.8	15.9	10.1	5.3	2.9	0.6	
10	117.1	103.8	85.9	68.2	44.4	28.5	16.1	9.3	5.5	2.6	1.3	0.1	

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 80
I = 310

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
8000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
6000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
4000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
3000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
2000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
1000	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
800	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
600	223.2	203.4	177.4	152.8	112.8	87.1	57.6	40.1	27.9	17.3	10.9	2.8	1.8
400	220.4	200.8	174.9	150.5	110.8	85.3	56.2	39.0	27.1	16.7	10.5	2.6	1.8
300	215.6	196.2	170.6	146.4	107.3	82.1	53.8	37.1	25.6	15.7	9.8	2.4	1.6
200	207.9	188.9	163.8	139.8	101.7	77.1	50.0	34.1	23.4	14.1	8.7	2.1	1.4
150	197.6	179.2	154.7	131.2	94.5	70.6	45.3	30.4	20.6	12.1	7.3	1.7	1.1
100	187.5	169.6	145.8	122.9	87.6	64.5	40.8	27.0	18.0	10.4	6.2	1.4	0.9
80	181.7	164.2	140.8	118.2	83.7	61.0	38.4	25.1	16.7	9.5	5.6	1.3	0.7
60	168.0	151.3	128.9	107.1	74.7	53.3	32.8	21.0	13.7	7.5	4.3	0.9	0.5
50	159.5	143.3	121.6	100.4	69.3	48.7	29.6	18.7	12.0	6.5	3.6	0.8	0.4
40	149.3	133.8	112.9	92.5	63.0	43.5	26.0	16.1	10.2	5.3	2.9	0.6	
30	138.4	123.6	103.6	84.0	56.4	38.1	22.4	13.5	8.4	4.3	2.3	0.2	
20	120.1	106.7	88.4	70.5	46.0	29.8	16.9	9.8	5.9	2.8	1.4	0.1	
10	94.4	83.0	67.4	52.1	32.5	19.7	10.5	5.7	3.2	1.4	0.4		

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Preparer: 3-18-08

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SUBPART G - EXHIBITS

502.60(a)

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 90
I = 310

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
8000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
6000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
4000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
3000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
2000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
1000	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
800	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
600	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
400	279.0	256.8	228.0	202.1	155.9	128.3	89.4	66.6	48.9	33.3	22.8	6.4	4.5
300	276.2	254.1	225.5	199.5	153.6	126.1	87.7	65.1	47.7	32.3	22.1	6.2	4.3
200	268.1	246.3	218.0	192.2	147.1	119.8	82.7	60.8	44.3	29.6	20.0	5.5	3.8
150	260.6	239.1	211.2	185.5	141.2	114.0	78.2	57.0	41.2	27.2	18.2	5.0	3.4
100	253.1	231.9	204.3	178.9	135.3	108.4	73.8	53.4	38.3	25.0	16.6	4.4	3.0
80	245.6	224.8	197.5	172.3	129.5	102.9	69.5	49.8	35.5	22.9	15.0	4.0	2.7
60	233.1	212.8	186.3	161.4	120.1	94.0	62.7	44.3	31.1	19.7	12.6	3.3	2.2
50	224.3	204.5	178.4	153.8	113.6	87.9	58.2	40.6	28.3	17.6	11.1	2.8	1.9
40	215.6	196.2	170.6	146.4	107.2	82.1	53.8	37.1	25.6	15.6	9.8	2.4	1.6
30	197.9	179.4	154.9	131.5	94.7	70.7	45.4	30.5	20.6	12.2	7.4	1.7	1.1
20	175.3	158.1	135.2	113.0	79.5	57.4	35.7	23.2	15.2	8.6	4.9	1.1	0.6
10	138.6	123.8	103.8	84.3	56.6	38.2	22.5	13.6	8.4	4.3	2.3	0.2	

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 90
I = 310

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
8000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
6000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
4000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
3000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
2000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
1000	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
800	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
600	251.1	230.0	202.5	177.1	133.8	106.9	72.6	52.4	37.5	24.4	16.1	4.3	3.0
400	248.3	227.4	200.0	174.7	131.6	104.9	71.1	51.1	36.5	23.7	15.6	4.1	2.8
300	243.6	222.8	195.7	170.5	128.0	101.4	68.4	48.9	34.8	22.3	14.6	3.8	2.6
200	235.8	215.4	188.7	163.7	122.1	95.8	64.2	45.4	32.0	20.3	13.1	3.4	2.3
150	225.8	205.8	179.7	155.0	114.6	88.9	58.9	41.2	28.7	17.9	11.4	2.9	1.9
100	215.7	196.3	170.7	146.4	107.3	82.1	53.8	37.1	25.6	15.7	9.8	2.4	1.6
80	208.2	189.1	164.0	140.1	101.9	77.2	50.2	34.2	23.4	14.1	8.7	2.1	1.4
60	192.1	174.0	149.8	126.7	90.7	67.2	42.8	28.5	19.1	11.2	6.7	1.6	1.0
50	183.4	165.7	142.2	119.5	84.8	62.0	39.1	25.7	17.0	9.7	5.7	1.3	0.7
40	174.2	157.1	134.2	112.1	78.7	56.7	35.3	22.8	15.0	8.4	4.8	1.1	0.6
30	160.5	144.2	122.4	101.2	69.9	49.2	30.0	19.0	12.2	6.6	3.7	0.8	0.4
20	140.4	125.5	105.3	85.6	57.7	39.1	23.0	14.0	8.7	4.5	2.4	0.2	
10	109.3	95.6	79.5	62.6	40.2	25.3	14.1	7.9	4.6	2.1	1.0	0.1	

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

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Checker: [signature] 3/18/08

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1. **Calculation No.:** 08023-CAL-C-002	2. **Revision No.:** 0	3. **Date:** 3-18-08	4. **Project No.:** 08023	5. **Pages** 9
6. **Calculation Title:** Area 5 ~~RMWS~~ RWMS Internal Drainage		7. **Project Title:** Area 5 Closure Plan for the 92 Acre Area		
8. **Calculation Type:** ☐ Preliminary ☒ Final ☐ Voided/ Superseded (RJM 4/1/08)	9. **Quality Grade** ☐ QG-1 ☒ QG-3 ☐ QG-2 ☐ QG-4	10. **Performance Category** ☒ PC-1 ☐ PC-2 ☐ PC-3	11. Superseded by Calculation No.: N/A 12. Supersedes Calculation No.: N/A	

Original and Revised Calculation/Analysis Approval (Signature/Date)

13.	Revision 0	Revision	Revision
14. **Preparer:**	Lloyd Desotell		3-18-08 Date
15. **Checker:**	Vefa Yucel		3/18/08 Date
16. **Peer Reviewer:**	N/A		Date
17. **Discipline Section Supervisor:**	Richard Greenwold		4-1-08 Date

Affected Documents

Document No.	Document Title	Revision No	Responsible Discipline Lead Initials

Record of Revision

Revision No.	Reason for Revision
0	Original

Attachments

Attachment No.	Title	Total Pages
A.	Site Map and Subbasin Delineation	3
B.	Point Precipitation Frequency Estimates From NOAA Atlas 14	5
C.	HEC-HMS Basin Schematic and Summary Output	2
D.	HEC-HMS Input Files	4
E.	Travel Time Velocity	1
F	Culvert Nomograph Analyses	3
	Total Calculation Page Count	27

1 Introduction

This calculation was generated to determine the 25-YR 24-HR flood flows impacting the proposed final landfill closure cover for the "92-acre" area within the Area 5 Radioactive Waste Management Site (RWMS). This calculation will be used to size diversion channels, culverts and estimate riprap requirements on the closure cover sideslopes due to a 25-YR 24-HR precipitation event. Riprap estimates will be presented in a separate calculation.

This calculation addresses drainage within the berm/channel system protecting the Area 5 RWMS from offsite flooding. The drainage area is split into two basic subbasins (see Attachment A figure A-1): (1) the "expansion area" and (2) the final closure cover within the "92-acre" area. The expansion area is an area of active waste disposal. Once a disposal cell is filled, the cell is operationally closed with a bare soil cover. Flow from the expansion area will be diverted to the west of the final closure cover. Flows were also calculated from two partial areas within the 92-acre area to size an internal diversion channel and calculate required sideslope riprap (see Attachment A figure A-2).

2 Basis

The 25-YR 24-HR design storm level and location of the final closure cover was given by Waste Management closure project personnel.

2.1 Design Inputs

- Basin losses were modeled using the SCS curve number approach, curve numbers were assigned to areas based on engineering judgment and tabulated values given in Table 604 of CCRFCD, 1999.

- Site location information was derived from areal photographs and the NSTec engineering CADD database. Attachment A contains site maps.

- Watersheds were delineated from interpretation of site topographic maps, orthophotos and field reconnaissance. Watershed areas were derived using aerial photographs and preliminary closure cover designs. The watersheds drain to the south/southwest with a maximum slope of 2%, based on preliminary closure cover designs and site topographic information.

- Approximate location of the final closure cover is E 593,130, N 4,079,388, UTM zone 11 NAD 83, meters.

- Design storm precipitation data was obtained from NOAA, 2006 and is presented as Attachment B.

2.2 Criteria

Compute flood flows impacting the proposed final closure cover for the "92-acre" within the Area 5 Radioactive Waste Management Site (RWMS) from a 25-YR 24-HR design storm.

2.3 Assumptions

- The precipitation design event has a 5 minute maximum intensity, 50% peak center.
- The 92-acre disposal area will be closed with a monolayer evapotranspiration type final closure cover using native alluvium and vegetated with native plant species. The maximum cover slope is 2%.
- The entire expansion area has only a bare soil cover and a 2% slope.
- The 92-acre area final closure cover areas have established native vegetation with a curve number (CN) of 63, the expansion area has a CN of 72, urban area CN = 98 (table 604 CCRFCD, 1999). Assume AMC II conditions.
- A triangular shaped diversion channel separating the expansion area and 92-acre area will be constructed (see Attachment A figure A-3). This channel will be sized to convey the peak flow from the expansion area from a 25-YR 24-HR precipitation event.
- A swale south of zone 1 will be constructed (see Attachment A figure A-3). This swale will be sized to convey the peak flow from zone 1 from a 25-YR 24-HR precipitation event.
- Channels and swales have a mannings "n" of 0.035.
- Culverts will be placed in locations as shown in Attachment A figure A-3. The maximum allowable headwater on proposed culverts is 2 ft. Culverts will be 24 inch diameter corrugated metal pipe with a mannings "n" of 0.024.

3 References

National Oceanic and Atmospheric Administration(NOAA), Precipitation-Frequency Atlas of the United States, NOAA Atlas 14 Volume 1 Version 4 National Weather Service Silver Spring, Maryland, 2006, accessed January 23, 2008 http://www.nws.noaa.gov/ohd/hdsc/

Clark County Regional Flood Control District (CCRFCD), Hydrologic Criteria and Drainage Design Manual Las Vegas, Nevada. 1999.

U.S. Army Corps of Engineers, 2003. 'Hydrologic Modeling System HEC-HMS' (HEC-HMS computer program version 2.2.2) Davis California. May 2003.

Mays, Larry W. Water Resources Engineering. John Wiley & Sons, Inc, Hoboken NJ, 2001.

Microsoft Excel 2002 SP3

USDOT, 2001 – Hydraulic Design of Highway Culverts, Hydraulic Design Series Number 5. FHWA-NHI-01-020.

French,D. Open Channel Hydraulics. McGraw-Hill, Inc. 1985

4 Methods

- Runoff flows for all basins were calculated with the SCS synthetic unit hydrograph model and curve number method to represent basin losses.
- The frequency storm option within HEC-HMS was used for the meteorologic model.

5 Results and Conclusions

The below table summarizes the calculated flows impacting the 92-acre area final landfill closure for a 25-YR 24-HR design storm event.

subbasin	Area (mi^2)	Total precipitation (in)	Peak discharge (cfs)	Total volume of discharge (acre-ft)
expansion area	0.26	2.17	38.0	5.1
92 acre area	0.19	2.17	17.9	2.8
Zone 1 plus swale	0.044	2.17	2.6	0.47
West section	0.026	2.17	0.85	0.2

A triangular channel with slope of 0.5%, 10H:1V sideslopes and 1.5 ft deep is recommended to divert the flow from the expansion area around the west side of the final closure cover.

The HEC-HMS basin model schematic and summary output is presented as Attachment C.

The following three (3) HEC-HMS generated files presenting model input and topology and are included as Attachment D.

C:\hmsproj\A5_RWMS_internal\Basin_1.basin
C:\hmsproj\A5_RWMS_internal\Met_1.met
C:\hmsproj\A5_RWMS_internal\Control_1.control

Four 2 ft diameter, 130 ft long CMP culverts are required to convey the flow from the expansion area.

Two 2 ft diameter, 40 ft long CMP culverts are required to convey the flow from the 92 acre area.

6 Calculations and Analyses

All rainfall-runoff calculations were performed with HEC-HMS using the SCS curve number method to account for basin losses and the SCS synthetic unit hydrograph approach for transformation of rainfall into runoff.

The time of concentration for each subbasin is calculated using equation 601 from CCRFCD, 1999.

$$t_c = t_i + t_t$$

where:

t_c = time of concentration (min)
t_i = initial or overland flow time (min)
t_t = travel time in the ditch, channel, gutter, storm sewer, gully etc. (min)

from CCRFCD, 1999 Equation 602

$$t_i = \frac{1.8(1.1-K)L_o^{0.5}}{S^{1/3}}$$

where:
t_i = initial or overland flow time (min)
K = flow resistance coefficient
L_o = length of overland flow (500 ft maximum)
S = average basin slope (%)

from CCRFCD, 1999 Equation 603

$$K = 0.0132CN - 0.39$$

where:
CN = SCS curve number

The gully flow velocity (V_g) is obtained from Figure 602 (CCRFCD, 1999) (included as Attachment E). The length of gully flow is obtained from the below equation.

$$L_g = L_b - L_o$$

where:
L_g = length of gully flow (ft)
L_b = length of the subbasin (ft)
L_o = length of overland flow (500 ft maximum)

The gully flow travel time (t_t) is obtained from the below equation:

$$t_t = L_g \frac{1}{V_g} \frac{1\min}{60s}$$

where:

t_t = travel time in the ditch, channel, gutter, storm sewer, gully etc. (min)
L_g = length of gully flow (ft)
V_g = gully flow velocity (ft/s)

The lag time (t_{lag}) for each subbasin is calculated using the SCS relationship to time of concentration shown below (Equation 612 from CCRFCD, 1999):

$$t_{lag} = 0.6t_c$$

Subbasin Curve number summary

Subbasin	% vegetative cover	% bare cover	% urban	Weighted CN
expansion area	0	100	0	72
92 acre area	46	50	4	69
Zone 1 plus swale	70	30	0	65.7
West section	100	0	0	63

Subbasin physical parameter summary

Subbasin	Area (mi^2)	CN	L_b (ft)	L_o (ft)	L_g (ft)	Slope (%)	K
expansion area	0.26	72	3165	500	2665	2	0.56
92 acre area	0.19	69	2600	500	2100	1.5	0.52
Zone 1 plus swale	0.04	65.7	1250	500	750	1.5	0.48
West section	0.026	63	1400	500	900	2	0.44

Subbasin lag time parameter summary

Subbasin	t_i (min)	V_g (ft/s)	t_t (min)	t_c (min)	t_{lag} (min)
expansion area	17.2	2.8	15.9	33.1	19.9
92 acre area	20.4	2.5	14.0	34.4	20.6
Zone 1 plus swale	21.9	2.5	5.0	26.9	16.1
West section	21.0	2.8	5.4	26.4	15.8

Diversion channels

The proposed diversion channels (see Attachment A) must be sized to convey the peak discharge from each area. Using Manning's equation and an assumed channel geometry, the depth of flow for the peak discharge can be computed.

From Mays 2001 p 93 Manning's equation can be written as the following:

$$Q = \frac{1.49}{n} AR^{2/3} S^{0.5}$$

where:
Q = discharge (cfs)
A = cross sectional area (ft^2)
R = hydraulic radius (ft)
S = channel slope (ft/ft)
n = Mannings "n" (dimensionless)

Solving Manning's equation iteratively with Microsoft Excel for each design Q, yields the below flow depths and velocities.

location	Design Q (cfs)	Channel geometry	Sideslopes	Mannings "n"	channel slope (ft/ft)	Normal depth (ft)	Velocity (ft/s)
Expansion	38	triangular	10H:1V	0.035	0.007	1.22	2.55

area							
Zone 1	2.6	triangular	5H:1V	0.035	0.001	0.84	0.75
all others	10	triangular	5H:1V	0.035	0.01	0.9	2.47

A channel depth of 1 ft for the zone 1 channel is recommended. 2 feet deep channels are recommended for the expansion area and all other diversion channels.

All channels can convey at least a 50% increase in the design flow without over topping.

Triangular channel **expansion area**

z	10
Q (cfs)	38
n	0.035
S (ft/ft)	0.007

AR^2/3 = 10.67

normal depth (ft)	**A (ft^2)**	**P (ft)**	**R (ft)**	**AR^2/3**	**velocity (ft/s)**	**Fr**	**T (ft)**	**D(ft)**
1.22	14.88	24.52	0.61	10.67	2.55	0.58	24.40	0.61

0.00 = (n*Q)/(1.49*S^.5) - AR^(2/3)

v^2/2g 0.10

set equal to zero using solver and adjusting normal depth

Triangular channel **zone 1**

z	5
Q (cfs)	2.6
n	0.035
S (ft/ft)	0.001

AR^2/3 = 1.93

normal depth (ft)	**A (ft^2)**	**P (ft)**	**R (ft)**	**AR^2/3**	**velocity (ft/s)**	**Fr**	**T (ft)**	**D(ft)**
0.84	3.50	8.53	0.41	1.93	0.74	0.20	8.37	0.42

0.00 = (n*Q)/(1.49*S^.5) - AR^(2/3)

v^2/2g 0.01

set equal to zero using solver and adjusting normal depth

Triangular channel **all others**

z	5							
Q (cfs)	10	(~ half the total 92 acre peak discharge)						
n	0.035							
S (ft/ft)	0.010		**AR^2/3 =**	2.35				

normal depth (ft)	**A (ft^2)**	**P (ft)**	**R (ft)**	**AR^2/3**	**velocity (ft/s)**	**Fr**	**T (ft)**	**D(ft)**
0.90	4.05	9.18	0.44	2.35	2.47	0.65	9.00	0.45

0.00 = (n*Q)/(1.49*S^.5) - AR^(2/3)

v^2/2g
0.09

set equal to zero using solver and adjusting normal depth

Culvert Sizing

Culverts are assumed to be 2 ft diameter corrugated metal pipe.

Location	Drainage area	Length (ft)	Slope (%)	Peak flow to convey (cfs)
North	Expansion area	130	0.54	38
South	92-acre area	40	0.34	18

Peak flow assuming 2 feet maximum headwater (HW) is calculated with both inlet and outlet control to determine which condition is controlling.

Assuming inlet control and maximum headwater of 2 feet the culvert capacity is 12 cfs per barrel, using the nomograph presented in Attachment F.

Outlet control calculations are performed using the method presented in CCRFCD, 1999. The approximate method for partially full flow conditions is employed.

Critical depth within the culvert is calculated from French p 50

$$y_c = \left(\frac{1.01}{d^{0.26}}\right)\left(\frac{Q^2}{g}\right)^{0.25}$$

where:
y_c is the critical depth (ft)
d is the pipe diameter (ft)
Q is the flow (cfs)
g is the gravitational constant (32.2 ft/s^2)
Note: only applicable for $0.02 <= y_c/d <= 0.85$

To calculate outlet control culvert capacity, tailwater depths of flow leaving the culvert is required. The North culvert discharges into a trapezoidal channel of width ~ 80 ft wide and a slope of 1 %. A normal depth calculation for this channel with 40 cfs of flow is less than 0.5 ft. The south culvert discharges into an area which is essentially sheet flow with 1% slope resulting in a very small tailwater depth.

The culvert outlet hydraulic grade line (h_o) is assumed to be the maximum of the tailwater depth or

$$\frac{(y_c + D)}{2}$$

where:
y_c is the critical depth (ft) inside the culvert
D is the culvert diameter (ft)

$$H_w = H + h_0 - LS_0$$

where :
H_w is the head water (ft)
H is the head loss through the culvert (ft)
L is the length of the culvert (ft)
S_0 is the slope of the culvert (ft/ft)
h_o is the hydraulic grade line at the culvert outlet (ft)

North culvert (130 ft long, slope =0.54%, 2 ft diameter)

Assuming Q = 10 cfs and an entrance loss coefficient of 0.9 (K_e) (projecting from fill).
y_c = 1.1 ft, (yc +D)/2 = 1.5, therefore h_o= 1.5

Using the culvert parameters and the nomograph presented in Attachment F, the head loss (H) through the culvert is 1.15ft.

Solving the above headwater equation (Hw) yields an acceptable headwater of 2 ft. Therefore outlet control. To pass the design 38 cfs 4 barrels are required at the North location.

South culvert (40 ft long, slope = 0.34%, 2 ft diameter)

Assuming Q = 10 cfs and an entrance loss coefficient of 0.9 (K_e) (projecting from fill).
y_c = 1.1 ft, (yc +D)/2 = 1.5, therefore h_o= 1.5

The shortest culvert length on the nomograph is 50 ft. Conservatively, 50 is assumed. From the culvert anlyses presented in Attachment F, the head loss through the culvert is 0.65 ft. This yields an acceptable headwater of 2 ft. To pass the design 18 cfs, 2 barrels are required at the Sorth location.

Note: Review/revise culvert calculation when the mannings n of culvert to be installed is known.

Attachment A

Site Map and Subbasin Delineation

Expansion area and 92-acre area subbasin delineation

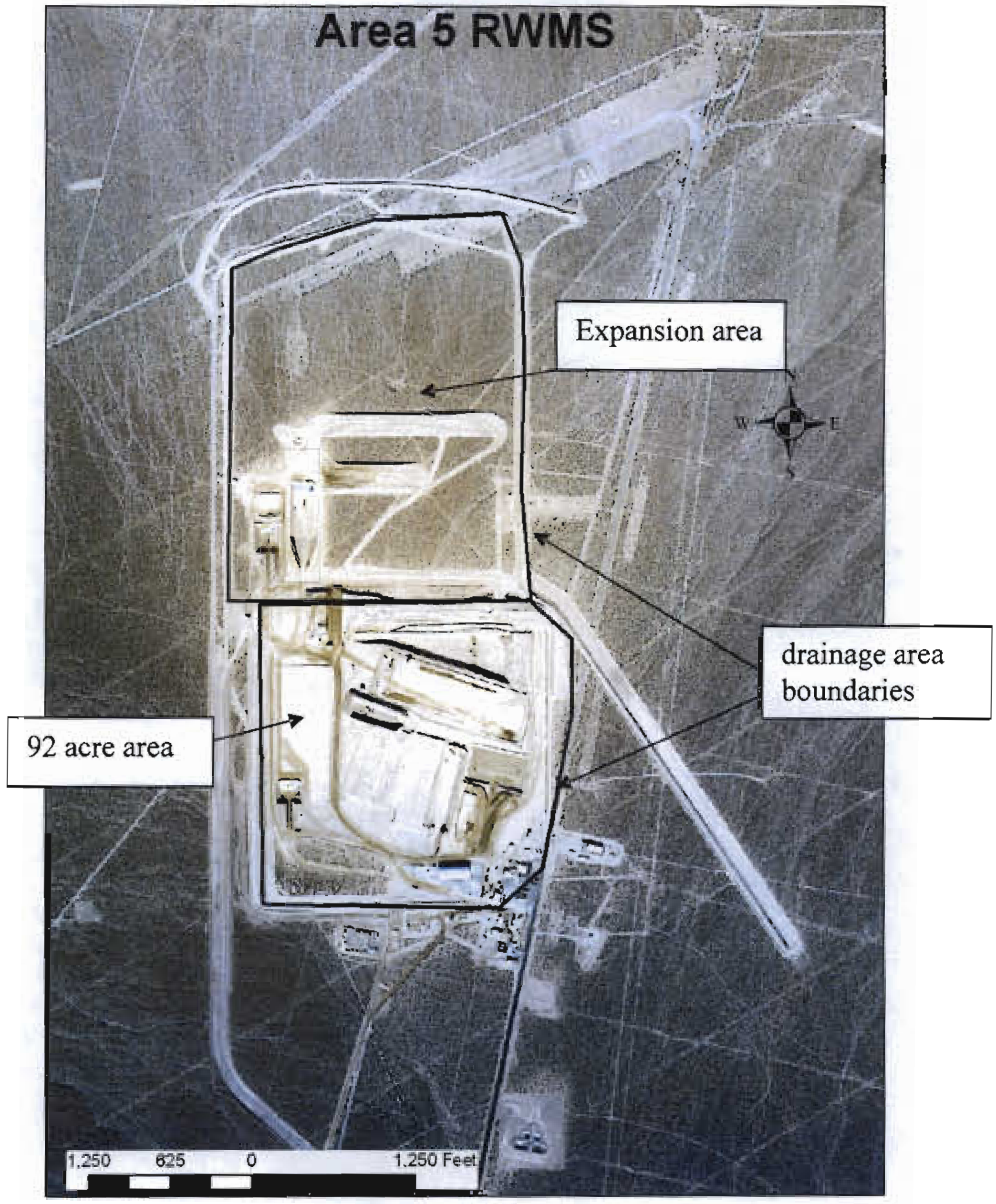

Figure A- 1

preparer: [signature] 3-18-08 checker: [signature] 3/18/08

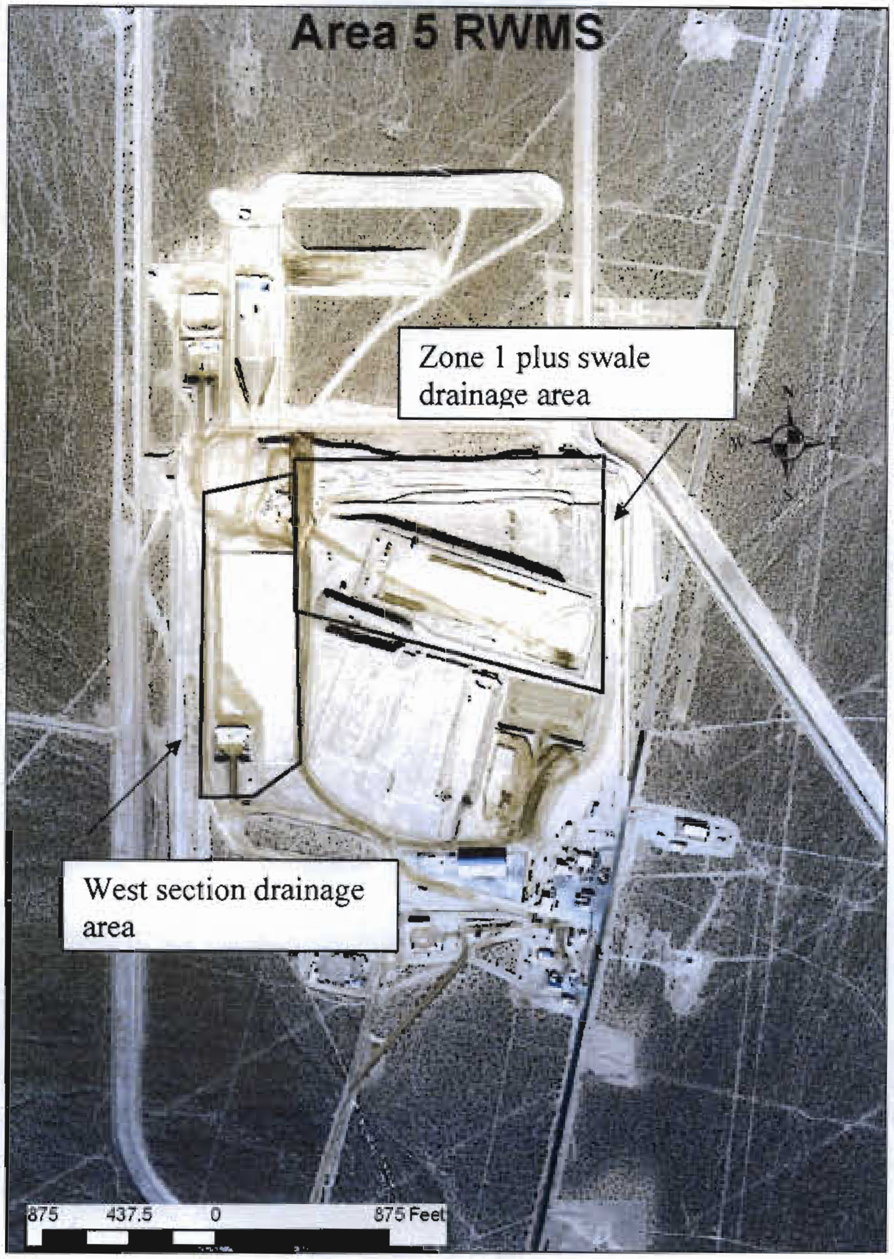

Figure A- 2

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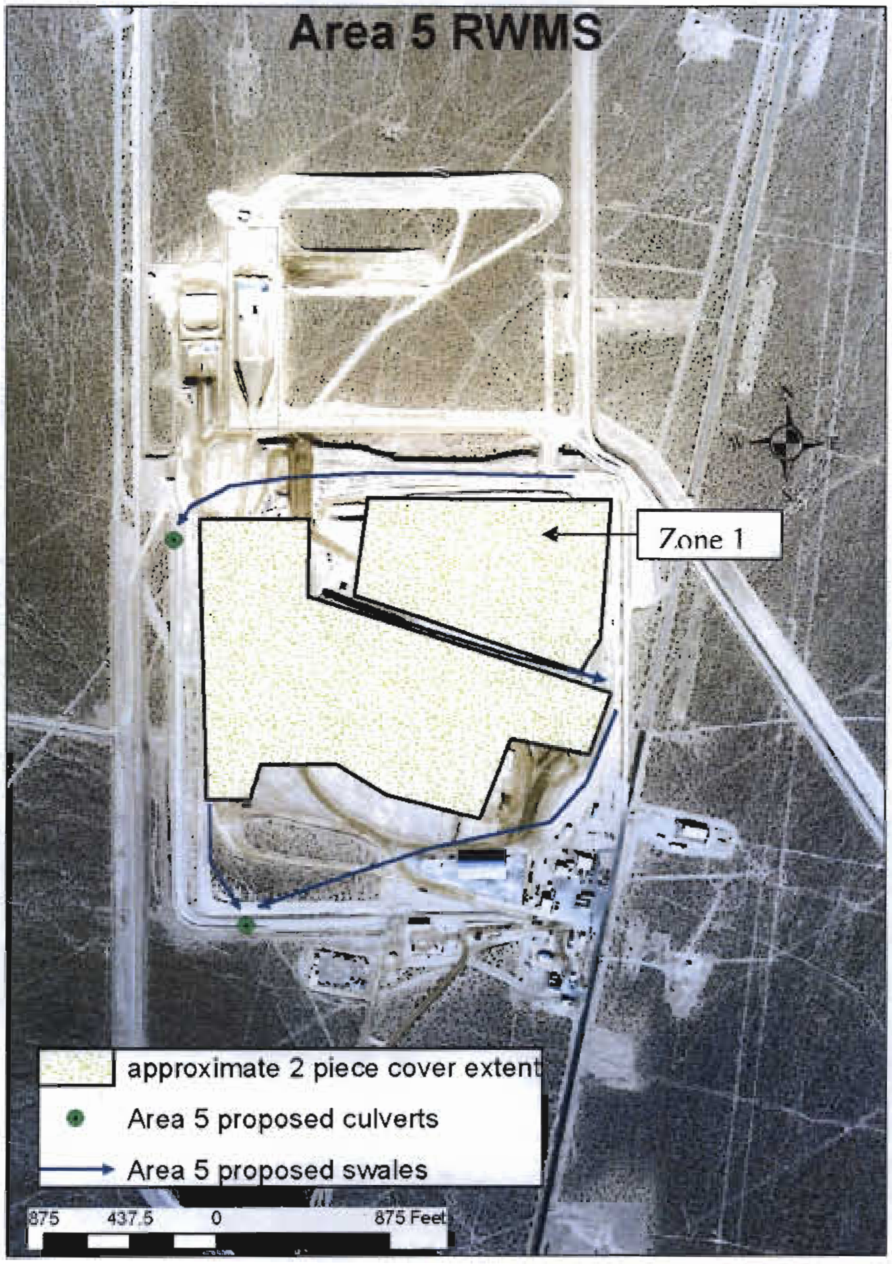

Figure A- 3

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Attachment B

Point Precipitation Frequency Estimates from NOAA Atlas 14

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Nevada 36.8556 N 115.9217 W 3267 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 4
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2006
Extracted: Wed Jan 23 2008

Confidence Limits Seasonality Location Maps Other Info. GIS data Maps Help Docs U.S. Map

Precipitation Frequency Estimates (inches)

AEP* (1-in-Y)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.13	0.19	0.24	0.32	0.40	0.46	0.52	0.68	0.85	0.96	1.05	1.15	1.30	1.39	1.62	1.86	2.08	2.34
5	0.19	0.29	0.37	0.49	0.61	0.69	0.78	1.00	1.26	1.42	1.56	1.71	1.95	2.09	2.44	2.84	3.20	3.64
10	0.25	0.38	0.46	0.63	0.77	0.88	0.97	1.23	1.55	1.75	1.91	2.11	2.40	2.56	2.98	3.49	3.97	4.53
25	0.33	0.49	0.61	0.83	1.02	1.16	1.26	1.56	1.94	2.17	2.38	2.62	2.98	3.16	3.68	4.33	4.97	5.71
50	0.39	0.60	0.74	1.00	1.23	1.40	1.50	1.83	2.25	2.50	2.74	3.02	3.42	3.63	4.21	4.97	5.75	6.63
100	0.47	0.72	0.89	1.19	1.48	1.68	1.78	2.13	2.57	2.84	3.11	3.44	3.88	4.10	4.74	5.61	6.54	7.59
200	0.56	0.85	1.05	1.42	1.75	1.99	2.10	2.47	2.91	3.20	3.50	3.87	4.35	4.59	5.29	6.26	7.37	8.58
500	0.70	1.06	1.31	1.77	2.19	2.49	2.60	2.99	3.39	3.70	4.04	4.47	5.00	5.26	6.03	7.15	8.50	9.96
1000	0.82	1.25	1.54	2.08	2.57	2.93	3.04	3.45	3.86	4.09	4.47	4.96	5.52	5.79	6.61	7.84	9.41	11.07

Text version of table

* These precipitation frequency estimates are based on an annual maxima series. **AEP** is the Annual Exceedance Probability.
Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

*** Upper bound of the 90% confidence interval**
Precipitation Frequency Estimates (inches)

AEP** (1-in-Y)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.15	0.22	0.27	0.37	0.46	0.55	0.63	0.80	0.99	1.11	1.21	1.33	1.50	1.61	1.87	2.15	2.41	2.72
5	0.23	0.34	0.43	0.57	0.71	0.84	0.93	1.17	1.47	1.65	1.79	1.97	2.25	2.41	2.81	3.27	3.70	4.22
10	0.29	0.44	0.55	0.74	0.91	1.06	1.16	1.44	1.80	2.02	2.20	2.42	2.76	2.95	3.43	4.01	4.58	5.26
25	0.39	0.59	0.73	0.99	1.22	1.41	1.50	1.83	2.25	2.51	2.73	3.01	3.42	3.65	4.24	4.98	5.75	6.63
50	0.47	0.72	0.89	1.20	1.49	1.70	1.80	2.15	2.61	2.90	3.16	3.48	3.94	4.20	4.85	5.73	6.66	7.72
100	0.57	0.88	1.09	1.46	1.81	2.05	2.14	2.52	3.00	3.30	3.61	3.97	4.49	4.77	5.50	6.48	7.61	8.86
200	0.69	1.06	1.31	1.76	2.18	2.46	2.54	2.93	3.42	3.73	4.08	4.50	5.07	5.36	6.17	7.29	8.63	10.08
500	0.89	1.35	1.68	2.26	2.79	3.10	3.20	3.60	4.03	4.35	4.77	5.26	5.90	6.22	7.10	8.42	10.08	11.85
1000	1.07	1.63	2.01	2.71	3.36	3.70	3.78	4.20	4.63	4.85	5.34	5.89	6.57	6.91	7.85	9.31	11.26	13.30

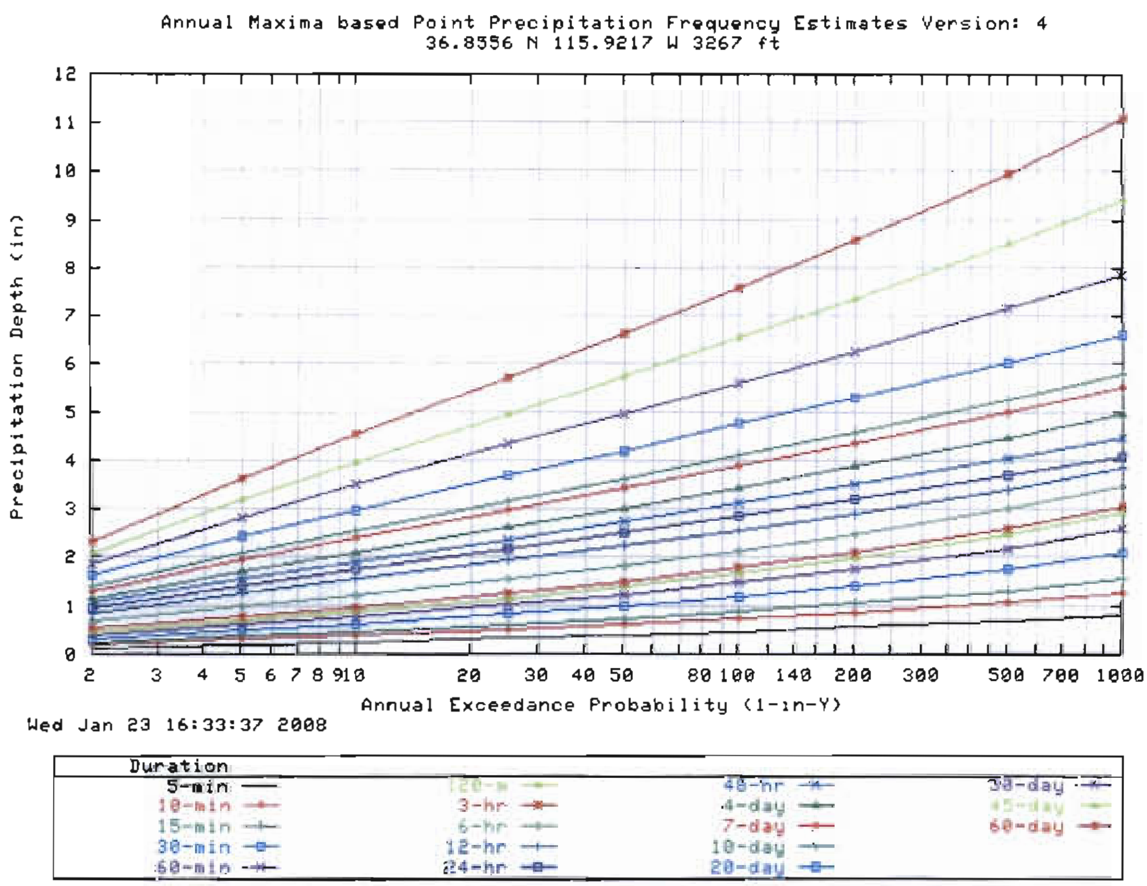
* The **upper** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **greater** than.
** These precipitation frequency estimates are based on an annual maxima series. **AEP** is the Annual Exceedance Probability.

Preparer: UD 3-18-08 Checker: UY 3/18/08

Please refer to the documentation for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

* Lower bound of the 90% confidence interval Precipitation Frequency Estimates (inches)																		
AEP** (1-in-Y)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.10	0.15	0.19	0.25	0.31	0.38	0.45	0.58	0.74	0.83	0.91	0.99	1.12	1.20	1.39	1.60	1.78	1.99
5	0.15	0.23	0.29	0.39	0.48	0.58	0.66	0.85	1.09	1.23	1.35	1.48	1.68	1.80	2.10	2.43	2.73	3.09
10	0.19	0.30	0.37	0.49	0.61	0.73	0.82	1.05	1.33	1.50	1.65	1.80	2.05	2.19	2.55	2.98	3.39	3.84
25	0.26	0.39	0.49	0.65	0.81	0.94	1.04	1.31	1.66	1.85	2.03	2.23	2.53	2.69	3.14	3.68	4.21	4.81
50	0.31	0.47	0.58	0.78	0.97	1.12	1.23	1.52	1.90	2.12	2.32	2.54	2.88	3.06	3.56	4.18	4.83	5.54
100	0.36	0.55	0.69	0.92	1.14	1.32	1.43	1.75	2.15	2.38	2.60	2.86	3.23	3.43	3.98	4.69	5.44	6.28
200	0.42	0.64	0.80	1.07	1.33	1.53	1.65	1.99	2.40	2.64	2.88	3.18	3.58	3.79	4.38	5.19	6.06	7.01
500	0.52	0.78	0.97	1.31	1.62	1.86	1.98	2.36	2.74	3.00	3.26	3.60	4.04	4.26	4.91	5.83	6.86	7.97
1000	0.59	0.90	1.12	1.51	1.86	2.12	2.26	2.66	3.07	3.27	3.54	3.92	4.39	4.62	5.30	6.32	7.47	8.72

* The **lower** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **less** than.
** These precipitation frequency estimates are based on an annual maxima series. **AEP** is the Annual Exceedance Probability.
Please refer to the documentation for more information. NOTE: Formatting prevents estimates near zero to appear as zero.



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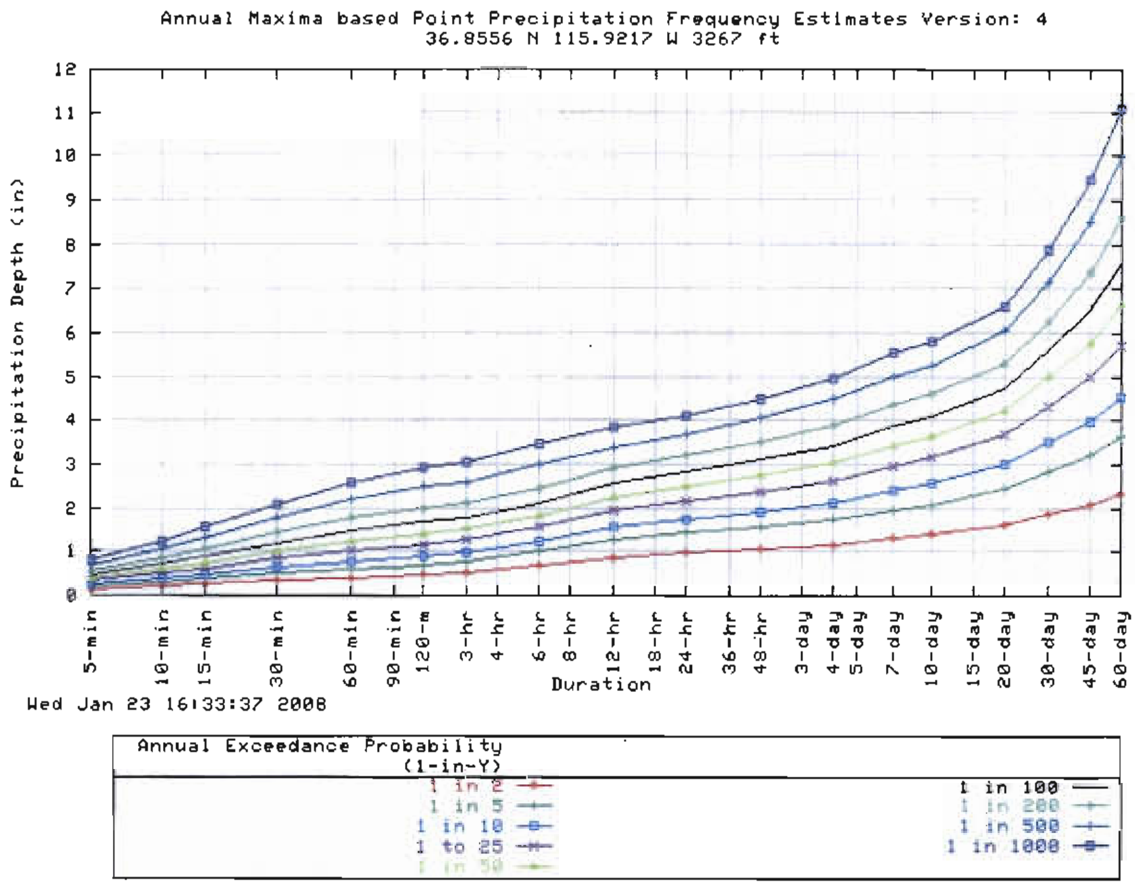
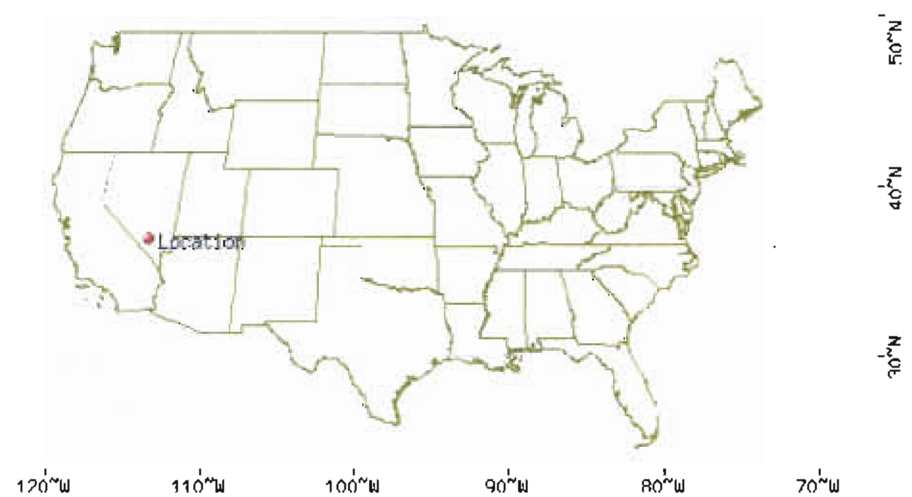


Maps -



These maps were produced using a direct map request from the
U.S. Census Bureau Mapping and Cartographic Resources
Tiger Map Server.

Please read disclaimer for more information.

Preparer: [signature] 3-18-08 Checker: [signature] 3/18/08

Other Maps/Photographs -

View USGS digital orthophoto quadrangle (DOQ) covering this location from TerraServer; **USGS Aerial Photograph** may also be available
from this site. A DOQ is a computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map. Visit the USGS for more information.

Watershed/Stream Flow Information -

Find the Watershed for this location using the U.S. Environmental Protection Agency's site.

Climate Data Sources -

Precipitation frequency results are based on data from a variety of sources, but largely NCDC. The following links provide general information
about observing sites in the area, regardless of if their data was used in this study. For detailed information about the stations used in this study,
please refer to our documentation.

Using the **National Climatic Data Center's (NCDC)** station search engine, locate other climate stations within:

+/-30 minutes ...OR... +/-1 degree of this location (36.8556/-115.9217). Digital ASCII data can be obtained directly from NCDC.

Find Natural Resources Conservation Service (NRCS) SNOTEL (SNOwpack TELemetry) stations by visiting the **Western Regional Climate Center's state-specific SNOTEL station maps**.

Hydrometeorological Design Studies Center
DOC/NOAA/National Weather Service
1325 East-West Highway
Silver Spring, MD 20910

Preparer: [signature] 3-18-08 Checker: [signature] 3/18/08

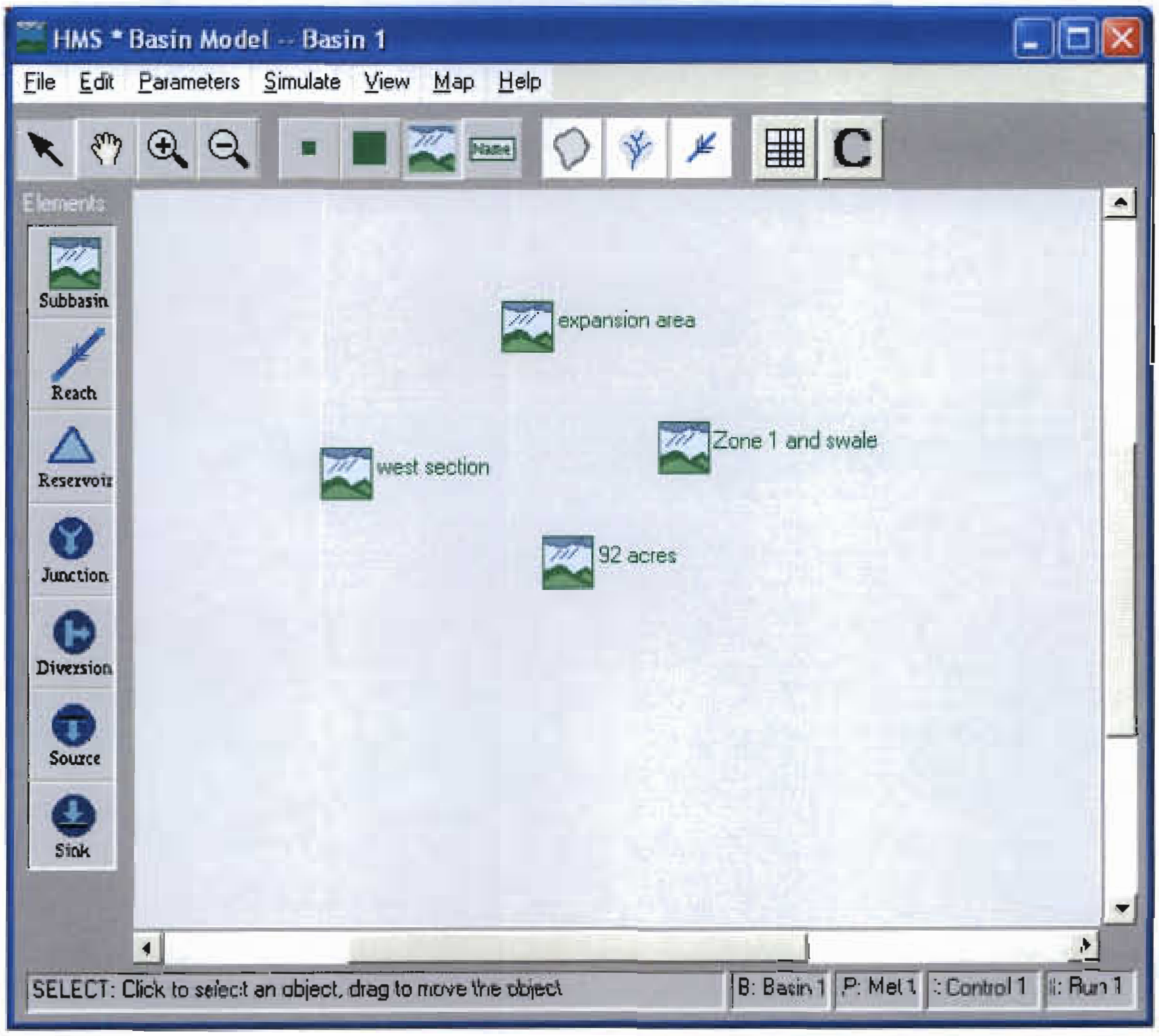
(301) 713-1669
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Attachment C

HEC-HMS Basin Schematic and Summary Output

HEC-HMS Basin Model Schematic



Preparer: ___ 3-18-08

Checker: ___ 3/18/08

HEC-HMS Results Summary

HMS * Summary of Results

Project : A5 RWMS internal Run Name : Run 1

Start of Run : 01Jan07 0000 Basin Model : Basin 1

End of Run : 02Jan07 1200 Met. Model : Met 1

Execution Time : 06Mar08 1048 Control Specs : Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
expansion area	38.022	01 Jan 07 1228	5.0845	0.260
92 acres	17.903	01 Jan 07 1230	2.8397	0.190
Zone 1 and swale	2.6177	01 Jan 07 1228	0.46859	0.044
west section	0.84897	01 Jan 07 1232	0.20001	0.026

Print Close

Preparer: [signature] 3-18-08 Checker: [signature] 3/18/08

Attachment D

HEC-HMS Input Files

C:\hmsproj\A5_RWMS_internal\Basin_1.basin

Basin: Basin 1
Last Modified Date: 6 March 2008
Last Modified Time: 10:48:20
Version: 2.2.2
Default DSS File Name:
C:\hmsproj\A5_RWMS_internal\A5_RWMS_internal.dss
Unit System: English
End:

Subbasin: expansion area
Canvas X: -329.835
Canvas Y: 1329.034
Label X: 16
Label Y: 0
Area: 0.26

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 72

Transform: SCS
Lag: 19.900000

Baseflow: None
End:

Subbasin: 92 acres
Canvas X: -329.834
Canvas Y: 1329.027
Label X: 16
Label Y: 0
Area: 0.19

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 69

Transform: SCS
Lag: 20.600000

Baseflow: None
End:

Subbasin: Zone 1 and swale
Canvas X: -329.830
Canvas Y: 1329.030
Label X: 16
Label Y: 0
Area: 0.044

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 65.7

Transform: SCS
Lag: 16.100000

Baseflow: None
End:

Subbasin: west section
Canvas X: -329.840
Canvas Y: 1329.029
Label X: 16
Label Y: 0
Area: 0.026

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 63

Transform: SCS
Lag: 15.800000

Baseflow: None
End:

Default Attributes:
Default Basin Unit System: English
Default Meteorology Unit System: SI
Default Loss Rate: Initial+Constant
Default Transform: Modified Clark
Default Baseflow: Recession
Default Route: Muskingum
Enable Flow Ratio: No
Enable Evapotranspiration: No
Compute Local Flow At Junctions: No
Missing Flow To Zero: No
End:

C:\hmsproj\A5_RWMS_internal\Met_1.met

Precip: Met 1
    Last Modified Date: 27 February 2008
    Last Modified Time: 13:09:17
    Version: 2.2.2
    Default DSS File Name:
C:\hmsproj\A5_RWMS_internal\A5_RWMS_internal.dss
    Unit System: English
    Enable Evapotranspiration: No
    Precipitation Method: Frequency Based Hypothetical
End:

Method Parameters: Frequency Based Hypothetical
    Exceedence Frequency: 4
    Single Hypothetical Storm Size: Yes
    Convert to Annual Series: Yes
    Storm Size:
    Total Duration: 1440
    Time Interval: 5
    Percent of Duration Before Peak Rainfall: 50
    Depth: 0.33
    Depth: 0.61
    Depth: 1.02
    Depth: 1.16
    Depth: 1.26
    Depth: 1.56
    Depth: 1.94
    Depth: 2.17
End:

Subbasin: classified area
End:

Subbasin: expansion area
End:

Subbasin: Subbasin-1
End:

Subbasin: expansion with SCS
End:

C:\hmsproj\A5_RWMS_internal\Control_1.control

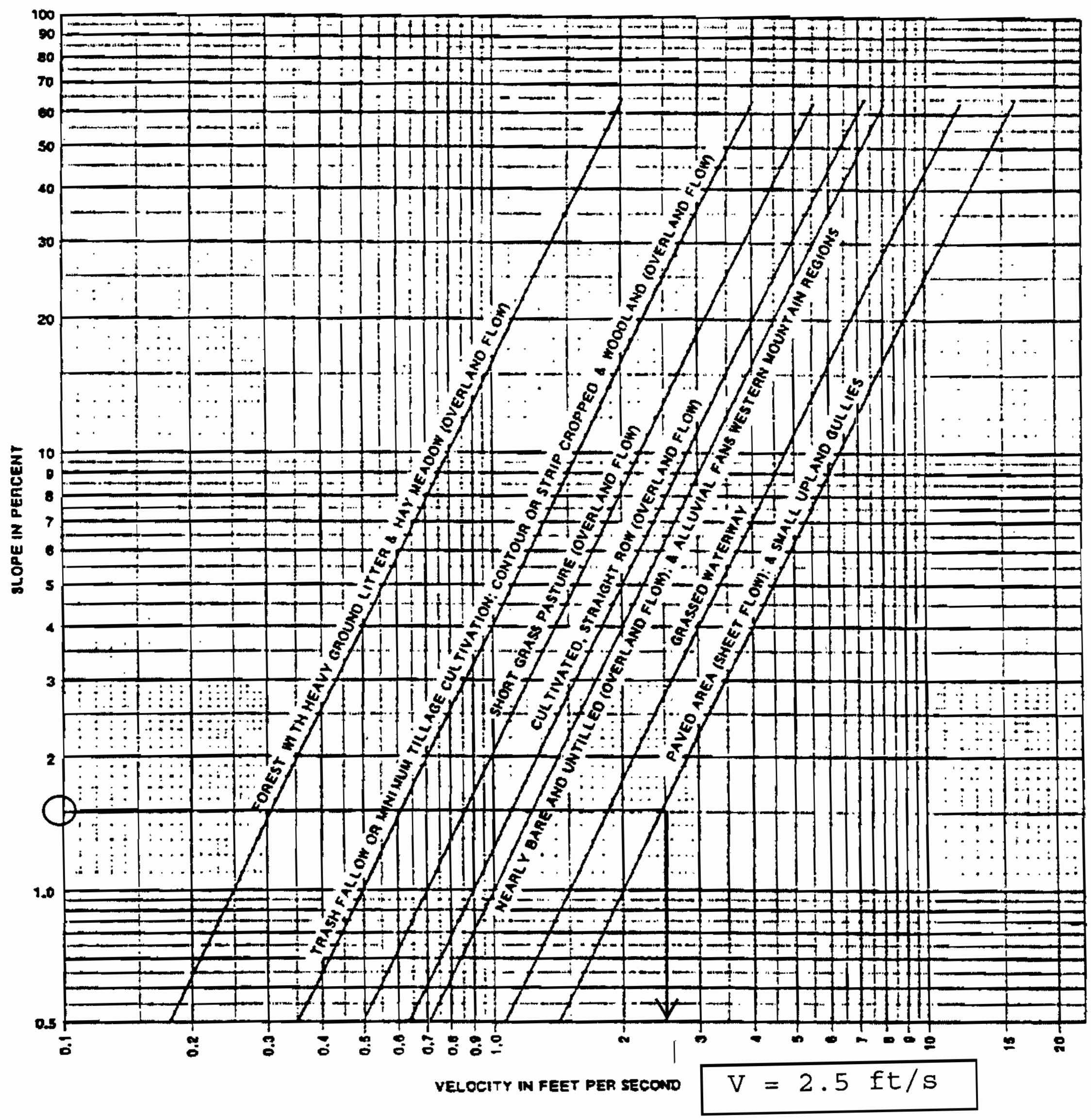
Control: Control 1
Last Modified Date: 21 February 2008
Last Modified Time: 14:44:11
Start Date: 1 January 2007
Start Time: 00:00
End Date: 2 January 2007
End Time: 12:00
Time Interval: 2
End:

Attachment E

Travel Time Velocity

HYDROLOGIC CRITERIA AND DRAINAGE DESIGN MANUAL

TRAVEL TIME VELOCITY



Revision	Date

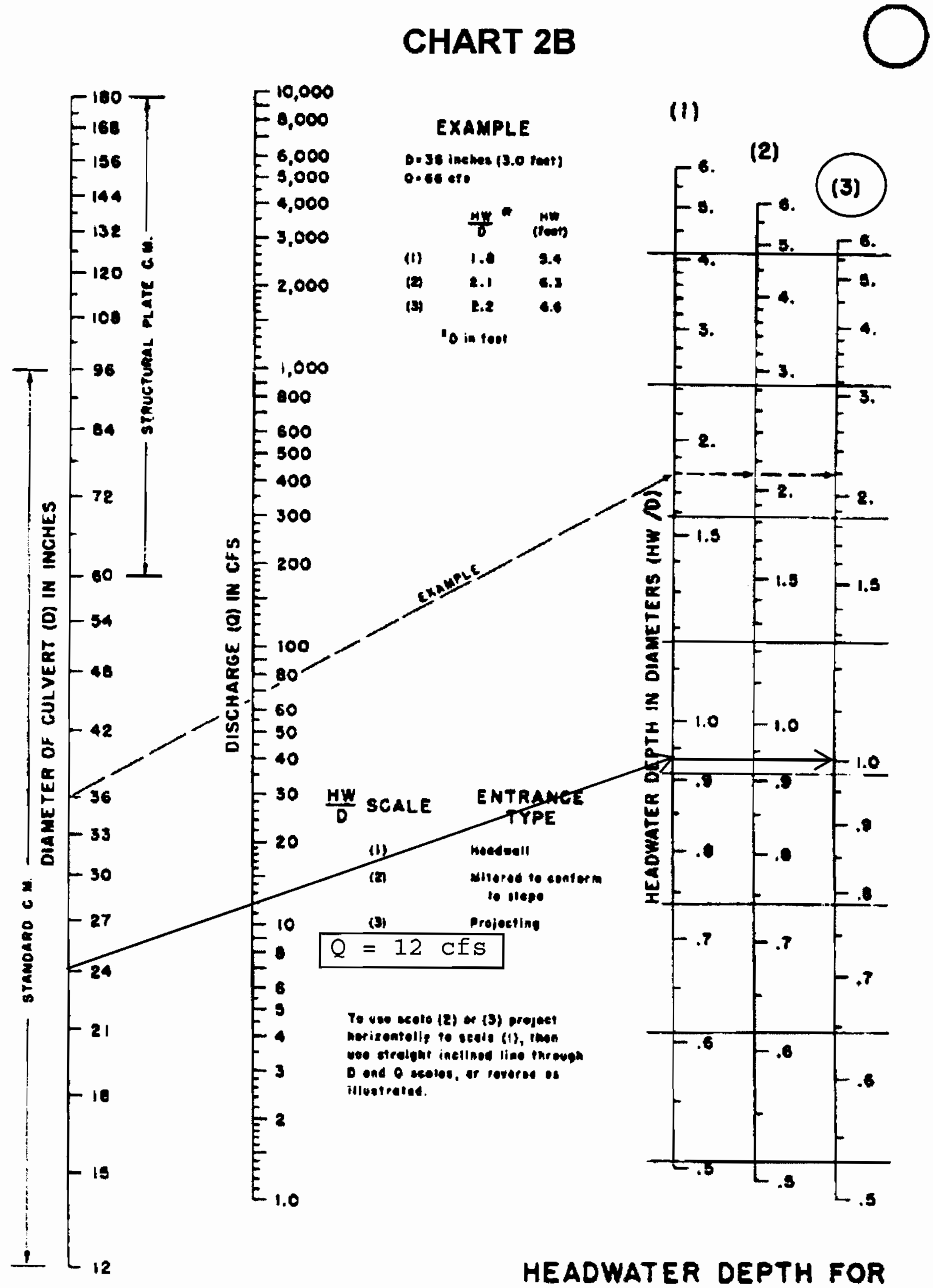
WRC ENGINEERING	REFERENCE: SCS National Engineering Handbook Section 4, Hydrology, March, 1985	FIGURE 602

prepared by: UD 3-18-08 checked by: VY 3/18/08

Attachment F

Culvert Nomograph Analyses

CHART 2B

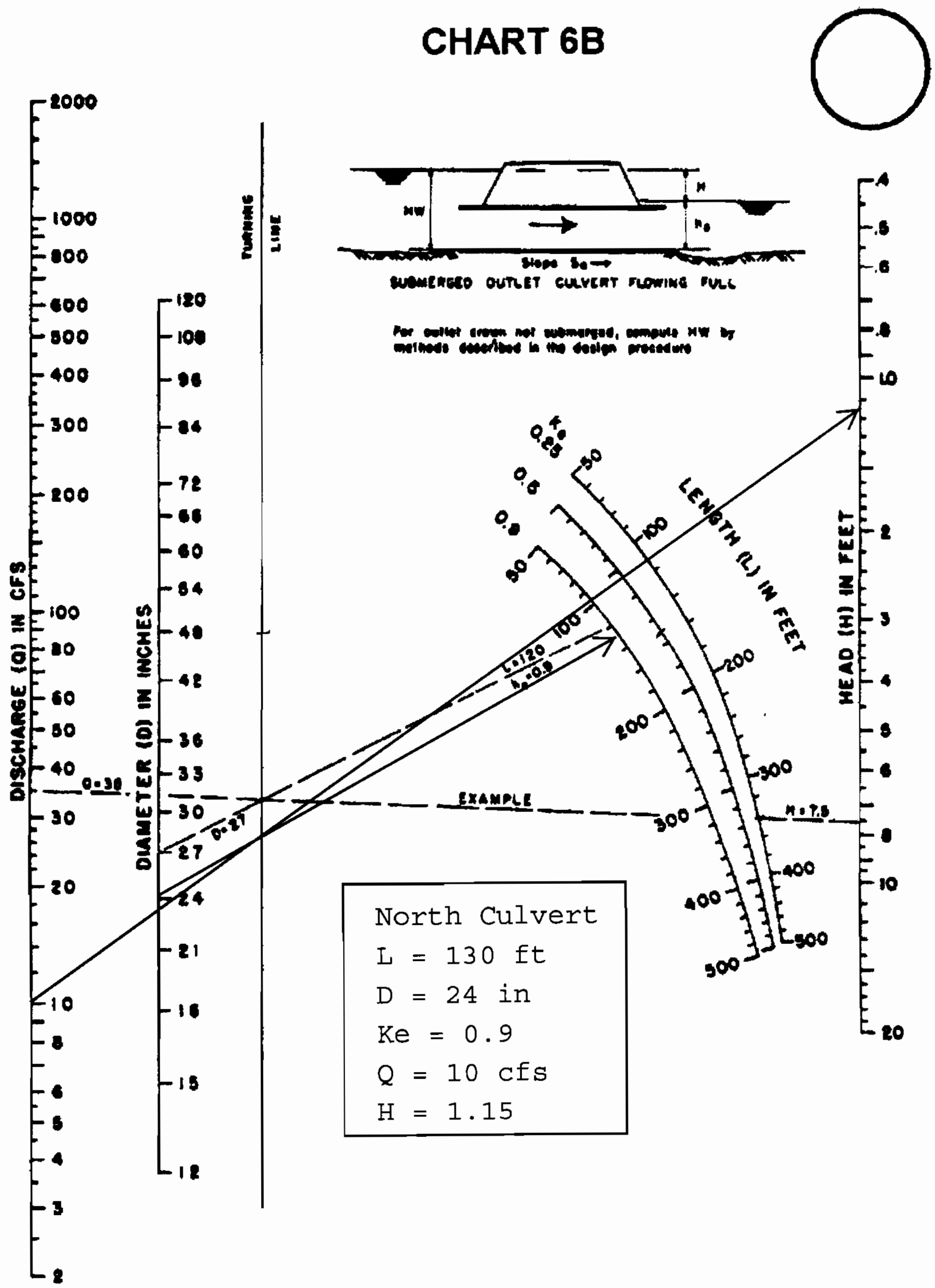


HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Preparer: [signature] 3-18-08 Reference: USDOT, 2001 Checker: [signature] 3/18/08

CHART 6B

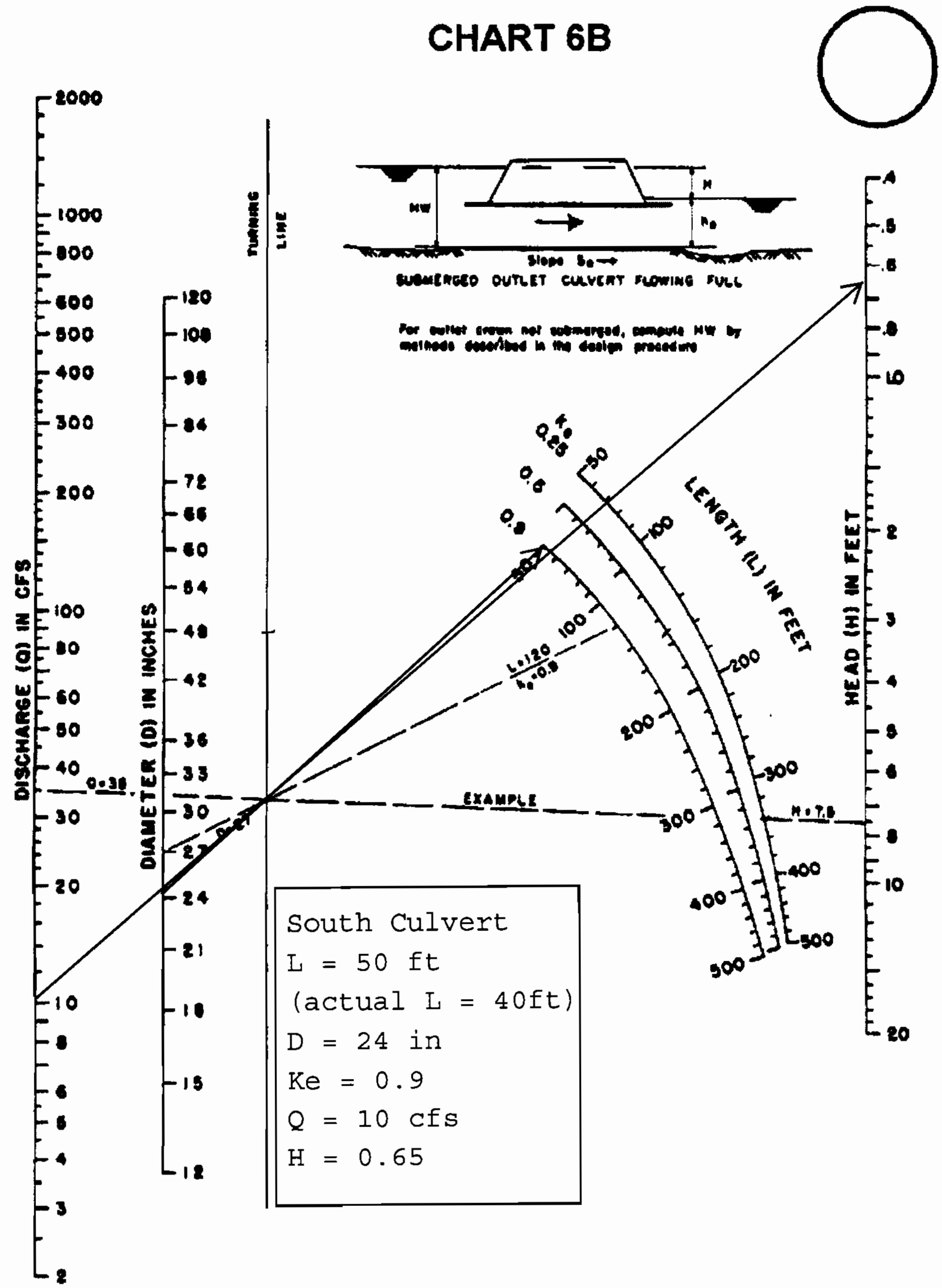


HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN 1963

Preparer: [signature] 3-18-08 Reference: USDOT,2001 Checker: [signature] 3/18/08

CHART 6B



BUREAU OF PUBLIC ROADS JAN 1963

HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL
n = 0.024

Preparer: [signature] 3-18-08 Reference: USDOT, 2001 Checker: [signature] 3/18/08

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1. **Calculation No.:**	2. **Revision No.:**	3. **Date:**	4. **Project No.:**	5. **Pages**
08023-CAL-C-003	0	3-18-08	08023	6

6. **Calculation Title:**	7. **Project Title:**
Area 5 ~~RMWS~~ RWMS Water Erosion (EJM 4/1/08)	Area 5 Closure Plan for the 92 Acre Area

8. **Calculation Type:**	9. **Quality Grade**	10. **Performance Category**	11. Superseded by Calculation No.: N/A
☐ Preliminary ☒ Final ☐ Voided/ Superseded	☐ QG-1 ☒ QG-3 ☐ QG-2 ☐ QG-4	☒ PC-1 ☐ PC-2 ☐ PC-3	12. Supersedes Calculation No.: N/A

Original and Revised Calculation/Analysis Approval (Signature/Date)

13.	Revision 0	Revision	Revision
14. Preparer:	Lloyd T. Desotell (signature) Lloyd Desotell		3-18-08 Date
15. Checker:	Vefa Yucel (signature) Vefa Yucel		3-18-08 Date
16. Peer Reviewer:	N/A		Date
17. Discipline Section Supervisor:	(signature) Richard Greenwold		4.1.08 Date

Affected Documents

Document No.	Document Title	Revision No	Responsible Discipline Lead Initials

Record of Revision

Revision No.	Reason for Revision
0	Original

Attachments

Attachment No.	Title	Total Pages
A.	RUSLE R factor map	1
	Total Calculation Page Count	7

1 Introduction

This calculation was generated to evaluate potential waterborne erosion of the proposed final landfill closure cover for the "92-acre" area within the Area 5 Radioactive Waste Management Site (RWMS). Calculations include: average annual soil loss from the final landfill cover using the Revised Universal Soil Loss Equation (RUSLE) and riprap requirements for the cover sideslopes.

2 Basis

Calculations are performed to support landfill closure design. The design 25-year 24-hour storm level and location of the final closure cover was given by Waste Management closure project personnel.

2.1 Design Inputs

- The cover will have a maximum of 2% slope, sideslopes are 5H:1V.
- Site location information was derived from areal photographs and the NSTec engineering CADD database.
- Approximate location of the final closure cover is E 593,130, N 4,079,388, UTM zone 11 NAD 83, meters.
- Design storm flows used for the sideslope riprap calculation are taken from 08023-CAL-C-003.
- Soil texture information for the cover material is taken from Shott et al 1998.

2.2 Criteria

Compute annual average of soil loss due to water erosion of the final landfill cover. Compute sideslope armoring requirements from flood flows impacting the proposed final closure cover for the "92-acre" within the Area 5 Radioactive Waste Management Site (RWMS) from a 25-YR 24-HR design storm.

2.3 Assumptions

- The 92-acre disposal area will be closed with a monolayer evapotranspiration type final closure cover using native alluvium and vegetated with native plant species.

3 References

Nelson J.D., S.R Abt, R.L. Volpe, D. van Zyl, N.E. Hinkle and W.P. Staub. Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments.

NUREG/CR—4620, TI86 007859.

Haan C.T., B.J. Barfield and J.C. Hayes. Design Hydrology and Sedimentology for Small Catchments. Academic Press. 1994.

Microsoft Excel 2002 SP3

Shott GJ, Barker LE, Rawlinson SE, Sully MJ, and BA Moore. Performance assessment for the Area 5 Radioactive Waste Management Site, Nye County, Nevada. Las Vegas, NV: Bechtel Nevada, DOE/NV/11718—176; 1998.

08023-CAL-C-003 (Area 5 drainage calc)

EPA. Design and Construction of RCRA/CERCLA Final Covers. EPA/625/4-91/025. May 1991

4 Methods

- Annual potential soil loss from the final closure cover was determined using the Revised Universal Soil Loss Equation (Haan et al. 1994).
- Sideslope armoring was estimated using the Stephenson Method (Nelson et at. 1986).

5 Results and Conclusions

The calculated average soil loss from the final cover is 0.56 tons/acre/year. This is below the EPA guidance of 2 tons/acre/yr (EPA, 1991 p.3). Over 30 years, 0.1 inches of the cover will have potentially eroded.

Riprap armoring of the cover sideslopes is not warranted. The calculated rock size required is very small (d_{50}< 0.25 inches). Any repairs needed due to erosion can be accommodated through the maintenance program (per Vefa Yucel project manager).

6 Calculations and Analyses

Cover Erosion

Cover erosion is calculated using the Revised Universal Soil Loss Equation:

$$A = R\,K\,L\,S\,C\,P$$

where

A = the average soil loss per unit of area, expressed in units selected for K and the time period specified by R.
R = the rainfall/runoff factor, which is the number of rainfall units for rainfall energy and runoff plus a factor from snowmelt.
K = the soil erodibility factor, which is the rate of soil loss per unit of R (erosion index units) for a

given soil under continuous fallow with up and downhill cultivation on a slope of 9 percent with a slope length of 72.6 ft.

L = the slope length factor, which is the ratio of soil loss from a defined slope length relative to that from a slope length of 72.6 ft.

S = the slope steepness factor, which is the ratio of soil loss from a slope with a given steepness relative to that from a 9 percent slope.

C = the cap and management factor, which is the ratio of soil loss from an area with a given cap and management relative to that from an identical area in continuous fallow.

P = the supporting conservation practice factor, which is the ratio of soil loss from a field with a conservation support practice (such as contouring) relative to that with straight row farming up and downhill.

R value is based on geographic location (Haan et al 1994, see Attachment A)

K value is obtained from Haan et al 1994 p255 for sand texture (texture obtained from Shott et al 1998). Note: using the equation 8.36 on p 255 of Haan et al 1994 yields and unreasonably low K value. Therefore a K value is select from the Haan et al Table 8.4 based on the texture class of sand.

Soil Grain-Size Data - Mean Percent Passing Indicated Size

3/4 in	3/8 in	#4	#6	#10	#16	#40	#70	#140	#200
19.0 mm	9.52 mm	4.75 mm	3.35 mm	2.0 mm	1.18 mm	0.425 mm	0.212 mm	0.106 mm	0.075 mm
96.0%	91.3%	85.1%	80.3%	74.7%	65.5%	51.3%	31.8%	12.9%	8.4%

(Shott et al, 1998)

Maximum slope = 2% design criteria

The L factor is calculated using the following equation from Haan et al 1994:

$$L = \left[\frac{\lambda}{72.6}\right]^m$$

where:
λ is the horizontal length of the cover (1400 ft from design drawings)

m is a variable slope exponent obtained from Table 8.6 Haan et al 1994 assuming a low rill to interrill erosion ratio as suggested by Haan et al 1994 for rangeland soils.
m = 0.14

The calculated L = 1.51

The S factor is calculated using the following equation from Hann et al 1994:

$$S = 10.8 \sin\theta + 0.03$$

where:
θ is the slope angle (the eq is valid only for sin θ < 0.09)
θ = 1.15 degrees
The calculated S = 0.24

C assume conservative factor of 1 (bare soil)

P assume conservative factor of 1 (no conservation practices)

RUSLE Parameters

Parameters	Value
R	10
K	0.15
LS	0.37
C	1
P	1

A = (10)(0.15)(0.37)(1)(1) = 0.56 tons/acre/year

Assuming a bulk density of 1.6 g/cm^3 for the cover material, over 30 years 0.1 inches of the cover will have eroded.

Sideslope Riprap

A representative sideslope armouring calculation is performed for western section of the (see below figure) proposed final cover. This section has the longest overland flow lengths. From 08023-CAL-C-002, the peak discharge from this area is 0.85 cfs. Due to the relatively long watercourse lengths (>1000 ft) of this area, there is a potential for overland to concentrate. Assuming a concentration factor of 3, the design discharge for this area is 2.55 cfs. Assuming a flow width of 580 ft, the maximum flow rate per unit width is 0.0044 cfs/ft. Cover sideslopes are assumed to be 5H:1V. The Stephenson Method (from Nelson et al 1986) is used to calculate the required stone size for a stable slope.

$$d_{50} = \left[\frac{q(\tan\theta)^{\frac{7}{6}} n^{\frac{1}{6}}}{C\,g^{0.5}\left[(1-n)(S-1)\cos\theta(\tan\phi-\tan\theta)\right]^{\frac{5}{3}}} \right]^{\frac{2}{3}}$$

where:
d_{50} is the representative diameter at which rock movement is expected for unit discharge q (ft)
q is the maximum flow rate per unit width (cfs/ft)
n is the rockfill porosity (dimensionless)
g is the acceleration constant (ft/s^2)
θ is the angle of the sideslope (degrees)
Φ is the angle of internal friction (degrees)
C is an empirical factor (varies from 0.22 for gravel and pebbles to 0.27 for crushed granite)
S is the relative density of the rock

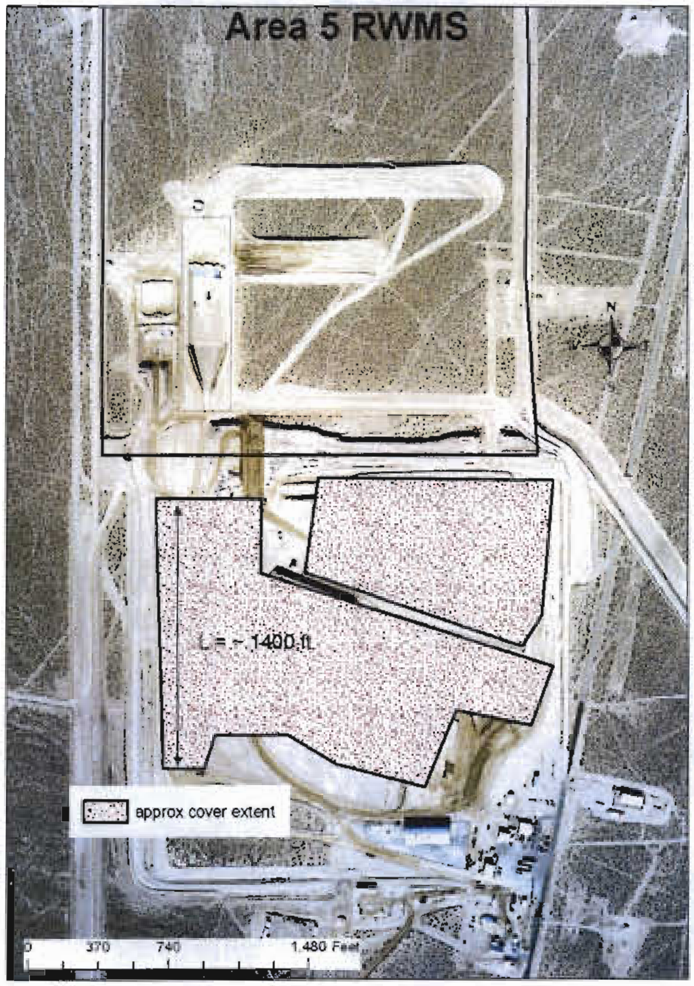
Parameter	Value
q	0.0044
n	0.35
g	32.2
θ	11.3
Φ	35
C	0.22
S	2.6

The calculated median rock diameter is then multiplied by Olivier's constant to insure stability (1.2 for gravel). Design rock size = 1.2* 0.15 (in) = 0.18 in.

d_{50} design = 0.18 in

Due to the small size of the calculated rock, infrequent runoff producing rainfall events at the project site and an already required cover maintenance period, it is recommended not to armor the sideslopes. Maintenance/repair of significant erosion of the sideslopes is recommended.

Cover sideslopes of 4H:1V yield a d_{50} design = 0.24 in



Attachment A

RUSLE R factor map

prepared by: [signature] 3-18-08

checked by: [signature] 3/18/08

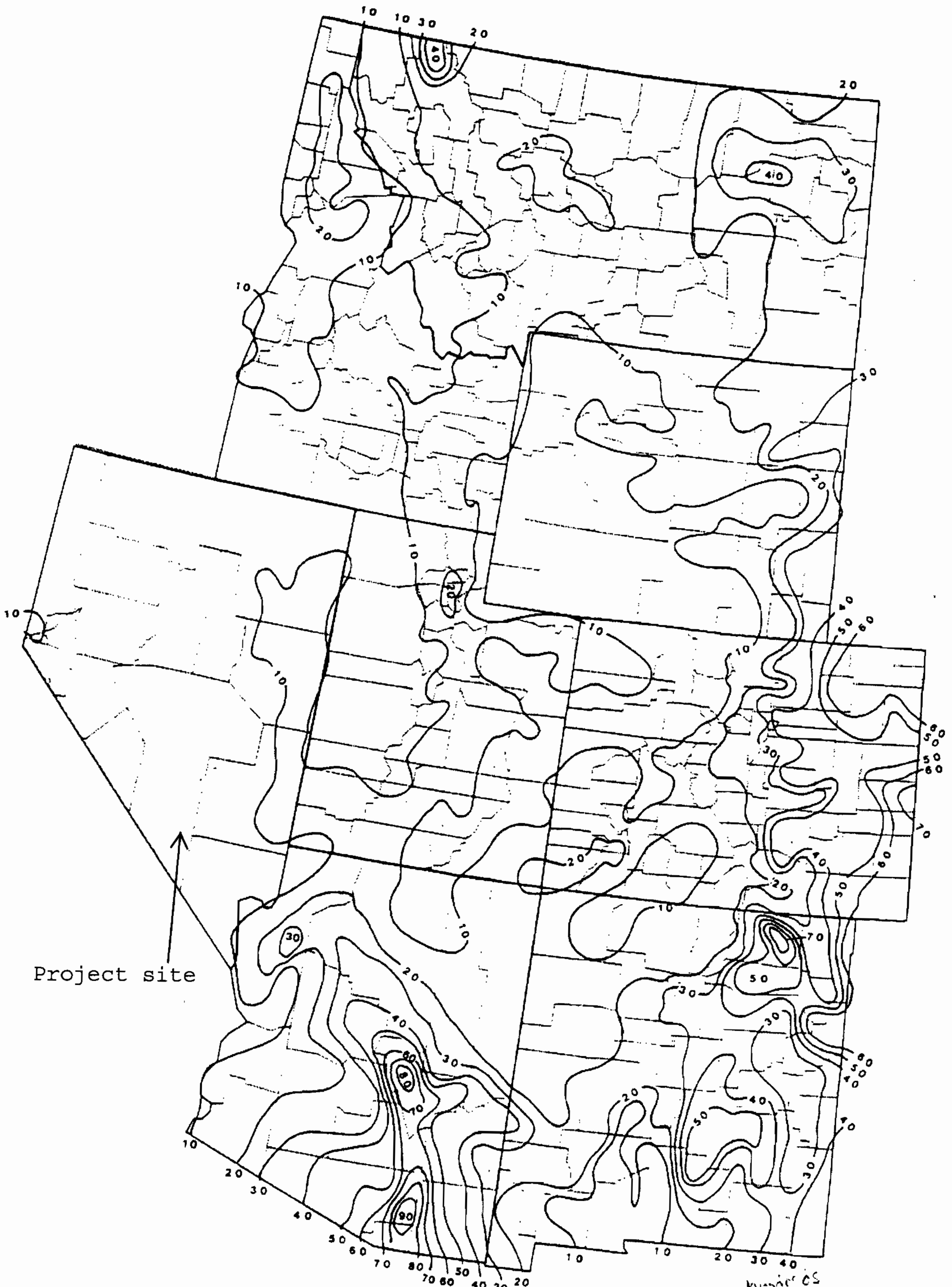


Figure 8A.1 Isolines of R factor for Western U.S. (after Renard *et al.*, 1993b). Units on R are (hundreds) ft · tonsf · in./acre · hr · year. To convert to metric, MJ · mm/ha · h · year, multiply by 17.02.

prepared by: [illegible]

checked by: [illegible]

APPENDIX C

CONSTRUCTION QUALITY ASSURANCE PLAN

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APPENDIX A-1

CONSTRUCTION
QUALITY ASSURANCE PLAN

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

NSTec

CLOSURE PLAN FOR AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE NEVADA TEST SITE

CONSTRUCTION QUALITY ASSURANCE PLAN

08023-CQAP-001, Revision A

MARCH 2008

ISSUED FOR 90% DESIGN REVIEW
NOT FOR CONSTRUCTION

U.S. National Nuclear Security Administration
Nevada Operations Office

CLOSURE PLAN FOR AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE NEVADA TEST SITE

CONSTRUCTION QUALITY ASSURANCE PLAN

08023-CQAP-001, Revision A

National Security Technologies, LLC

Prepared by:____________________________________ Date:

Gregory N. Doyle
Engineering Geologist

Checked by: ____________________________________ Date:

Julie A. Sorola
Civil Technical Lead

Approved by:____________________________________ Date:

Richard Greenwold
C/S/A Section Supervisor

Approved by: ____________________________________ Date:

Brian Memmott
Project Engineer

Approved by: ____________________________________ Date:

Vefa Yucel
Environmental Restoration Project Manager

TABLE OF CONTENTS

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ACRONYM AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
NSTec	National Security Technologies, LLC
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
CQA	Construction Quality Assurance
DOE/NV	U.S. Department of Energy, Nevada Operations Office
ER	Environmental Restoration
NTS	Nevada Test Site
PE	Professional Engineer
QA	Quality Assurance
RCRA	Resource Conservation Recovery Act
TDR	Time-Domain Reflectometry

SECTION I

CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN NARRATIVE

SECTION I
Construction Quality Assurance (CQA) Plan Narrative

1.0 INTRODUCTION

The Area 5 Radioactive Waste Management Site (RWMS) Resource Conservation and Recovery Act (RCRA) Equivalent Closure Cover will be designed and constructed to meet the following Code of Federal Requirements (CFR):

- RCRA Closure and Post Closure Requirements (40 CFR 265.310)
  - Minimize liquid migration
  - Minimize maintenance
  - Minimize erosion
  - Accommodate subsidence
  - Permeability of the cover must be less than, or equal to, that of the bottom of the unit
  - Promote drainage away from the cover

- Closure CQA Program (40 CFR 265.19)
  - Written CQA Plan
    - Unit description and construction (cover)
    - Personnel qualifications and functions
    - Description of inspection and sampling activities

- Certification of Closure (40 CFR 265.115)
  - Documentation
    - Independent, Registered Professional Engineer (PE) Certification (of Closure)

1.1 Background

The U.S. National Nuclear Security Agency (NNSA), Nevada Operations Office, through its Environmental Restoration Division, has authorized their Performance-Based Management Contractor, National Security Technologies (NSTec) to design and construct a RCRA compliant (40 CFR 265.310), closure cover for the Area 5 RWMS in Area 5 of the Nevada Test Site (NTS). The Area 5 RWMS unit description and location information are shown on the engineering drawings (see Section III).

This plan is in accordance with RCRA 40 CFR 265.19, the DOE/NV Area 5 RWMS Closure Plan, and design-specified requirements. This plan describes the CQA organizational and implementation controls that will be in place during the design and construction phases of this project, and which will also be used to make final acceptance determination of the constructed closure cover.

1.2 Project Organization

The organizations involved in regulating, designing, and constructing the Area 5 RWMS closure cover are listed below:

- NNSA — Owner
- State of Nevada — Regulating agency
- NSTec — Project management and regulatory analysis, engineering construction, survey, inspection and testing services
- TBD — Independent PE/CQA Officer (subcontractor)

The relationships, roles, and responsibilities of the principal organizations are depicted in the Project Functional Organization Chart (Figure 1.1).

Project Functional Organization Chart

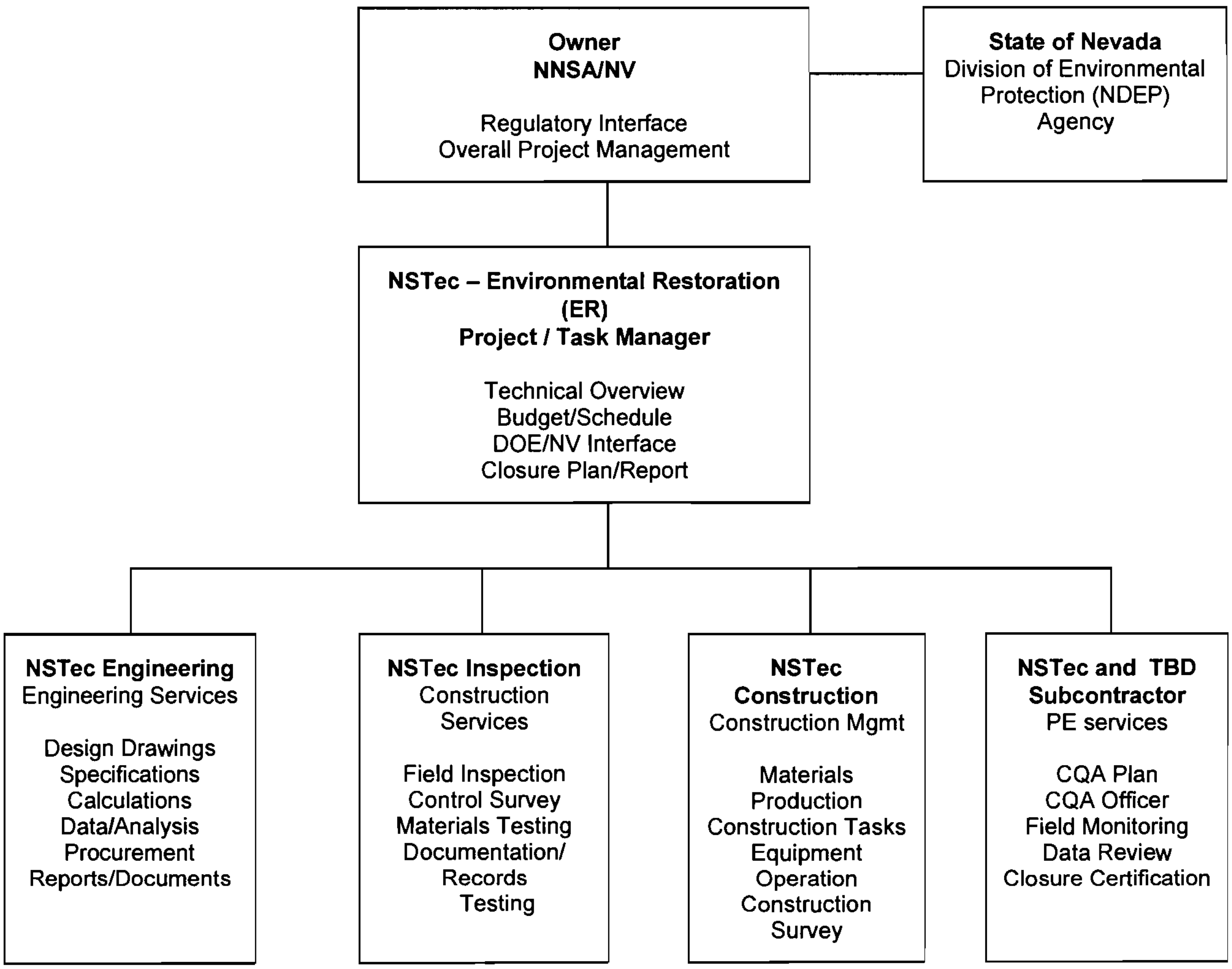

Figure 1.1

2.0 CQA PERSONNEL

2.1 Identification of Key Personnel

Key project personnel for NSTec are listed below; however, personnel are subject to change and it is suggested that the NSTec Environmental Restoration (ER) Project Manager be contacted for further information.

NSTec:	ER Project Manager	Vefa Yucel
	C/S/A Section Supervisor	Richard Greenwold
	Project Engineer	Brian Memmot
	Civil Design Technical Lead	Julie Sorola
	Engineering Geologist	Gregory Doyle
	ER Field Coordinator	TBD
	Construction Superintendent	TBD
	Construction Field Engineer	TBD
	Survey Supervisor	Jack Mahan
	Materials Testing Supervisor	Bryan Spicer
	Inspection	TBD
Subcontractor	PE/CQA Officer	TBD
	Field Representative	TBD

2.2 CQA Officer Qualifications

Qualifications for the project PE/CQA Officer will require, as a minimum, registry as a Professional Engineer (PE) in Nevada (40 CFR 265.115). A copy of the project PE/CQA Officer qualifications will be included in the final plan (see Section V).

2.3 Quality Assurance (QA)/Quality Control Inspection Program

NNSA/NV has a rigorous QA program based on department orders and national standards, including requirements of American National Standards. The QA program is promulgated through procedures that have been prepared by NNSA/NV and NSTec, over all activities inherent to this closure plan. The Hierarchy of Documents is shown in Figure 2.1.

3.0 INSPECTION STRATEGIES

3.1 Design/Construction Documents

Section III contains design drawings for the project. Table 3.1 describes the American Society for Testing and Materials (ASTM) standards, inspection methods, and requirements for the closure cover.

HIERARCHY OF DOCUMENTS

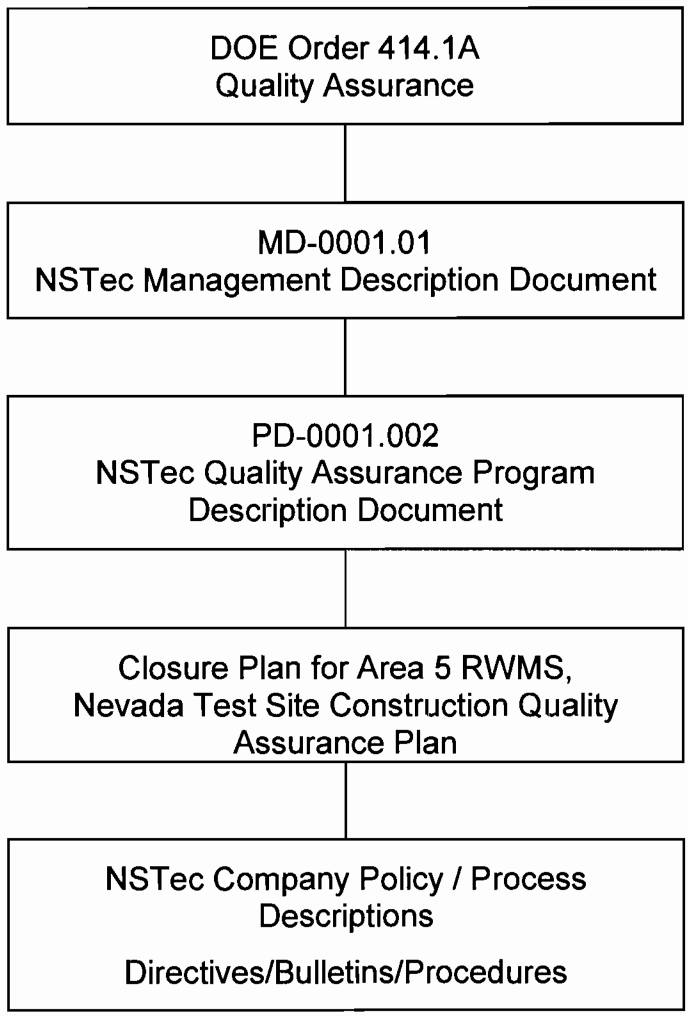

Figure 2.1

3.2 Inspection Procedures

The itemized Approval Matrix and Checklist contains the governing design, procurement, construction, and inspection functions for the Area 5 RWMS cover (see Section II). A completed copy of the Approval Matrix and Checklist, including CQA plan compliance verification signoff(s), will become part of this plan at project completion.

The Area 5 RWMS closure project central file will include the following documents: this plan; working drawings/specifications; inspection reports upon completion, e.g., logs, change orders, etc.; photographs; and other documentation pertinent to construction, inspection, and acceptance procedures. The central file location will be at the NTS, Area 5 RWMS project field office during the construction phase, and will be under the control of the NSTec Project Manager.

Inspection personnel, who are responsible for construction acceptance inspection services, shall provide acceptance/rejection inspection functions in conjunction with existing procedures at prescribed ***hold point*** locations shown in Section II. Acceptance determination shall be in accordance with current design requirements specified in the technical documents (design drawings). Table 3.1 provides the guidance for inspection methods and testing requirements for the Area 5 RWMS closure project.

The observations, inspection, and survey data will be used to verify that the Area 5 RWMS closure cover construction meets all design criteria, plans, and specifications, as described in the Approval Matrix and Checklist, including CQA Plan compliance verification signoff(s).

Table 3.1 Area 5 RWMS, 92 Acre, Closure Cover Inspection Schedule

Inspection/Testing NSTec/Subcontractor Phase/Task	**Inspection/Test Method Reference**	**Sample/Test Quantity/Frequency**	**Sample/Location Requirement**	
			Stockpile	**Cover per Lift**
FIELD INSPECTION OPERATIONS (General)				
General Project Support	Visual, plus basic measurements, include survey/material data where applicable	100% During Construction	N/A	Yes
Borrow Site Evaluation	Gradation, ASTM D-422-63	1 per 5,000 Cubic Yards Excavated	Yes	N/A
Lift/Layer Thickness	Visual/12 inch maximum compacted thickness	Each Lift	N/A	Yes
Lift/Layer Compaction	ASTM D 6938 Min. 99 pcf Max. 112 pcf Dry Density	1 Test Per 1,000 cubic yards of fill placed.	N/A	Yes
As Built Topographic Survey	Survey Check: Thickness, elevation, Slope as required	As required per construction phase completion (see hold points)	N/A	Yes, Final Lift Only
VEGETATIVE FILL LAYER PLACEMENT				
Grade Checking	Grade check: thickness, elevations, slopes as required	Completion	N/A	Yes
As-built Topographic Survey	Survey Check: thickness, elevations, slopes	Completion	N/A	Yes
MONUMENTS, FENCING AND SIGN PLACEMENT				
Monuments	Installation/ Survey Data	Completion	N/A	N/A
Fencing	Installation	Completion	N/A	N/A
Signage	Installation	Completion	N/A	N/A
Survey	Cap Surface As-built	Final	N/A	N/A
VEGETATIVE COVER SURFACE PREPARATION				
Prepare Cover	Verify disking of surface to a depth	None	N/A	N/A

Inspection/Testing NSTec/Subcontractor Phase/Task	Inspection/Test Method Reference	Sample/Test Quantity/Frequency	Sample/Location Requirement	
			Stockpile	Cover per Lift
	of 12 – 16 inches			
AREA 5 RWMS CLOSURE COVER CONSTRUCTION COMPLETION				
Site Tour Confirmation	Schedule acceptance tour with Client and State	None	N/A	N/A
Site Tour		Final Inspection	N/A	N/A
Final Records Review		Final Inspection	N/A	N/A

4.0 SAMPLING STRATEGIES (NOT APPLICABLE)

5.0 DOCUMENTATION

5.1 Overview

The project document types that will be generated by the various organizations involved in this CQA plan shall include (as applicable):

- Project Closure Plan and Closure Report and discussion of closure activities
- Project schedule(s)
- Materials field sampling/testing tables and guides (Section II)
- Design drawings and their revisions (Section III)
- Design calculations and material test data (Section IV)
- Construction Work Packages
- Daily construction/site activity log, summary reports/memos
- Inspection or observation document(s)
- Material/test data sheets (sampling and testing)
- In-field survey data sheets
- Design interim change (Design Change Notice, Field Change Request)
- Deficiency documents (correctable deficiency log/nonconformance reports)
- Final inspection/survey as-built drawings
- Independent PE/CQA closure summary and certification

In addition, other miscellaneous documents; i.e., memos, sketches, audits, etc., will become a part of the project records file.

5.2 Photography

Preparing and maintaining a photographic log of all key construction activities, is the responsibility of NSTec authorized (permitted) personnel. Photographs will be clearly marked as to photographer identity, date, time, and brief description of each activity, and will be kept in a separate log as part of the central file. Photography personnel assignments will be delegated by the NSTec Project Manager.

5.3 Closure Report

A closure report will be prepared for distribution to NNSA and NDEP:

- Summary documentation of design and construction activities
- Actual (or by reference) test data, daily logs, intermediate reports, schedule, and other related documentation to support RCRA equivalency of the constructed closure cover
- Reduced-size copies of as-built drawings
- Photographs of the completed project site

5.4 Project Central Files

The central project files will include a copy of the approved CQA plan, project drawings, inspection reports, design changes, documented deficiency reports, etc. Access to these files will be under the control of the NSTec Project Manager.

6.0 REFERENCES

American Society for Testing and Materials Annual Book of ASTM Standards. 1999.

40 CFR Part 265 Subpart19, Construction Quality Assurance Program, 1999.

40 CFR Part 265 Subpart 115, Certification of Closure, 1999.

40 CFR Part 265 Subpart 310, Closure and Post-Closure Care, 1999.

DOE/NV/11718—758-REV0, Characterization Report, Operational Covers for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, June 2005.

SECTION II

APPROVAL MATRIX AND CHECKLIST

AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE APPROVAL MATRIX AND CHECKLIST

MATRIX: Use for further definition of quality responsibilities and for identification of relevant procedures.

NOTE: NSTec organizations, in accordance with the Quality Management Process Description document PD-0001.002, will provide the necessary controls during construction to verify that all design-specified hold points outlined in this plan are complied with prior to proceeding with subsequent process steps. Independent hold-point monitoring/data review will be conducted by the Independent Professional Engineer (PE)/CQA Officer representative.

ITEM – AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE	I ENG/TM GM/INSP/TL	II CONST/ OTHERS	III SUB- CONTR	IV MTL/RVY/I INSP	V CQA HP*	VI CHECKLIST INITIALS/DATE
1.0 GENERAL INSPECTIONS/OBSERVATIONS						
General Project Support	ENG	CONSTR		SRVY/INSP	CP	
Lift/ Layer Thickness	INSP/TL	CONSTR		INSP	CP	
As-built Topographic Survey	ENG			SRVY/INSP	HP	
2.0 NATIVE FILL LAYER PLACEMENT						
Borrow mat'l meets requirements on Drawing 08023-C-3001	INSP/TL	CONSTR		INSP	CP	
Lift/Layer Thickness	INSP/TL	CONSTR		INSP	CP	
Lift/Layer Compaction	INSP/TL	CONSTR		INSP	HP	
As-built Topographic Survey	ENG			SRVY/INSP	HP	

CONSTR = NSTec Construction Superintendent; CQA = Construction Quality Assurance; ENG/TM = NSTec Engineering/Task Manager; HP = Hold Point; INSP = NSTec Inspection; PE/CQA = Independent Professional Engineer/Construction Quality Assurance Officer (TBD); MTL = NSTec Materials Test Lab; SRVY = NSTec Survey; SUB-CONTR = NSTec Subcontractor; TL = NSTec Technical Lead; GM = NSTec Group Manager; CP = NSTec Check Point; * See Table 3.1 of this plan

ITEM – AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE	I ENG/TM GM/INSP/TL	II CONST/ OTHERS	III SUB-CONTR	IV MTL/RVY/I INSP	V CQA HP*	VI CHECKLIST INITIALS/DATE
3.0 MONUMENTS, FENCING, & SIGNAGE PLACEMENT						
Monuments	ENG	CONSTR		SRVYINSP	CP	
Fencing	INSP/TL	CONSTR		SRVY/INSP	CP	
Signage	INSP	CONSTR		SRVY.INSP	CP	
Survey	ENG			SRVY/INSP	HP	
4.0 VEGETATIVE LAYER PROCEDURE						
Prepare Cover Surface for Seeding Only	INSP/TL	CONSTR		INSP	HP	
5.0 AREA 5 RWMS, 92 ACRE, RCRA EQUIVALENT CLOSURE CAP CONSTRUCTION COMPLETION						
Site Tour Confirmation	ENG/TM/GP	CONSTR			HP	
Site Tour/Documentation PE/CQA Review/Acceptance	ENG/TM/GM/ PE	CONSTR			HP	PE

CONSTR = NSTec Construction Superintendent; CQA = Construction Quality Assurance; ENG/TM = NSTec Engineering/Task Manager; HP = Hold Point; INSP = NSTec Inspection; PE/CQA = Independent Professional Engineer/Construction Quality Assurance Officer (TBD); MTL = NSTec Materials Test Lab; SRVY = NSTec Survey; SUB-CONTR = NSTec Subcontractor; TL = NSTec Technical Lead; GM = NSTec Group Manager; CP = NSTec Check Point; * See Table 3.1 of this plan

SECTION III

ENGINEERING DRAWINGS

SECTION IV

DESIGN CALCULATIONS

SECTION V

CQA OFFICER QUALIFICATIONS

(TBD)

APPENDIX D

REVEGETATION PLAN FOR THE AREA 5 RWMS 92-ACRE AREA

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REVEGETATION PLAN
FOR THE AREA 5
RADIOACTIVE WASTE MANAGEMENT SITE
92-ACRE AREA

--

Prepared by

David C. Anderson

Environmental Technical Services

Ecological Services

January 2008

1.0 INTRODUCTION

The Radioactive Waste Management Site (RWMS) in Area 5 on the Nevada Test Site (NTS) is used for the disposal of low-level radioactive waste and abestiform waste. A large section, approximately 92 acres, of the Area 5 RWMS has been operationally closed, and a closure cover will be placed over it in the near future. Besides no longer accepting waste material, closing an area includes covering the disposal area with approximately 2.4 meters (m) (8 feet [ft]) of soil. The cover extends beyond the boundaries of the disposal units and is contoured to allow drainage off of the unit while minimizing erosion. The closure cover designed for the Area 5 RWMS is a vegetated monolayer, which has been approved by the Nevada Division of Environmental Protection at other NTS sites and uses an evapotranspirative technique to meet cover performance objectives.

Objectives for the final closure cover are to minimize the migration of water off and through the cover, create a cover that requires minimal maintenance, maintain the integrity of the cover over time, and meet U.S. Department of Energy (DOE) performance objectives (DOE M 435.1-1, Chapter IV, P[1]). The establishment of a native plant community will minimize wind and water erosion and thus help maintain the integrity of the closure cover. The loss of water through transpiration will be maximized and the potential for water to penetrate the buried waste materials is minimized with the reestablishment of a native plant community. The native vegetative cover prevents the establishment of invasive plant species (National Security Technologies, LLC [NSTec], 2007; Anderson and Ostler, 2002). Invasive plants, which are typically annual plants, do not create a cover that will meet the closure cover objectives. Annual plants do not maximize evapotranspiration nor are they as effective in controlling wind and water erosion, which could compromise the integrity of the cover.

The objective of this revegetation plan is to provide guidelines that, if followed, will enhance the potential for successfully reestablishing a native plant community on the Area 5 RWMS closure cover. Revegetation is the colonization of a disturbance by plants through natural plant succession or by human-induced means. Natural plant succession may require centuries for complete plant colonization, especially in the Mojave Desert (Vasek et al., 1975a; 1975b; 1980; Romney et al., 1980; Wallace et al., 1980; Webb and Wilshire, 1980; Carpenter et al., 1986; Angerer et al., 1995). However, when human-induced means are used, the time for reestablishment of a viable plant community may be shortened. Various revegetation efforts in arid and semiarid regions of the Southwest have shown that establishing a plant community by re-seeding (human-induced) is practical and cost-effective when proper revegetation techniques are employed (Graves et al., 1978; Kay, 1979; Clary, 1983; Anderson, 1987; EG&G/Energy Measurements [EM], 1993; 1994; TRW, 1999; Bainbridge et al., 1995; Anderson and Ostler, 2002; Ostler et al., 2002a).

The revegetation of the cover and associated disturbed areas at Area 5 RWMS presents unique challenges. The site is located in the harsh Mojave/Great Basin Transition Desert, which is characterized by extreme temperatures and limited, erratic precipitation. Perennial plant establishment under natural conditions usually occurs only during favorable rainfall years (Wallace and Romney, 1972; Beatley, 1975; Romney et al., 1980; Anderson and Ostler, 2002), which occur approximately one out of five years (Ries and Day, 1978). This low and unpredictable precipitation is almost without exception the factor limiting successful revegetation in the arid/semi-arid West (May, 1975).

The revegetation strategy outline in this plan employs proven reclamation techniques. The first (and critical task) is site preparation, followed by seeding with native adapted species, mulching to conserve soil moisture, supplemental irrigation to ensure seed germination and plant establishment, fencing to minimize herbivory, and monitoring to evaluate revegetation success and identify any remedial actions necessary to ensure the maintenance of a viable vegetative cover (Ostler et al., 2002a; Winkel et al., 1999). Paramount to the success of this strategy is timing. There is a period in late fall and sometimes in early spring that affords the greatest potential for successful seed germination and eventual plant establishment. The late fall seeding window extends from October 15 to December 15, and the spring window can be as early as February extending into early March. Implementation of these site-specific revegetation techniques creates the optimum conditions for seed germination and plant establishment (Ostler et al., 2002a; Anderson and Ostler, 2002).

2.0 PROCEDURES

2.1 Site Preparation

The proposed cover for Area 5 RWMS encompasses approximately 41.8 hectares [ha] (92.0 acres [ac]). The top layer of soil on the cover should have physical and chemical characteristics that will support plant growth (Table 1). Based on the physical and chemical properties of the upper 30 centimeters (cm) (12 inches [in.]) of soil used for the cover, appropriate amendments will be identified that will enhance germination and establishment of seeded species. Types of soil amendments could include (1) macro- or micronutrient additions (e.g., fertilizers), (2) organic matter additions, (3) water-holding copolymers, and (4) remedies for sodic soils such as gypsum.

Table 1. Soil parameters as they relate to topsoil suitability for use in revegetation (adapted from USDA, 1979).

Soil Parameter	Suitability	
	Good	**Fair**
Soil Texture	Fine sandy loam, very fine sandy loam, loam, silt loam, sandy loam	Clay loam, sandy clay loam, silty clay loam
Soil Salinity (EC; mmhos/cm)	<3	3 to 6
Alkalinity (Exchangeable Sodium Percentage	<4	4 to 8
Soil pH	6.1 to 7.8	5.1 to 6.1 7.8 to 8.4
Organic Matter (%)	>1.5	0.5 to 1.5

Parameters are listed in order of relative importance.

A key component of site preparation is the alleviation of soil compaction. Typically sites that have been closed are subject to increased vehicular traffic, which results in compacted soils, a condition that is not conducive to plant growth. A sequence of ripping, disking, and harrowing is used to alleviate soil compaction, which increases water infiltration and provides a firm seedbed for good soil-to-seed contact (Munshower, 1994; Ostler et al., 2002a). Compacted soils are first ripped perpendicular to the slope at a depth of 30–46 cm (12–18 in.). Ripping typically creates large clods of soil and a tractor-drawn tandem disk is needed to break up the soil clods. After disking, the site is harrowed to create a firm seedbed. Disking and harrowing, like ripping, are done with the contour of the area so as not to create channeling or drainage off of the cover.

The cover will be designed and constructed to allow access for revegetation equipment such as farm tractors, road graders, four wheel drive trucks, strawblowers, and tractor-drawn implements such as a drill seeder, disks, or chisel-tooth harrow or crimper.

2.2 Seeding

Plant species recommended for use during revegetation are all native to the area (Table 2). They were selected based on data collected (EG&G/EM, 1992) from adjacent undisturbed areas, visual surveys of the vegetation in the region, and a review of local literature (Beatley, 1976; Ostler et al., 2000). Most of the species have been successfully used in other revegetation projects in the area (NSTec, 2007), and most seed is available from commercial sources. The percentage of each species used in the mix is based on the relative contribution of that particular species to the total perennial plant cover that is typical of adjacent native plant communities, the size of the seed, and performance of the species at the NTS. The final seed mix will depend on seed availability but will only include those species listed in Table 2. Some seed may have to be treated in order to break seed dormancy (Ostler et al., 2002b; Hansen, 1989). This may include washing, chemical treatments, or mechanical treatments.

The area to be revegetated will be broadcast-seeded at a rate of 24.1 pure live seed (PLS) kilograms per hectare (kg/ha) (21.4 PLS pounds per acre [lb/ac]). Seeding will be done with a tractor-drawn seed drill having seedboxes that accommodate small, fluffy, and large seeds. Drag chains will be used behind the seed drill to cover the seed.

2.3 Mulching

The site will be mulched with grain straw at a rate of 4,484 kg/ha (4,000 lb/ac). The mulch will be applied evenly over the soil surface with a strawblower. The mulch will then be crimped into the soil surface with a tractor-drawn disk crimper, which aids in securing the straw. Crimping also incorporates a portion of the straw into the soil that, over time, can improve the amount of organic matter in the soil. The direction of crimping is to be perpendicular to the slope, just like ripping, disking, harrowing, and seeding.

Table 2. Recommended seed mix and seeding rates for revegetation of disturbed areas at Area 5 RWMS.

Scientific Name	Common Name	PLS* kg/ha	PLS* lb/ac
Shrubs			
Ambrosia dumosa	White bursage	2.24	2.00
*Atriplex polycarpa***	Desert Saltbush	0.06	0.05
Atriplex confertifolia	Shadscale	1.12	1.00
*Atriplex canescens***	Fourwing saltbush	1.20	1.00
Encelia farionosa	Brittlebush	0.56	0.50
T-*Ephedra nevadensis*	Nevada Ephedra	3.36	3.00
Ericameria nauseosa	Rubber Rabbitbrush	0.34	0.30
Eriognum fasciculatum	Buckwheat	1.12	1.00
Grayia spinosa	Spiny Hopsage	0.56	0.50
Hymenoclea salsola	Burrobush	0.11	0.10
Krascheninnikovia lanata	Winterfat	5.61	5.00
T-*Larrea tridentata***	Creosote	2.24	2.00
T-*Lycium andersonii*	Desert Thorn	0.22	0.20
Grasses			
Achnatherum hymenoides	Indian Ricegrass	3.36	3.00
Elymus elymoides	Squirreltail	1.12	1.00
Forbs			
Baileya multiradiata	Marigold	0.28	0.25
Sphaeralcea ambigua	Globe Mallow	0.28	0.25
Penstemon palmeri	Palmer's penstemon	0.28	0.25
	Totals	24.07	21.40

*** Pure Live Seed or Number of seeds per acres divided by percent germination**
**** Deep-rooted plants**
T Species should be considered for transplanting

2.4 Irrigation

The use of irrigation is a critical component to ameliorate the harsh growing conditions resulting from sporadic and unpredictable precipitation. It is used to ensure there is sufficient moisture for seed germination and growth the first year. Plants typically can survive harsh desert conditions if roots have penetrated deeper water sources, which can occur the first year of growth.

The Area 5 RWMS site receives approximately 17 cm (6.69 in.) of precipitation annually, which is well below the 25-cm (9.84-in.) level suggested for successful reclamation (National Academy of Science, 1974). Due to the risks associated with establishing plants by re-seeding, an initial period of supplemental irrigation provides sufficient moisture for seed germination and plant establishment (Hall and Anderson, 1999; Winkel and Boone, 1999). If seeding occurs and insufficient natural precipitation is not received for several years after seeding, much of the seed will be lost to predation or poor viability (Plummer et al., 1968; Ostler et al., 2002a). Under these circumstances the site would probably have to be reseeded to achieve any revegetation success.

Prior to irrigating the site, the water source will be tested to determine the quality of the water. Four basic criteria (Ludwig et al., 1976) will be used to evaluate water quality:

1. Total soluble salt content (salinity hazard)
2. Relative proportion of sodium cations to other cations (sodium hazard)
3. Bicarbonate anion concentration as related to calcium plus magnesium cations
4. Concentration of elements that may be toxic

The irrigation system will be a solid set sprinkler-type system designed to produce an even distribution of water across the entire cover. Sprinkler heads are selected to apply water at the optimal rate, spray pattern, and droplet size, and at the same time minimize runoff and wind drift.

Supplemental irrigation occurs at three physiologically important phases: prior to germination, during germination, and after germination (Ries and Day, 1978, Aldon et al., 1976, Danielson, 1967). Irrigation prior to germination (late fall, early winter) mimics precipitation events that would recharge the soil profile and encourage deep rooting once germination occurs. Irrigation during late winter, early spring is designed to keep the surface soils moist, which promotes seed germination and seedling emergence. Irrigation during the late spring and early summer aids plant establishment and survival over the typically hot and dry summers. The frequency of application will be based on the amount of rainfall received to date and other climatic conditions at the time of implementation.

2.5 Fencing

The revegetated site will be fenced to reduce the effects of herbivory on plant establishment. Fencing may include a four-strand barbed wire fence to exclude horses and antelope, and a 1.2 meter (4 foot) high wire netting to exclude rabbits. Fencing has been shown to be important for plant establishment at revegetation sites on the NTS, the Tonopah Test Range, and the Central Nevada Test Area (NSTec, 2007).

2.6 Schedule

Seeding is most effective if conducted from late October to early December. The preferable period for seeding is mid to late November. Seeding at this time ensures that dormancy-breaking requirements for germination of most seeded species are met and seeds are in the ground prior to winter precipitation. Site preparation, delivery of seed and straw, and mobilization of reclamation equipment will take place prior to the seeding window. Soil amendments would be incorporated into the soil either during site preparation or during the seeding process. Mulching and crimping will occur immediately after seeding. The irrigation system will be installed after revegetation is completed. Irrigation will begin shortly thereafter and continue into late June or as may be required.

2.7 Special Considerations

2.7.1 Interim Soil Stabilization

In the event that cover construction is completed after the seeding window, revegetation may have to be rescheduled for the following fall or spring. In this situation a temporary means of soil stabilization may be required to minimize soil and water erosion. Interim soil stabilization may include applying a surface soil stabilizer. Soil stabilizers typically have an effective life of 6 to 12 months depending on application rates and weather conditions. The site would be monitored following application of the copolymer to check the integrity of the soil stabilization. If the copolymer is not adequately controlling erosion from the cover, reapplication of the copolymer may be necessary.

A chemical soil stabilizer may be the most cost-effective. However, if a more permanent stabilization of the surface soils is required, the application of a straw mulch followed by crimping may be appropriate. Surface soils are disked and ripped. A layer of straw mulch is then applied and the straw is crimped into the loosened soils.

2.7.2 Transplants

Many native plant species are difficult to establish using the direct seeding method. Two such species included in the seed mix (Table 2) are *Larrea* and *Lycium*. The best method for establishing these species would be to use transplants. The use of transplants requires more time. Seed from both species is collected from native populations of the species on or near the revegetation area. The seed is then used to grow plants under greenhouse conditions for approximately one year. After a hardening period, they are placed in the field, typically some time after seeding. Each transplant will be watered as it is placed in the ground to ensure sufficient soil moisture for survival. Subsequent watering may occur using the irrigation system.

2.7.3 Remediation

In the unlikely event that plants do not become established on the cover, remedial action may be taken. Such action may involve additional site preparation, re-seeding, mulching, or use of transplants.

3.0 REVEGETATION MONITORING

Monitoring should occur the first 2–3 years to evaluate the success of revegetation and identify areas of concern such as increased soil erosion, poor seed germination, or plant establishment. Soil erosion is evaluated using a modified soil-erosion rating and classification system used by the Bureau of Land Management (Table 3). Monitoring during these first few years focuses on erosion conditions and plant densities. The success of seed germination and plant establishment is estimated annually the first 2–3 years by determining the density of plants that were seeded and those that were not seeded but have naturally invaded the site.

Long term establishment of plants is monitoring in subsequent years, typically in year five and every five years thereafter, or as may be requested or required by agreement. Plant density, plant cover, and other vegetative parameters are measured during the sampling events and provide a quantitative assessment of the success of revegetation. An undisturbed area, typical in a vegetation type similar to the one of the revegetation site, is also sampled and serves as a reference for the revegetation sites.

Table 3. Modified soil erosion rating and classification form (Toy, 1983).

Erosion Condition Classification

Surface Litter	**Pedestalling**	**Rills <9"**	**Rills >9"**
1 Accumulating in place	1 No visual evidence	1 No visual evidence	1 No visual evidence
2 Slight movement	2 Slight pedestalling at intervals >10'	2 Rills in evidence at intervals >10'	2 Rills in evidence
3 Moderate movement	3 Small rock and plant pedestalling	3 Rills at 10' intervals	3 Rills at 10' intervals
4 Extreme movement	4 Pedestalling plant roots exposed	4 Rills at 5–10' intervals	4 Rills at 5–10' intervals
5 Very little remaining litter	5 Most plants and rocks pedestalled and roots exposed	5 Rills at <5' intervals	5 Rills at <5' intervals
Rating ____________	Rating ____________	Rating ____________	Rating ____________

Total ____________

Numerical Rating	**Erosion Condition Class**
0.0 to 4.0	Stable
4.1 to 8.0	Slight
8.1 to 12.0	Moderate
12.1 to 16.0	Critical
16.1 to 20.0	Severe

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