Waste Isolation Pilot Plant

Compliance Certification Application

Reference 202

DOE (U.S. Department of Energy), 1995
Waste Isolation Pilot Plant Safety Analysis Report. DOE/WIPP-95-2065, Revision 0, November 1995. Carlsbad, NM.

Submitted in accordance with 40 CFR §194.13, Submission of Reference Materials.

DOE/WIPP-95-2065

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WASTE ISOLATION PILOT PLANT SAFETY ANALYSIS REPORT

November 1995

Prepared for

United States Department of Energy

Westinghouse Electric Corporation
Waste Isolation Division

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ACRONYMS

AC	Administrative Control
AIHA	American Industrial Hygiene Association
AIS	Air Intake Shaft
ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standard Institute
ARF	Airborne Release Fraction
ARMS	Area Radiation Monitors
ASME	American Society of Mechanical Engineers
BIR	Baseline Inventory Report
BLM	Bureau of Land Management
BR	Breathing Rate
C&C	Working Agreement for Consultation and Cooperation
CA	Controlled Area
CAO	Carlsbad Area Office (DOE)
CAM	Continuous Air Monitor
CCTV	Closed Circuit Television
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CH	Contact Handled
Ci	Curie
CMR	Central Monitoring Room
CMS	Central Monitoring System
D&D	Decontamination and Decommissioning
DAC	Derived Air Concentration
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBT	Design Basis Tornado
DCF	Dose Conversion Factor
DOE	Department of Energy
DOE-EM	Department of Energy, Office of Environmental Restoration
DOI	Department of Interior
DOP	Dioctylphthalate
DOT	Department of Transportation
DR	Damage Ratio
ECO	Engineering Change Order
EEG	Environmental Evaluation Group
EEGL	Emergency Exposure Guidance Level
EFB	Exhaust Filter Building
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ERPG	Emergency Response Planning Guideline
ESH	Environment, Safety, and Health
ERT	Emergency Response Team
FAS	Fixed Air Sampler
FGE	Fissile Gram Equivalent

FEIS	Final Environmental Impact Statement
FLIRT	First Line Initial Response Team
FMEA	Failure Mode and Effects Analysis
FSEIS	Final Supplement Environmental Impact Statement
FY	Fiscal Year
GM	General Manager
GPDD	General Plant System Design Description
HAZOP	Hazard and Operability Study
HEPA	High Efficiency Particulate Filter
HVAC	Heat, Ventilation, and Air Conditioning
ICRP	International Commission on Radiological Protection
ICV	Inner Containment Vessel
IDLH	Immediately Dangerous to Life and Health
LCO	Limiting Condition for Operation
LCS	Limiting Control Setting
LPF	Leakpath Factor
LPU	Local Processing Unit
LWA	Land Withdrawal Act
MAR	Material at Risk
MDC	Minimum Detectable Concentrations
NIST	National Institute of Science and Technology
MOC	Management and Operating Contractor
MOI	Maximally Exposed Off-site Individual
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Administration
NFPA	National Fire Protection Agency
NMBMMR	New Mexico Bureau of Mines and Mineral Resources
NMDG&F	New Mexico Department of Game and Fish
NMVP	No Migration Variance Petition
NRB	Nuclear Review Board
NRC	Nuclear Regulatory Commission
NVP	Natural Ventilation Pressure
OHP	Operational Health Physics
OP&RR	Overpack and Repair Room
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
OSR	Operational Safety Requirement
PABX	Private Automatic Branch Exchange
PA	Public Address
PEL	Permissible Exposure limit
PE-Ci	Plutonium Equivalent Curie
ppmv	Parts per Million Volume
PSM	Process Safety Management
PTB	Project Technical Baseline
Pu	Plutonium
QA	Quality Assurance
QAPD	Quality Assurance Program Description
QC	Quality Control
RADCON	Radiological Control
RBP	Radiological Baseline Program

RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RF	Respirable Fraction
RFAR	Radio Fire Alarm Reporter
RH	Remote Handled
RBA	Radiological Buffer Area
RMA	Radioactive Material Area
RMS	Radiation Monitoring System
ROD	Record of Decision
RWP	Radiation Work Permit
SAR	Safety Analysis Report
SCR	Silicon Controlled Rectifier
SDD	System Design Descriptions
SEIS	Supplement Environmental Impact Statement
SH	Salt Handling Shaft
SOP	Standard Operating Procedure
SL	Safety Limit
SNL	Sandia National Laboratory
SPDV	Site and Preliminary Design Validation
SPEGL	Short-term Public Exposure Guidance Level
SR	Surveillance Requirement
SRS	Savannah River Site
SSC	System, Structure, and Component
STD	Standard
SWB	Standard Waste Box
TDS	Total Dissolved Solids
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Detector
TLV-C	Threshold Limit Value-Ceiling
TLV-STEL	Threshold Limit Value-Short Term Exposure Limit
TLV-TWA	Threshold Limit Value-Time Weighted Average
TRUPACT	Transuranic Package Transporter
TRU	Transuranic
TSC	Technical Support Contractor
TSR	Technical Safety Requirements
U/G	Underground
UBC	Uniform Building Code
UPS	Uninterruptible Power Supply
USGS	United States Geological Survey
USQ	Unreviewed Safety Questions
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WACC	Working Agreement for Consultation and Cooperation
WHB	Waste Handling Building
WIPP	Waste Isolation Pilot Plant
WWIS	WIPP Waste Information System

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1.1 Facility Background and Mission

The United States Department of Energy (DOE) was authorized by Public Law 96-164[1] to provide a research and development facility for demonstrating the safe permanent disposal of transuranic (TRU) wastes from national defense activities and programs of the United States exempted from regulations by the U.S. Nuclear Regulatory Commission (NRC). The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico near Carlsbad, was constructed to determine the efficacy of an underground repository for disposal of TRU wastes.

In accordance with the 1981 and 1990 Records of Decision (ROD),[2,3] the development of the WIPP was to proceed with a phased approach. Development of the WIPP began with a siting phase, during which several sites were evaluated and the present site selected based on extensive geotechnical research, supplemented by testing.

The site and preliminary design validation phase (SPDV) followed the siting phase, during which two shafts were constructed, an underground testing area was excavated, and various geologic, hydrologic, and other geotechnical features were investigated. The construction phase followed the SPDV phase during which surface structures for receiving waste were built and underground excavations were completed for waste emplacement.

At the conclusion of the construction phase, the DOE proposed a test phase, to be followed by the disposal phase for waste emplacement operations. The test phase was to involve the use of limited quantities of contact-handled (CH) TRU waste to conduct tests in the WIPP underground to provide data for reducing the uncertainties in the performance assessment required for compliance with the long-term waste isolation regulations of the U.S. Environmental Protection Agency (EPA), Subpart B of 40 CFR Part 191.[4] To enable the receipt of CH-TRU waste at the WIPP site for the tests the Congress enacted the WIPP Land Withdrawal Act[5] of 1992 (Public Law 102-579). The law also provides for authorizations of detailed regulatory requirements for the WIPP.

As a result of major program redirection in late 1993, the WIPP test phase was modified by substituting the previously planned WIPP underground radioactive tests with laboratory tests. In conjunction, WIPP operations will proceed directly with the disposal phase CH TRU waste emplacement operations starting in mid-1998, assuming successful demonstration of compliance with applicable federal and state laws and regulations, and successful completion of the WIPP CH Operational Readiness Review (ORR). The CH ORR will closely examine the safety bases of the facility and the status of attendant conformance to ensure that the facility is operationally ready and that CH waste emplacement operations will be conducted safely.

The disposal phase is scheduled to last 35 years, will consist of receiving, handling, and emplacing TRU waste in the repository for disposal, and will end when the design capacity of the repository has been reached.

The decommissioning phase will follow the disposal phase, during which the repository will be prepared for permanent closure. Surface facilities will be decontaminated and decommissioned, underground excavations will be prepared for closure, and shaft seals will be emplaced. This phase is projected to last for 10 years. The post-decommissioning phase will consist of active and passive institutional controls. Active institutional controls will include activities such as control of access to the site, implemented consistent with applicable regulations and permit conditions and will continue for at least 100 years. These controls will be designed to ensure that the potential for future, inadvertent human intrusion is reduced to a level that renders such intrusion unlikely.

This Safety Analysis Report (SAR) documents the safety analyses that develop and evaluate the adequacy of the WIPP CH TRU safety bases necessary to ensure the safety of workers, the public, and the environment from the hazards posed by WIPP waste handling and emplacement operations during the disposal phase and hazards associated with the decommissioning and decontamination phase.

The analyses of the hazards associated with the long-term (10,000 year) disposal of TRU and TRU mixed waste, and demonstration of compliance with the requirements of 40 CFR 191, Subpart B[4] and 40 CFR 268.6[6] will be addressed in detail in the WIPP Final Certification Application scheduled for submittal in October 1996 (40 CFR 191) and the No-Migration Variance Petition (40 CFR 268.6) scheduled for submittal in June 1996. Section 5.4, Long-Term Waste Isolation Assessment summarizes the current status of the assessment. Section 5.4 will be updated upon completion of the long-term assessment demonstration (currently scheduled for the FY-97 Annual Update).

References for Section 1.1

1. Public Law 96-164, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, December 29, 1979.

2. U.S. Department of Energy, 46 FR 9162, Record of Decision, Waste Isolation Pilot Plant, January 28, 1981.

3. U.S. Department of Energy, 55 FR 256892, Record of Decision, Waste Isolation Pilot Plant, June 22, 1990.

4. U.S. Environmental Protection Agency, 40 CFR 191, Environmental Radiation Protection for Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Wastes, Subpart B, Environmental Standards for Disposal, December 1993.

5. Public Law 102-579, Waste Isolation Pilot Plant Land Withdrawal Act, October, 1992.

6. U.S. Environmental Protection Agency, 40 CFR 268.6, Petitions to Allow Land Disposal of a Waste Prohibited Under Subpart C of Part 268.

1.2 Facility Overview

1.2.1 Facility Design

The WIPP is located in Eddy County in southeastern New Mexico, 26 miles east of Carlsbad as shown in Figure 1.2-1. The amount of land that has been set aside for the WIPP includes an area of 10,240 acres. The WIPP is located in an area of low population density with less than 30 permanent residents living within a ten-mile radius. The area surrounding the facility is used primarily for grazing and development of potash, oil, and gas resources. Development of these resources results in a transient population (non-permanent) consisting principally of workers at three potash mines that are located within ten miles of the WIPP. The largest population center nearest the WIPP is the city of Carlsbad, 26 miles to the west, with approximately 25,000 inhabitants. Two smaller communities, Loving (population approximately 1300) and Malaga (population approximately 200), are located about 20 miles southwest of the facility. As the result of land use restrictions imposed by the U.S. Bureau of Land Management, and administrative action by the DOE to purchase lease holdings, no resource development is allowed within the 10,240 acres that have been set aside for the WIPP (with the exception of existing leases).

The WIPP is designed to receive and handle a maximum of 500,000 ft^3/yr CH TRU waste and 10,000 ft^3/yr remote handled (RH) TRU waste. The CH TRU waste will be contained in 55-gallon drums and standard waste boxes. The WIPP facility is designed to have a disposal capacity for TRU waste of 6.2×10^6 ft^3. Current design is that RH waste will be packaged in steel canisters and transported to the WIPP facility in shielded road casks. The WIPP facility has sufficient capacity to handle the 250,000 ft^3 of RH TRU that was established in the ROD[1] as a total volume. In addition, the Working Agreement for Consultation and Cooperation (WACC)[2] limits the total RH TRU activity to 5.1×10^6 curies.

CH TRU wastes will be disposed of in the 100-acre disposal area on a horizon located 2150 feet beneath the surface in a deep, bedded salt formation. Waste will be transferred from the surface to the disposal horizon through a waste shaft using a hoisting arrangement. The disposal phase is currently scheduled to last for 35 years.

The WIPP is divided into three basic groups: surface structures, shafts, and subsurface structures as shown in Figure 1.2-2. The WIPP surface structures (see Figure 1.2-3) accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground. The surface structures are located in an area within a perimeter security fence. The primary surface operations at the WIPP are conducted in the Waste Handling Building (WHB), which is divided into the CH TRU waste handling area, the RH TRU waste handling area, and support areas. The CH TRU waste handling area includes the entrance air locks, CH Bay, a shielded holding area, an overpack and repair room and CH TRU support facilities.

The current design of the RH TRU waste handling area includes an RH Bay, cask receiving and preparation areas, hot cell complex, and a shielded cell for shielded road cask unloading, waste canister inspection, overpacking canisters, as required, and facility cask loading prior to transfer underground.

The vertical shafts extending from the surface to the underground horizon (see Figure 1.2-2) are the waste shaft, the salt handling shaft, the exhaust shaft, and the air intake shaft. These shafts are lined from the shaft collar to the top of the salt formation (about 850 ft below the surface), and are unlined through the salt formation. The shaft lining is designed to withstand the full piezometric water pressure associated with any water-bearing formation encountered. The waste shaft is located between the CH TRU and RH TRU areas in the WHB. It is nominally 19 feet in diameter and is serviced by a hoist utilizing a hoist cage that is primarily used for transportation of CH TRU and RH TRU wastes from the surface to underground disposal areas.

The underground areas (see Figure 1.2-4) consist of the waste disposal area, the support area, and the experimental area. The disposal area has four main entries (two entries for fresh air and two entries for return air) and a number of disposal rooms. The layout of the shafts and entries allows mining and disposal operations to proceed simultaneously. The first disposal panel is used to dispose waste while the next panel is being mined. Successive stages follow in a similar manner.

A typical disposal panel consists of up to seven disposal rooms. Each room is 33 feet wide, 13 feet high, and 300 feet long. The disposal rooms are separated by pillars of salt 100 feet wide and 300 feet long. Panel entries at the end of each of these disposal rooms are also 33 feet wide and 13 feet high and will be used for waste storage, except for the first 200 feet from the main entries which are 22 feet wide by 14 feet high. This first 200 feet will be used for installation of panel closure systems.

1.2.2 Facility Operations

The principal operations of the WIPP involve the receipt of TRU and TRU mixed waste and emplacement in the underground salt repository for disposal. Transporters carrying TRU waste arrive at the WIPP and are unloaded outside the WHB. The shipments are surveyed for external contamination prior to their movement into the WHB for unloading.

CH TRU waste will be shipped to the WIPP in Nuclear Regulatory Commission (NRC)-certified shipping containers. After the CH TRU waste shipping container is inspected for contamination, the loaded shipping container is moved into the WHB and placed on a handling dock. The container is opened, surveyed for radiation and contamination levels, and the waste containers are removed and placed on a facility pallet. This pallet is then transferred to the conveyance loading car, which is moved into the hoist cage in the Waste Shaft for transfer to the disposal horizon.

At the disposal horizon, the pallet is removed from the hoist cage, placed on the underground transporter, and moved to the CH TRU waste disposal room. In the disposal room, the containers are removed from the pallet and placed in the waste stack. The empty pallet is returned to the surface for reuse.

The waste received for placement in the WIPP facility must conform with the WIPP Waste Acceptance Criteria (WAC).[3] The operational philosophy at the WIPP facility is to start radiologically clean and stay radiologically clean. Consequently, any containers of waste that are found to be externally contaminated or damaged will be decontaminated or placed in a larger container (overpacked), as required. Also, any local area of contamination will be isolated and/or decontaminated prior to continuation of the waste handling process.

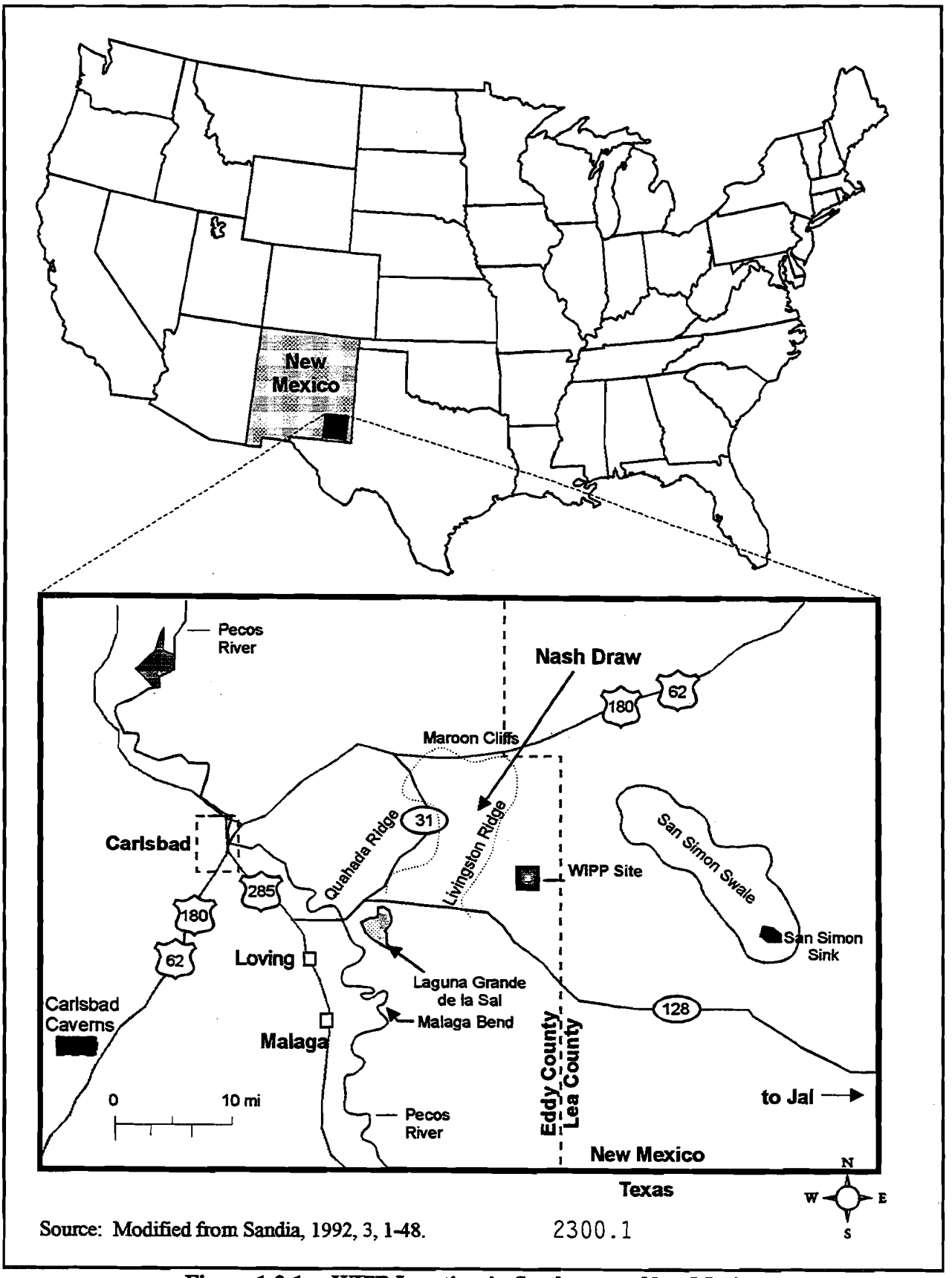
RH TRU waste handling and emplacement operations will be updated in future revisions of this SAR.

References for Section 1.2

1. U.S. Department of Energy, 46 FR 9162, Record of Decision, Waste Isolation Pilot Plant, January 28, 1981

2. Working Agreement for Consultation and Cooperation, signed by the U.S. DOE and the State of New Mexico, July 1981 and subsequent revisions.

3. WIPP-DOE-069, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Revision 4, December 1991.



Source: Modified from Sandia, 1992, 3, 1-48. 2300.1

Figure 1.2-1, WIPP Location in Southeastern New Mexico

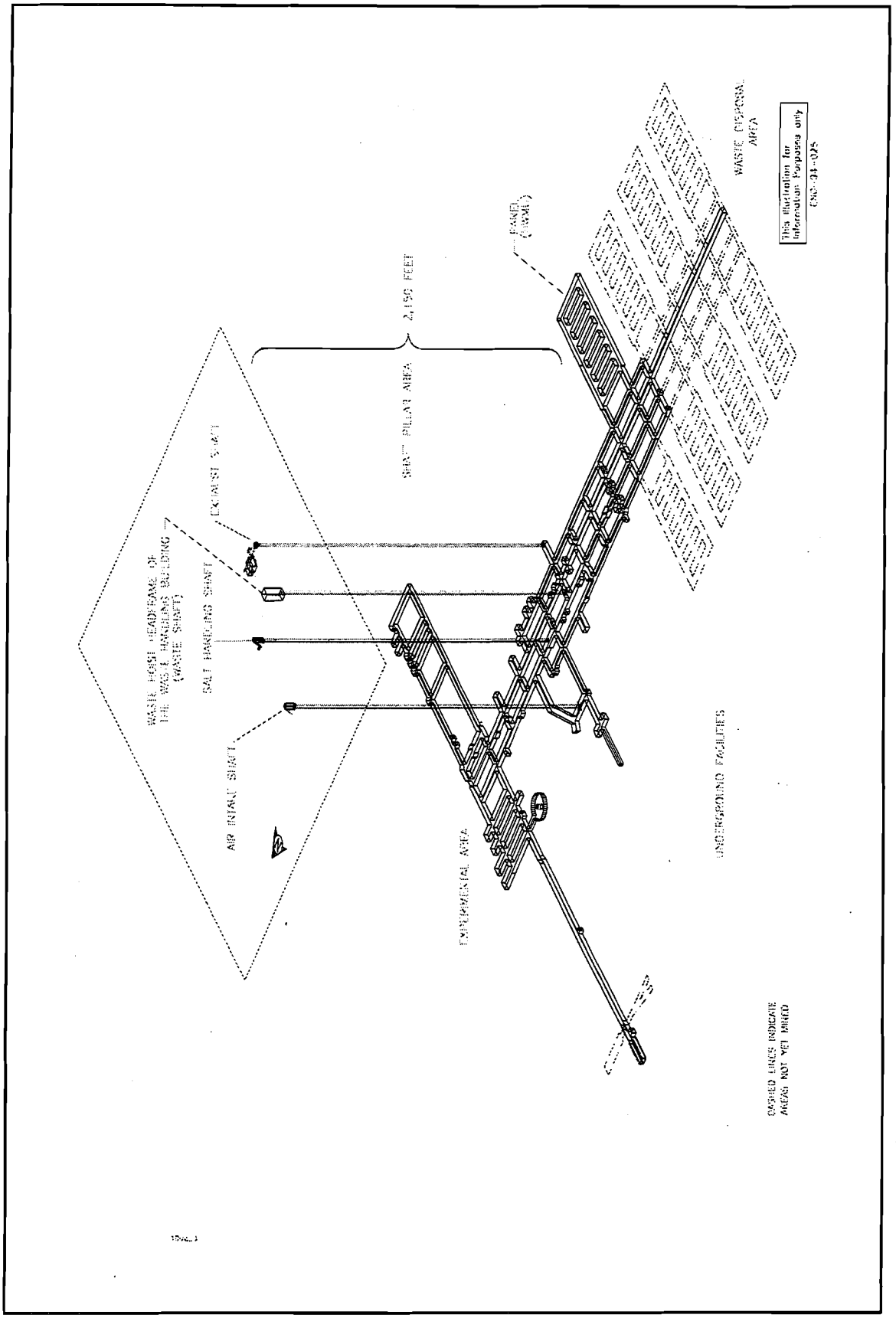
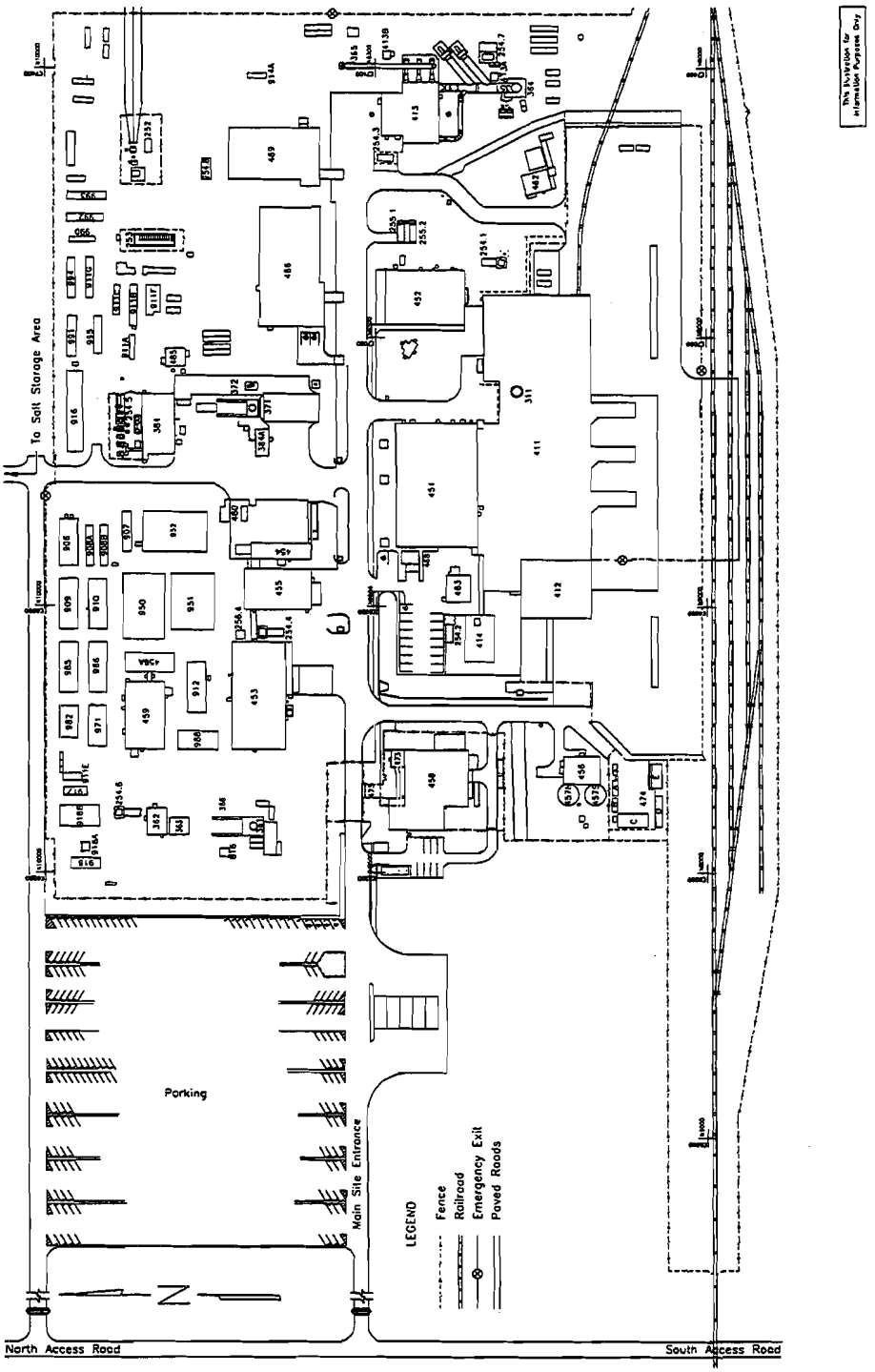


Figure 1.2-2, Spatial View of the WIPP Facility



1003.2

Figure 1.2-3a, WIPP Surface Structures

1004.1

BLDG./ FAC. #	DESCRIPTION
252	SPS UTILITY SUBSTATION
253	13.8 KV SWITCHGEAR 25P-SWG15/1
254.1	AREA SUBSTATION NO.1 25P-SW15.1
254.2	AREA SUBSTATION NO.2 25P-SW15.2
254.3	AREA SUBSTATION NO.3 25P-SW15.3
254.4	AREA SUBSTATION NO.4 25P-SW15.4
254.5	AREA SUBSTATION NO.5 25P-SW15.5
254.6	AREA SUBSTATION NO.6 25P-SW15.6
254.7	AREA SUBSTATION NO.7 25P-SW15.7
254.8	AREA SUBSTATION NO.8 25P-SW15.8
255.1	EMERGENCY GENERATOR #1 25-PE 503
255.2	EMERGENCY GENERATOR #2 25-PE 504
311	WASTE SHAFT
351	EXHAUST SHAFT
361	AIR INTAKE SHAFT
362	AIR INTAKE SHAFT/HOIST HOUSE
363	AIR INTAKE SHAFT/WINCH HOUSE
364	EFFLUENT MONITORING INSTRUMENT SHED A
365	EFFLUENT MONITORING INSTRUMENT SHED B
366	AIR INTAKE SHAFT HEADFRAME
371	SALT HANDLING SHAFT
372	SALT HANDLING SHAFT HEADFRAME
384	SALT HANDLING SHAFT HOISTHOUSE
384A	SALT HOIST OPERATIONS
411	WASTE HANDLING BUILDING
412	TRUPACT MAINTENANCE BUILDING
413	EXHAUST FILTER BUILDING
413A	EFFLUENT MONITORING ROOM A
413B	EFFLUENT MONITORING ROOM B
414	WATER CHILLER FACILITY & BLDG
451	SUPPORT BUILDING
452	SAFETY & EMERGENCY SERVICES FACILITY
453	WAREHOUSE/SHOPS BUILDING
454	VEHICLE SERVICE BUILDING
455	AUXILLIARY WAREHOUSE BUILDING

BLDG./ FAC. #	DESCRIPTION
456	WATER PUMPHOUSE
457N	WATER TANK 25-D-001A
457S	WATER TANK 25-D-001B
458	GUARD AND SECURITY BUILDING
459	CORE STORAGE BUILDING
459A	SANDIA ANNEX
463	COMPRESSOR BUILDING
465	AUXILIARY AIR INTAKE
468	TELEPHONE HUT
473	ARMORY BUILDING
474	HAZARDOUS WASTE STORAGE FACILITY
474A	HAZARDOUS WASTE STORAGE BUILDING
474B	HAZARDOUS WASTE STORAGE BUILDING
474C	OIL & GREASE STORAGE BUILDING
474D	GAS BOTTLE STORAGE BUILDING
474E	HAZARD MATERIAL STORAGE BUILDING
474F	WASTE OIL RETAINER
475	GATEHOUSE
480	VEHICLE FUEL STATION
482	EXHAUST SHAFT HOIST EQUIP. WAREHOUSE
485	SULLAIR COMPRESSOR BUILDING
486	ENGINEERING BUILDING
489	TRAINING BUILDING
816	SANDIA TEST WELL (NOT IDENTIFIED)
906	UNDERGROUND OPERATIONS TRAILER
907	TRANS. & HAZ. MATERIAL HANDLING TRAILER
908A	ENVIRONMENTAL MONITORING LAB TRAILER
908B	UNIVERSITY CONSORTIUM TRAILER
909	PROJECT CONTROL TRAILER
910	ENVIRONMENTAL MONITORING TRAILER
911A	SITE LOCKSMITH TRAILER
911B	SANDIA M101 TRAILER
911C	SANDIA OFFICES TRAILER
911E	SANDIA TRAILER
911F	SANDIA B49 AND B49 ANNEX

BLDG./ FAC. #	DESCRIPTION
911G	SANDIA LABS TRAILER
912	TRAINING TRAILER
914A	TRAINING TRAILER
915	NEW MEXICO ENVIR. DEPT. TRAILER
916	SANDIA OFFICES TRAILER
917	AIS MONITORING
918	VOC TRAILER
918A	VOC AIR MONITORING STATION
918B	VOC LAB TRAILER
950	WORK CONTROL TRAILER
951	PROCUREMENT / PURCHASING
952	TRAILER (7-PLEX)
971	HUMAN RESOURCES TRAILER
982	MAINTENANCE TRAILER
985	QA TRAILER
986	PUBLICATIONS & PROCEDURES TRAILER
988	TRAINING TRAILER
991	SANDIA OFFICES TRAILER
992	SANDIA CALIBRATION LAB TRAILER
993	SANDIA OFFICES TRAILER
994	SANDIA LAB TRAILER
995	SANDIA QA RECORDS TRAILER
SWR NO.1	SWITCHRACK NO. 1
SWR NO.2	SWITCHRACK NO. 2
SWR NO.3	SWITCHRACK NO. 3
SWR NO.4	SWITCHRACK NO. 4
SWR NO.6	SWITCHRACK NO. 6
SWR NO.7,7A,7B	SWITCHRACK NO. 7, 7A, 7B
SWR NO.7C	SWITCHRACK NO. 7C
SWR NO.8	SWITCHRACK NO. 8
SWR NO.9	SWITCHRACK NO. 9
SWR NO.10	SWITCHRACK NO. 10
SWR NO.11	SWITCHRACK NO. 11
--	SANDIA GENERATOR NO.1
--	SANDIA GENERATOR NO.2

This Illustration for Information Purposes Only

Figure 1.2-3b, Legend for Figure 1.2-3

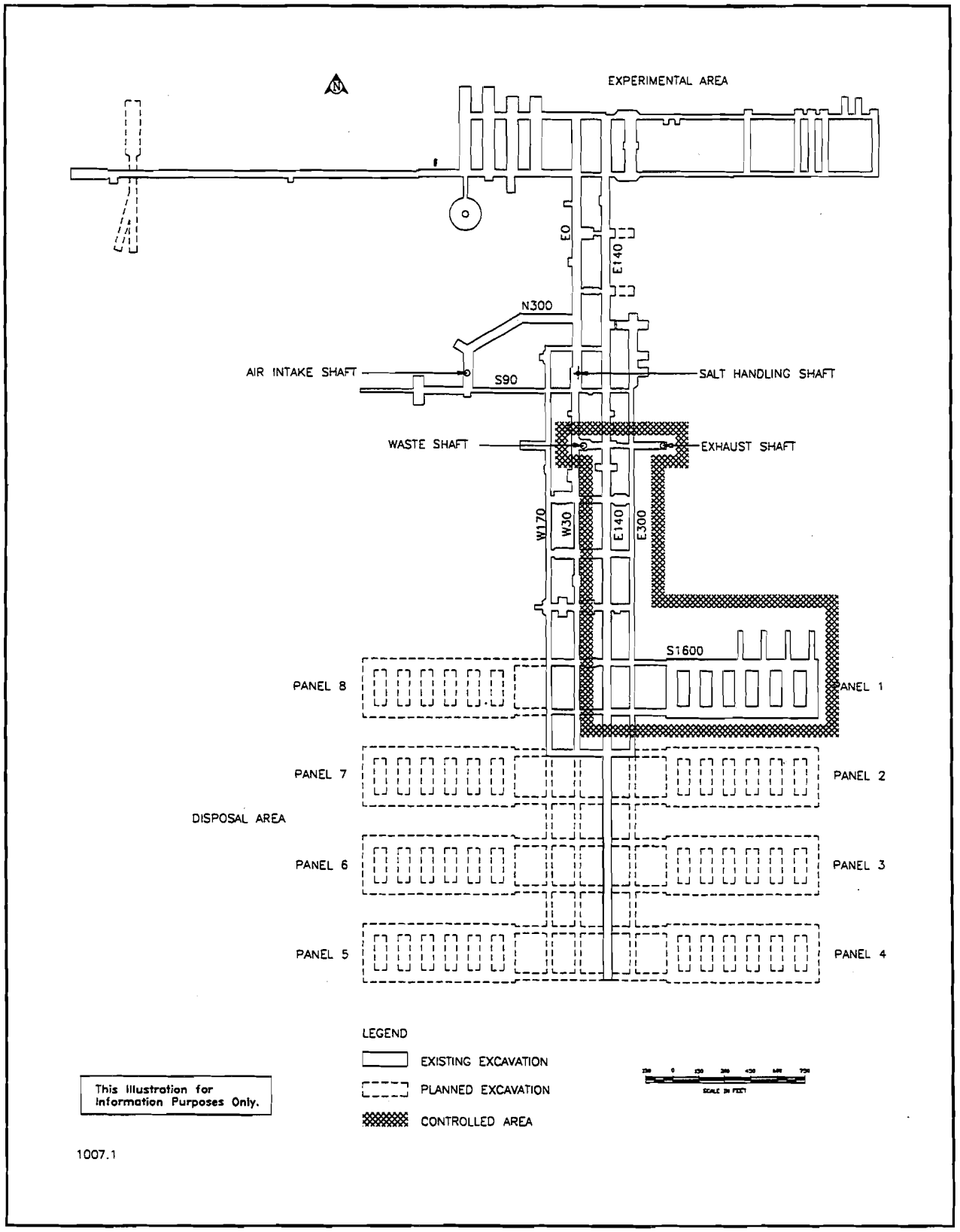


Figure 1.2-4, Underground Subsurface Areas

1.3 Safety Analysis Report Strategy and Approach

The WIPP SAR, originally issued in May 1990 following approval by the Department of Energy, Office of Environmental Restoration and Waste Management (DOE-EM), was prepared to satisfy: (1) the commitments in the Working Agreement for Consultation and Cooperation[1] (C&C) (Article III, Section C and Article IV, Section K, known as the Working Agreement) between the State of New Mexico and the U.S. Department of Energy; and (2) the requirements of DOE Order 5481.1B, Safety Analysis and Review System[2] and DOE Albuquerque Operations Office AL Order DOE-AL 5481.1B.[3]

Since the original approval by DOE-EM, the WIPP SAR has been reviewed and updated: (1) annually in the Fiscal Year (FY)-92, FY-93, and FY-94 updates; and (2) to ensure compliance with the requirements of DOE Orders 5480.21, Unreviewed Safety Questions,[4] 5480.22, Technical Safety Requirements,[5] 5480.23, Nuclear Safety Analysis Reports,[6] and 5480.24, Nuclear Criticality Safety.[7] Due to the cancellation of DOE Order 5481.1B, the SAR is being maintained per the requirements of DOE Order 5480.23. This SAR represents a statement and commitment by the DOE that the WIPP can be operated safely and at minimum risk. It also represents the "Final" SAR indicating that the WIPP facility is ready to begin operating versus "Preliminary," which generally refers to a facility in the design or construction stage.

In accordance with the requirements of DOE Order 5480.23,[6] the SAR documents the safety analyses that develop and evaluate the adequacy of the safety bases. The safety bases are defined by DOE Order 5480.23[6] as:

"the combination of information relating to the control of hazards at a nuclear facility (including design, engineering analyses, and administrative controls) upon which DOE depends for its conclusion that activities at the facility can be conducted safely."

This SAR establishes and evaluates the adequacy of the WIPP CH TRU safety bases in response to plant normal and abnormal operations, and credible accident conditions. The WIPP safety bases analyzed include; (1) the adequacy of the design basis of WIPP CH systems, structures, and components (SSCs), and the application of appropriate engineering codes, standards, and quality assurance requirements, (2) the selection of principal design and safety criteria, (3) the assignment of Technical Safety Requirements (TSRs), and (4) the management, conduct of operations, and institutional dimensions of safety assurance.

Analyses in this SAR update address CH TRU waste emplacement operations only. Existing RH TRU design and operations information were retained for design configuration management purposes only. RH TRU hazards and accident analyses were deleted from this SAR update, and will be included in future updates (currently scheduled for the 1999 Annual Update).

The following provides a summary of the specific issues addressed in this FY-95 Annual Update as they relate to the CH TRU safety bases:

Safety Analysis Report Organization

The WIPP SAR was originally structured to satisfy the specific commitments made in the C&C Agreement.[1] The C&C format is different from the 20 chapter SAR concept of DOE Order 5480.23[6] and DOE-STD-3009-94.[8] By applying the graded approach concepts as discussed in DOE-STD-3009-94, 10 of the 20 DOE Order 5480.23 chapters were consolidated into other identified chapters. This resulted in a 10 chapter WIPP SAR format that is similar to the C&C Agreement format. This graded approach consolidation and reformatting is consistent with the discussion in DOE Order 5480.23 Attachment 1, Sections 4.f.(1)(c), and 4.f.(3)(d). SAR chapter titles are retitled to follow selected DOE-STD-3009-94 or DOE Order 5480.23 titles and to be consistent with their individual contents. For this update effort, the WIPP SAR format was modified as follows:

Chapter 1 - Executive Summary
Chapter 2 - Site Characteristics
Chapter 3 - Principal Design and Safety Criteria
Chapter 4 - Facility Design and Operation
Chapter 5 - Hazards and Accident Analysis
Chapter 6 - Derivation of Technical Safety Requirements
Chapter 7 - Radiological and Hazardous Material Protection
Chapter 8 - Institutional Programs
Chapter 9 - Quality Assurance
Chapter 10 - Decontamination and Decommissioning

Table 1.3-1 provides a correlation between the FY-94 SAR and the FY-95 Annual Update. Table 1.3-2 provides a correlation between the C&C Agreement SAR Format and Content requirements and the FY-95 Annual Update, and Table 1.3-3 provides a correlation between the SAR topics required by DOE Order 5480.23 and the FY-95 Annual Update.

Facility Hazard Classification

The hazard classification categorization was determined in accordance with DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.[9] A deterministic approach was taken without considering facility segmentation, form location or dispersibility of the material at risk. The material at risk for the determination of the categorization was defined as the radiological contents of a single CH waste container as derived in Chapter 5. The WIPP Facility is classified as a Hazard Category 2 facility based on this single waste container inventory in comparison to the threshold quantities provided in Table A-1 of DOE-STD-1027-92.[9]

Design and Operation

The System Design Descriptions[10] (SDDs) for the WIPP were reviewed and incorporated into Chapter 3, Principal Design and Safety Criteria and Chapter 4, Facility Design and Operation. This provides the most currently available final engineering design information on waste emplacement operations throughout the disposal phase up to the point of permanent closure. Also, the criteria which define the TRU waste to be accepted for disposal at the WIPP facility were summarized in Chapter 3 based on the WAC for the Waste Isolation Pilot Plant.[11]

Safety protection criteria as they relate to confinement, fire protection, and radiological protection were updated to ensure safe operation of the facility and applicable requirements are met.

Chapter 8, Long Term Waste Isolation Assessment, has been replaced by a summary for the FY 95 Annual Update in Chapter 5. The detailed assessment of Long Term Waste Isolation will be covered in the WIPP Final Certification Application scheduled for submittal in October 1996. This section will be updated in the FY-97 Annual SAR Update with the WIPP Final Certification Application assessment.

The systematic evaluation of the human factors associated with the design and operation of the WIPP to meet the requirements of DOE Order 5480.23[6] was incorporated. Since design class functions are passive, the evaluation determined that well established policies and procedures are in place ensuring normal and emergency procedures are implemented, adequate directions have been provided to shift personnel concerning actions to be taken in a potential accident environment, and adequate procedures are available for follow-up response.

The WIPP site description in terms of geology, hydrology, climatology, air quality, ecology, and cultural and natural resources was updated based on information provided in the WIPP Project Technical Baseline for Regulatory Compliance.[12]

Hazard and Accident Analysis

The hazard and accident analyses were updated utilizing currently available DOE Orders, standards and guidance as documented in DOE-STD-3009-94[8] and DOE-STD-1027-92,[9] for determination of safety of the public, worker and the environment. Failure Mode and Effects Analyses were replaced with a qualitative Hazard and Operability Study (HAZOP).[13] The HAZOP[13] performed for the CH TRU Waste Handling System identified potential hazards that would require further evaluation of consequences to the public. Consequences to workers were qualitatively evaluated through the hazard analysis process which ensures worker safety at the WIPP is maintained through administrative safeguards/programs and systems that act to prevent and mitigate accidents.

Bounding estimates of the radiological Material at Risk (MAR) in waste containers were established based on the plutonium (Pu) "processes" and associated radionuclide distributions. Waste received at WIPP will be contaminated from Pu-238 and Pu-239 operations which include weapons grade, fuel grade, reactor grade, and heat source wastes. Past safety analyses have calculated inventories based; (1) strictly on the Pu-239 operations waste, or (2) on average or representative waste container content for use in accident analysis consequence calculations.

The average waste container inventory clearly masks the importance in terms of the radiological inhalation hazard of Pu-238 in the Pu-238 operations waste. Therefore, a radionuclide inventory is required that is based on the individual plutonium processes and their associated isotopic mass distributions that will; (1) encompass and allow for disposal at WIPP the stored waste contaminated from Pu-239 operations when considering the WIPP WAC[11] nuclear criticality limits, and (2) ensure that the estimated exposure to the public from postulated accidents from high curie content Pu-238 operations waste is within the established accident acceptance criteria.

The drum container radionuclide inventory of 80 PE-Ci and SWB inventory of 130 PE-Ci for use in accident consequence analyses is established to encompass the waste contaminated by Pu-239 operations, and introduce conservatism into the accident analysis drum MAR ensuring that accident consequences involving drums or SWBs with Pu-238 operations waste remain well within the established accident acceptance criteria.

A defense in depth section has been added to the SAR which identifies layers of defense against the abnormal and accidental release of radiological and nonradiological hazardous materials. The WIPP approach provides three layers of defense which include conservative design of the facility's SSCs, protection against anticipated operational occurrences and unlikely events and passive features that may be on line continuously or automatically/manually activated.

This update provides an analysis of the potential hazards that may exist at the WIPP at the level of analytical effort based on the magnitude of the hazards and the complexity of the CH TRU waste operations conducted at the WIPP. The path of using conservative assumptions and less detailed physical modeling to quantify accident consequences and likelihoods was performed in lieu of detailed probabilistic/quantitative risk assessments.

Analyses in this SAR update address CH TRU waste emplacement operations only. Existing RH TRU design and operations information were updated and retained for design configuration management purposes. RH TRU hazards and accident analyses will be included in future updates to the SAR, currently scheduled for the FY-1998 Annual Update.

Verification of Design

The hazard and accident analysis results indicate Design Class I SSCs are not required for the WIPP to prevent or mitigate accidental radiological or nonradiological consequences to acceptance levels. Secondary confinement is not required for the WIPP based on the criteria provided in DOE Order 6430.1A[15], Section 1300-1.4.2, Accidental Releases.

Although Design Class II and IIIA SSCs are not required to prevent or mitigate the consequences of an accident from exceeding the acceptance criteria, they contribute additional layers of defense in depth.

Technical Safety Requirements

Operational Safety Requirements (OSRs) were replaced based on the requirements provided in DOE 5480.22,[5] Technical Safety Requirements (TSRs). Based on the requirements and the results of the hazard and accident analysis, no Safety Limits, Operational Limits, or Surveillance Requirements are defined for the WIPP. Supporting the first layer of defense in depth (the prevention of accidents), WIPP TSR Administrative Controls (ACs) are established as follows:

- To maintain the design, quality, testability, inspectability, operability, maintainability, and accessibility of the facility, TSR ACs are required relating to: (1) configuration and document control, (2) maintenance, and (3) quality assurance.

- To ensure that the facility operations are conducted by trained/certified personnel, TSR ACs are required relating to: (1) facility operations chain of command and responsibilities, (2) facility staffing requirements, (3) procedures, (4) staff qualifications, (5) conduct of operations, and (6) training.

- To ensure the administrative accident prevention measures are maintained, TSR ACs are required relating to: (1) waste characteristics (Waste Acceptance Criteria), (2) waste container integrity, and (3) criticality safety.

Supporting the second and third layers of defense in depth, WIPP TSR ACs are identified which establish programs for radiation protection (including radiation monitoring equipment and airborne radioactivity monitoring), and emergency management. Basic elements and requirements defined for TSR AC programs are enforced by the associated implementing WIPP procedures.

Protection of Workers From Accidents

The HAZOP[13] for the CH TRU Waste Handling System identified a number of waste handling process hazards that could potentially lead to events resulting in work injury or fatality, or exposure to radiological and nonradiological hazardous materials.

Consistent with the defense-in-depth philosophy, and the philosophy of Process Safety Management (PSM), as published in 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals,"[19] reduction of the risk to workers from accidents is accomplished at the WIPP by identifying controls to **prevent the event from happening**. Total risk is therefore lowered by reducing the likelihood of the event, as opposed to focusing on post accident consequence mitigation through the performance of quantitative consequence calculations for workers.

The HAZOP Team identified a significant number of existing preventative safeguards that lower the likelihood of occurrence of each deviation, substantially reducing the risk of injury or fatality to workers. The HAZOP Team concluded, consistent with the first layer of defense in depth, substantial safeguards currently exist at the WIPP to prevent or reduce the likelihood of such deviations from occurring. Identified preventative safeguards generally include the following:

- Facility and equipment design, application of appropriate design classification and applicable design codes and standards,
- Programs relating to configuration and document control, quality assurance, and preventative maintenance and inspection,
- Administrative controls including the WIPP WAC, waste handling procedures and training, and the WIPP Emergency Plan and associated procedures.

Due to the importance of these preventative features in WIPP defense in depth and worker protection from accidents, TSR ACs are assigned in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR).

Waste Acceptance Criteria

The WIPP WAC[11] is used in SAR Chapter 3 to provide the initial set of criteria for use in the hazards and accident analyses. The waste accepted for placement in the WIPP facility must conform with the WIPP WAC unless an exception to the WAC has been approved as a result of examination in relation to the SAR. However, based on the updated analyses presented in Chapter 5, specific criteria used in the development of the safety analysis relating to: (1) Pu-239 Equivalent Activity, and (2) Surface Dose Rate require revision in the WAC. A TSR AC for Waste Characteristics require that the safety analysis criteria be incorporated into the WAC.

Program and Procedures

It is the firm commitment of the WIPP management that occupational radiological exposures are kept As Low As Reasonably Achievable (ALARA). This policy, as reflected in administrative programs and procedures established in accordance with 10 CFR 835[17] and the WIPP Radiological Control Manual,[18] ensures that the safety basis of the WIPP facility will maintain individual occupational radiation exposures to ALARA. Also, waste containers accepted for disposal at the WIPP are expected to meet external contamination limits established by this policy, accordingly containers are considered contamination free. Therefore, normal operations do not involve or entail any planned or expected releases of airborne radioactive materials to the workplace or the environment.

The institutional programs provide an inclusive strategy to support the safe operation of the facility through implementation of programs and procedures. These programs and procedures fulfill the objectives of radiological protection, project management system, safety management policies and programs, procedures and training, initial testing, in service surveillance, maintenance, operational safety, quality assurance, emergency preparedness, and decontamination and decommissioning.

1.3.1 Safety Analysis Overview

Safety analysis was performed for the WIPP to ensure that: 1) potential hazards are systematically identified, 2) unique and representative hazards that may develop into accidents are evaluated, 3) applicable reasonable measures to eliminate, control, or mitigate the accidents are taken, and 4) safety class (Design Class I) SSCs and accident specific TSRs, based on comparison of accident consequences to acceptance criteria, are identified.

The predicted waste (radioactive/chemical content) to be received in 55-gallon drums and SWBs at the WIPP was conservatively estimated based on data[14] from the generating sites, process knowledge, and limiting criteria provided in the WAC,[11] unless an exception to the WAC was approved as a result of examination in relation to this SAR. These estimates provided bounding container inventories used in the determination of potential consequences from postulated accidents.

Hazards associated with the facility processes were evaluated through a systematic hazard analysis process. The analysis encompassed the waste receipt, handling and disposal of CH TRU waste in the WIPP. The hazards analysis involved a multi-step process which included: 1) identification of the potential hazards associated with the CH TRU waste handling process, 2) characterization of the waste expected at the WIPP, and 3) a hazard evaluation in the form of a HAZOP[13] for the CH TRU waste handling process. This multi-step process provided a comprehensive examination of the potential hazards which may require quantitative evaluation in the accident analysis.

The major hazard associated with the CH TRU waste handling process is associated with the radiological and nonradiological hazardous materials within the waste containers. Hazards associated with mining operations are considered standard industrial hazards governed by Occupational Safety and Health Administration (OSHA) and Mine Safety and Health Administration (MSHA) regulations and are considered only when they may be an initiating event leading to the accidental release of radiological or nonradiological hazardous materials. Waste handling operations at the WIPP do not involve high temperature and pressure systems, rotating machinery, electromagnetic fields or the use of toxic material in large quantities outside of the waste containers. Therefore, for the purposes of establishing an inventory of radiological and nonradiological material, only that material contained in the waste drums was considered.

The hazard analysis process identified potential accident scenarios in the categories of: 1) operational accidents (caused by initiators internal to the facility), 2) natural phenomena events (e.g., earthquakes, tornadoes), and 3) external events (caused by man made initiators external to the facility). These potential accident scenarios were then qualitatively ranked in terms of consequence to the public and relative probability to determine unique and representative accidents for further quantitative analysis. The quantitative analysis evaluated the radiological and toxicological consequences to a hypothetical maximally exposed off-site individual (MOI). Although analyses are traditionally conducted for an MOI at a facility site boundary, in accordance with DOE Order 6430.1A, Section 1300-3.2,[15] the MOI chosen for this analysis is located at the "closest point of public access," or the DOE "Exclusive Use Area." Calculations are also performed at the site boundary for reference purposes. Operational, Natural Phenomena and External initiating events determined by the hazard analysis and quantitatively evaluated are listed below:

1. Operational Events

   - CH1 Spontaneous Ignition (Drum) in the WHB
   - CH2 Crane Failure in the WHB
   - CH3 Puncture and Drop of Waste Containers by Forklift in the WHB
   - CH4 Drop of Waste Containers by Forklift in the WHB
   - CH5 Waste Hoist Failure
   - CH7 Spontaneous Ignition (Drum) in the Underground
   - CH9 Drop of Waste Containers by Forklift in the Underground

2. Natural Events

   - CH6 Seismic Event
   - CH10 Tornado Event
   - CH11 Underground Roof Fall

3. External Events

   - CH8 Aircraft Crash

A summary of the radiological and toxicological consequences of these accidents and comparison to acceptance criteria is presented in Tables 1.3-4 and 1.3-5. Acceptance criteria based on ANSI/ANS-51.1[19] was adopted by the WIPP to compare accidental releases from postulated events to dose limits based on estimated likelihood of occurrence. Tables 1.3-4 and 1.3-5 also provide reference to those sections of the accident analysis where detailed discussions of the accident are located.

1.3.2 Safety Analysis Conclusions

The WIPP is classified as a Hazard Category 2 facility based on bounding estimates of a single waste container inventory of radiological material. The safety analysis utilized this category as a preliminary indication of the level of detail that should be contained in the SAR. In addition to the category, the level of detail was also determined by the level of complexity and potential hazards which may exist during operation of the facility.

This SAR establishes the adequacy of the WIPP CH TRU safety bases of the plant response to conditions ranging from normal operations to credible accident conditions considered to be "extremely unlikely." Waste containers accepted for disposal at the WIPP are expected to meet the WIPP Radiological Control Manual[18] external contamination limits. Waste container contamination levels are thus at undetectable levels and, as such, are contamination free. WIPP normal operations do not involve or entail any planned or expected releases of airborne radioactive materials. Therefore, no hazards exist to the public, worker, or environment from the airborne pathway as a result of normal operations. Radiological consequences to the offsite public from normal operations will therefore meet the criteria in 40 CFR 191, Subpart A[20] and 40 CFR 61.[21] External doses to workers from the handling of CH waste containers were estimated to be well within DOE ALARA goals. Additionally, consequences to the public and worker as a result of the release of volatile organic compounds (VOCs) during disposal phase normal operations were shown to be many orders of magnitude below health based limits.

As part of normal operation activities, the waste containers, having met the WIPP RADCON Manual Limits[18] as prescribed, are closely inspected and surveyed for radiation, contamination, and damage upon receipt at the WIPP and prior to transfer to the underground for disposal. Decontamination will be undertaken, if required. Decontamination and operations involving overpack and repair of damaged containers are considered abnormal activities, and the consequences to workers and the public were addressed qualitatively through the hazards analysis process.

The safety analysis utilized bounding estimates of drum inventory, release mechanisms and dispersion models to determine potential consequences from postulated accidents. Mitigated as well as unmitigated radiological and nonradiological accident consequences were compared to accident acceptance criteria and found to be within the criteria. Therefore, based on the accident analysis of unmitigated releases of radiological and non-radiological material from the WIPP, no Design Class I systems are required to prevent or mitigate an accidental release from the WIPP. Additionally, this safety analysis indicates TSR Safety Limits, Limiting Control Settings, Limiting Conditions for Operations, and Surveillance Requirements are not required for the safe operation of the WIPP.

The safety analysis established the adequacy of; (1) the design classification of the WIPP CH SSCs, and the application of appropriate engineering codes, standards, and quality assurance requirements, (2) the selection of principal design and safety criteria, and (3) the management, conduct of operations, and institutional safety programs currently in place.

In spite of the foregoing favorable safety characteristics of the WIPP, a defense-in-depth safety philosophy is employed in establishing the safety commitments and objectives of the WIPP.

The WIPP defense-in-depth safety approach provides layers of defense against release of radiological and nonradiological hazardous materials to the environment. The WIPP approach provides three layers of defense against releases. Each successive layer provides an additional measure of the combined defense strategy. These layers are defined as follows:

1) The ultimate safety objective of the first, or primary layer of WIPP defense in depth is **accident prevention**. The reduction of risk (as the product of frequency and consequence) to both workers and the public from WIPP CH TRU waste handling and emplacement operations is primarily achieved by reducing the frequency of occurrence of postulated abnormal events or accidents. The conservative design of the facility's SSCs, with operations conducted by trained/certified personnel to the standards set forth in approved procedures, provides the first layer.

2) The second layer of defense in depth provides protection against anticipated and unlikely operational events that might occur in spite of the protection afforded by the first layer of defense. The second defense layer is characterized by detection and protection systems, and controls that: (1) indicate component, system, or process performance degradation created by compromises of the first layer, and (2) provide adequate mitigation and accommodation of the consequences of those operational accidents which may occur.

3) The third layer of defense in depth supplements the first two layers by providing protection against extremely unlikely operational, natural phenomenon, and external events. These events represent extreme cases of failures and are analyzed in Chapter 5 using conservative assumptions and calculations to assess the radiological and nonradiological effects of such accidents on the public to verify that a conservative design bases has been established.

TSR ACs assigned for features discussed above that are of major significance to the WIPP defense-in-depth approach are derived in Chapter 6.

References for Section 1.3

1. Working Agreement for Consultation and Cooperation, signed by the U.S. DOE and the State of New Mexico, July 1981 and subsequent revisions.

2. U.S. Department of Energy, DOE Order 5481.1B, Safety Analysis and Review System, September 23, 1986.

3. U.S. Department of Energy, DOE-AL Order 5481.1B, Albuquerque Operations Office, Safety Analysis and Review System, January 1, 1988.

4. U.S. Department of Energy, DOE Order 5480.21, Unreviewed Safety Questions, December 21, 1991.

5. U.S. Department of Energy, DOE Order 5480.22, Technical Safety Requirements, February 25, 1992.

6. U.S. Department of Energy, DOE Order 5480.23, Nuclear Safety Analysis Reports, April 30, 1992.

7. U.S. Department of Energy, DOE Order 5480.24, Nuclear Criticality Safety, August 12, 1992.

8. U.S. Department of Energy, DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports, July 1994.

9. U.S. Department of Energy, DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, 1992.

10. Waste Isolation Pilot Plant General Plant System Design Description (GPDD), Rev. 1, April 1995.

11. WIPP-DOE-069, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 4, December 1991.

12. WIPP-CAO-95-1014, Rev. 0, Waste Isolation Pilot Plant Project Technical Baseline for Regulatory Compliance, April 20, 1995.

13. WCAP-14312, Hazard and Operability Study for CH TRU Waste Handling System, Waste Isolation Pilot Plant, Westinghouse Waste Isolation Division, April 1995.

14. U.S. Department of Energy, DOE/CAO-94-1005, U.S. Department of Energy Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report, Rev. 0, May 1994.

15. DOE Order 6430.1A, General Design Criteria, Division 13, Special Facilities, April 1989.

16. 29 CFR 1910-119, Process Safety Management of Highly Hazardous Chemicals.

17. 10 CFR 835, Occupational Radiation Protection.

18. WP12-5, WIPP Radiological Control Manual, October 1994.

19. ANSI/ANS-51.1, American National Standards Institute, Standard Nuclear Safety Criteria for the Design of Stationary Presurized Water Reactor Plants.

20. 40 CFR 191, Environmental Radiation Protection for Management and Disposal of Spent Nuclear Fuel, High-Lead and Transuranic Wastes, Subpart A, Environmental Standards for Management and Storage.

21. 40 CFR 61, National Emission Standards for Hazardous Air Pollutants, Subpart H, National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities.

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation 1 of 7

FY-94 SAR Section		FY-95 SAR Section	
Chapter 1 - Introduction and General Description			
1.1	Introduction	1.1	Facility Background and Mission
1.2	General Description of the WIPP Facility	1.2.1	Facility Design
1.3	General Description of Operations at the WIPP Facility	1.2.2	Facility Operations
1.4	Identification of Agents and Contractors	1.4	Organizations
1.5	Technical Programs	Deleted -	Material available in other DOE Documents and Performance Assessment. SAR Emphasis on Disposal Operations vs. Experimental Operations
Appendix 1A	Bibliography of Documentation Supporting the Development of the WIPP Facility	Deleted -	Material dated. SAR Emphasis on Disposal Operations vs. Experimental Operations
Chapter 1A Summary Safety Analysis		1.3	Safety Analysis Strategy and Approach
Chapter 2 - Site Characteristics			
2.1	Geography and Demography of the Area Around the WIPP Facility	2.1	Geography and Demography of the Area Around the WIPP Facility
2.2	Nearby Industrial, Transportation and Military Facilities	2.2	Nearby Industrial, Transportation and Military Facilities
2.3	Meteorology	2.5	Meteorology
2.4	Subsurface Hydrology	2.6	Surface-Water and Groundwater Hydrology
2.5	Surface Hydrology	2.6	Surface-Water and Groundwater Hydrology
2.6	Regional Geology	2.7	Geology
2.7	Geology in the Vicinity of the WIPP Facility	2.7	Geology
2.8	Vibratory Ground Motion	2.8	Vibratory Ground Motion
2.9	Surface Faulting	2.7	Geology

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation **2 of 7**

FY-94 SAR Section		FY-95 SAR Section	
2.10	Stability of Subsurface Materials and Foundations	2.7	Geology
2.11	Slope Stability	2.5.2.5	Topography
Chapter 3 - Principal Design Criteria			
3.1	General Design Criteria	3.1	General Design Criteria
3.1.1	Waste Characterization	5.1.2	CH Waste Characterization
3.1.2	CH TRU Waste Handling and Emplacement Criteria	3.1.1	TRU Waste Criteria
3.1.3	RH TRU Waste Handling and Emplacement Criteria	3.1.1	TRU Waste Criteria
3.1.4	Underground Development Criteria	3.1.1	TRU Waste Criteria
3.1.5	Monitoring and Surveillance Programs	Deleted - not criteria	
3.1.6	Facility By-Products	3.1.2	Facility By-Products
3.1.7	Classification of Structures, Systems, and Components	3.1.3	Design Classification of Structures, Systems, and Components
3.2	Structural and Mechanical Design Criteria	3.2	Structural Design Criteria
3.3	Safety Protection Criteria		
3.3.1	Confinement Barriers and Systems	3.3.1	Confinement Requirements
3.3.2	Air Handling	4.4.1 4.4.2	Confinement Ventilation Systems
3.3.3	Fire and Explosion Protection	3.3.2	Fire Protection
3.3.4	Radiological Protection	3.3.3	Radiological Protection
3.3.5	Nuclear Criticality Safety	3.3.3.4	Nuclear Criticality Safety
3.3.6	Underground Mining Safety	3.3.4	Industrial and Mining Safety
3.4	Decommissioning and Decontamination Design Criteria	3.1.4	Decontamination and Decommissioning
3.5	Design Development, Construction, and Startup of the WIPP Facility	Deleted - not criteria	

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation 3 of 7

FY-94 SAR Section		FY-95 SAR Section	
Chapter 4 - Plant Design			
4.1	Summary Description	4.1	Summary Description
4.2	Surface Structures	4.2.1	Surface Facilities
4.2.1	Waste Handling Building	4.2.1.1	Waste Handling Building
4.2.2	Support Structures	4.2.1.2 4.2.1.3 4.2.1.4 4.2.1.5	Exhaust Filter Building Water Pumphouse Support Building Support Structures
4.3	Shafts and Subsurface Facilities	4.2.2 4.2.3	Shaft and Hoist Facilities Subsurface Facilities
4.3.1	Shafts and Hoists	4.2.2	Shaft and Hoist Facilities
4.3.2	Subsurface Structures	4.2.3	Subsurface Facilities
4.4	Service and Utility systems	4.4 4.5 4.6 4.7	Confinement Systems Safety Support Systems Utility and Auxiliary Systems Radioactive Waste (Radwaste) and Hazardous Waste Management
4.4.1	Ventilation Systems	4.4.1 4.4.2	Confinement Ventilation Systems
4.4.2	Electrical System	4.6.1	Electrical System
4.4.3	Fire Protection System	4.5.1	Fire Protection System
4.4.4	Water and Wastewater System	4.6.3 4.6.4 4.7	Domestic Water System Sewage Treatment System Radioactive Waste (Radwaste) and Hazardous Waste Management
4.4.5	Salt Handling System	4.3.5	Underground Mining Operations
4.4.6	Radioactive Waste Systems	4.7	Radioactive Waste (Radwaste) and Hazardous Waste Management
4.4.7	Transportation	2.2.7	Land Transportation
4.4.8	Safety Communications and Alarms	4.5.2	Plant Monitoring and Communications
4.4.9	Maintenance Provisions	8.3.5	Maintenance Program
4.4.10	Compressed Air	4.6.2	Compressed Air
4.4.11	Underground Fuel System	4.2.3.1	General Design

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation 4 of 7

FY-94 SAR Section		FY-95 SAR Section	
4.5	Waste Handling and Emplacement Equipment	4.3	Process Description
4.6	Underground Mining Equipment	Deleted	
Chapter 5 - Process Description			
5.1	CH TRU Waste Handling System	4.3.1	CH TRU Waste Handling System
5.2	RH TRU Waste Handling System	4.3.2	RH TRU Waste Handling System
5.4	Plant-Generated Radwaste System	4.7	Radioactive Waste (Radwaste) and Hazardous Waste Management
5.5	General Process Considerations		
5.5.1	Monitoring Instrumentation	4.5.2	Plant Monitoring and Communications
5.5.2	Criticality Safety	5.1.4	Nuclear Criticality
5.5.3	Process Interruption Modes	4.3.3	Process Interruption Modes
5.5.4	WIPP Waste Information System	4.3.4	WIPP Waste Information System
5.6	Underground Mining Operations	4.3.5	Underground Mining Operations
5.7	Central Monitoring System	4.5.2.1	Central Monitoring System
Chapter 6 - Environmental, Safety, and Health Protection			
6.1	Radiological Protection		
6.1.1	Measures to Assure ALARA Occupational Radiation Exposure	7.1.2 7.2.3.1	ALARA Policy and Program ALARA Policy
6.1.2	Radiation Sources	7.1.3.1.3.2	Direct Radiation Sources
6.1.3	Radiation Protection Design Features	7.1.3.1	Radiological Protection Design Features
6.1.4	On-Site Dose Assessment	7.1.4.1	On-site Dose Assessment
6.1.5	Radiological Control Program	7.1.1	Radiological Control Program and Organization
6.1.6	Off-Site Dose Assessment	7.1.4.2	Off-site Dose Assessment
6.1.7	Exposure to Hazardous Wastes	7.2	Hazardous Material Protection
6.2	Environmental Protection		

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation 5 of 7

FY-94 SAR Section		FY-95 SAR Section	
6.2.1	Program Description	7.1.4.2.1 7.2.4	Effluent Sampling/Monitoring and Environmental Monitoring Environmental Monitoring
6.3	Safety	8.1 8.4	Management, Organization, and Institutional Safety Provisions Operational Safety
6.3.1	Program Description	8.1.4	Safety Management Policies and Programs
6.3.2	Occupational Medical Program	7.2.3.6	Occupational Medical Program
6.3.3	Emergency Preparedness	8.5	Emergency Preparedness Program
6.3.4	Crisis Management	8.5	Emergency Preparedness Program
6.3.5	Operational Systems Safety	8.4	Operational Safety
6.3.6	Fire Protection	8.4.4	Fire Protection
6.3.7	Record keeping	8.1.4	Safety Management Policies and Programs
6.3.8	Evaluation	8.5.4.6	Training and Exercises
6.4	Industrial Hygiene	7.2	Hazardous Material Protection
6.4.1	Heat Stress	7.2.3.2	Hazard Identification, Evaluation, and Elimination
6.4.3	Threshold Limit Value Concept		TLV is used in Section 5.2.2
6.4.4	Industrial Hygiene Surveys	7.2.3.5	Workplace Monitoring
6A	Calculation of Airborne Concentrations and Releases	Deleted	
Chapter 7 - Accident Analysis			
7.1	Accident Classification	5.2	CH TRU Accident Analysis
7.2	Source Terms and Analytical Methodology	5.2	CH TRU Accident Analysis
7.2.1	Source Terms	5.1.2 5.2.1	CH Waste Characterization Accident Assessment Methodology
7.2.2	Dose Calculation Models	5.2.1	Accident Assessment Methodology
7.3	Accident Description and Analysis	5.2.3	Accident Analysis
7.4	Accidental Releases and Exposures to Hazardous Wastes	5.2.3	Accident Analysis

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation **6 of 7**

FY-94 SAR Section		FY-95 SAR Section	
7A	Plutonium-239 Equivalent Activity	Appendix B	
7B	Reliability of the Waste Hoist at the Waste Isolation Pilot Plant	Appendix E	
Chapter 8 -	**Long-Term Waste Isolation Assessments**	5.4	Long-Term Waste Isolation Assessment
Chapter 9 -	**Conduct of Operations**		
9.1	Organizational Structure		
9.1.1	Owner Organization	8.1.3	Organizational Structure, Responsibilities, and Interfaces
9.1.2	Management and Operating Contractor Organization	8.1.3	Organizational Structure, Responsibilities, and Interfaces
9.1.3	Personnel Qualification Requirements	8.1.3.3	Staffing and Qualifications
9.2	Startup Testing Preoperational Checkout		
9.2.1	Start-Up Testing Program Objective	8.3.3.2	Start-up Testing Program Objective
9.2.2	Administrative Procedures for Conducting the Startup Test Program	8.3.3.3	Administrative Procedures for Conducting the Start-up Testing Program
9.2.3	Vendor Testing	8.3.3.4	Vendor Testing
9.2.4	Preoperational Checkout	8.3.3.5	Preoperational Checkout
9.2.5	Ongoing Evaluation and Testing	8.3.4 8.3.5	In-Service Surveillance Program Maintenance Program
9.3	Training Program	8.2.4	Training Program
9.4	Normal Operations	8.4	Operational Safety
9.5	WIPP Facility Security Plan		Deleted
9.6	WIPP Facility Emergency Plan	8.5	Emergency Preparedness Program

Table 1.3-1, FY-94 SAR/FY-95 SAR Correlation 7 of 7

FY-94 SAR Section		FY-95 SAR Section	
Chapter 10 - Operational Safety Requirements			
10.1	Introduction	6.1 6.2	Requirements TSR Coverage
10.2	Safety Limits	6.4.1	Safety Limits (SLs)
10.3	Limiting Conditions for Operation (LCOs)	6.4.3	Limiting Conditions for Operations (LCOs)
10.4	Surveillance Requirements	6.4.4	Surveillance Requirements (SRs)
10.5	Design Features	6.5	Design Features
10.6	Administrative Controls	6.4.5	Administrative Controls
Chapter 11 - Quality Assurance		**Chapter 9 - Quality Assurance** Rewritten to new requirements of 10 CFR 830	
Chapter 12 - Decontamination and Decommissioning of the WIPP Facility			
12.1	General	10.1	Introduction
12.2	WIPP Facility	10.2	WIPP Facility Description
12.3	Decontamination and Decommissioning	10.3	Decontamination and Decommissioning
12.4	Closure, Monuments, and Records	10.4	Closure, Monuments, and Records
12.5	Post Closure Physical and Environmental Surveillance	10.5	Post Closure Surveillance
12.6	Decommissioning Activities Associated with the test phase	Deleted	

Table 1.3-2, Consultation and Cooperation (C&C) Agreement/FY-95 SAR Correlation 1 of 5

C&C Topic		FY-95 SAR Section	
Chapter 1 - Introduction and General Description			
1.1	Location	1.1	Facility Background and Mission
1.2	Mission	1.1	Facility Background and Mission
1.3	Organization	1.4	Organizations
1.4	Facilities - both surface and underground	1.2.1	Facility Design
1.5	Operations - including retrieval	1.2.2	Retrieval operations deleted. Disposal-phase operations are discussed with no intent to retrieve.
1.6	Research and Development programs	Deleted - SAR only addresses disposal phase	
Chapter 2 - Site Characteristics			
2.1	Geography and Demography	2.1	Geography and Demography of the Area Around the WIPP Facility.
2.2	Nearby Industrial, Transportation and Military Facilities	2.2	Nearby Industrial, Transportation and Military Facilities
2.3	Meteorology	2.5	Meteorology
2.4	Surface Hydrology	2.6	Surface-Water and Groundwater Hydrology
2.5	Subsurface Hydrology	2.6	Surface-Water and Groundwater Hydrology
2.6	Regional Geology	2.7	Geology
2.7	Site Geology	2.7	Geology
2.8	Vibratory Ground Motion	2.8	Vibratory Ground Motion
2.9	Surface Faulting	2.7	Geology
2.10	Stability of Subsurface Materials and Foundations	2.7	Geology
2.11	Slope Stability	2.5.2.5	Topography
Chapter 3 - Principal Design Criteria			
3.1	Definition of Mission		
	Waste Characterization	5.1.2	CH Waste Characterization

Table 1.3-2, Consultation and Cooperation (C&C) Agreement/FY-95 SAR Correlation 2 of 5

C&C Topic		FY-95 SAR Section	
	Repository Functions	3.1	General Design Criteria
	Storage Capacities	3.1.1	TRU Waste Criteria
	Retrievability	Deleted	
	By-Products	3.1.2	Facility By-Products
3.2	Structural and Mechanical Design	3.2	Structural Design Criteria
3.3	Safety Protection Criteria		
	Confinement	3.3.1	Confinement Requirements
	Handling	3.1	General Design Criteria
	Emplacement	3.1	General Design Criteria
	Retrieval	Deleted	
	Fire	3.3.2	Fire Protection
	Explosion	3.3.2	Fire Protection
	Radiological	3.3.3	Radiological Protection
	Criticality	3.3.3.4	Nuclear Criticality Safety
	Mine Safety	3.3.4	Industrial and Mining Safety
3.4	Design Classification	3.1.3	Design Classification of Structures, Systems, and Components
3.5	Decommissioning	3.1.4	Decontamination and Decommissioning
	Decontamination	3.1.4	Decontamination and Decommissioning
	Backfilling	Deleted	
	Sealing	3.1.4	Decontamination and Decommissioning
	Record Maintenance	3.1.4	Decontamination and Decommissioning
	Site Markers	3.1.4	Decontamination and Decommissioning

Table 1.3-2, Consultation and Cooperation (C&C) Agreement/FY-95 SAR Correlation 3 of 5

C&C Topic		FY-95 SAR Section	
Chapter 4 - Plant Design			
4.1	Location Details	4.1	Summary Description
4.2	Surface Facilities	4.2.1	Surface Facilities
	Waste Building Handling	4.2.1.1	Waste Handling Building
	Support Functions	4.2.1.2 4.2.1.3 4.2.1.4 4.2.1.5	Exhaust Filter Building Water Pumphouse Support Building Support Structures
4.3	Shafts and Subsurface Facilities	4.2.2 4.2.3	Shaft and Hoist Facilities Subsurface Facilities
	Shafts	4.2.2	Shaft and Hoist Facilities
	Storage	4.2.3	Subsurface Facilities
	Experimental Areas	4.2.3	Subsurface Facilities
4.4	Service and Utility systems	4.3 4.4 4.5 4.6 4.7	Process Description Confinement Systems Safety Support Systems Utility and Auxiliary Systems Radioactive Waste (Radwaste) and Hazardous Waste Management
	Ventilation	4.4.1 4.4.2	Confinement Ventilation Systems
	Electrical	4.6.1	Electrical System
	Fire Protection	4.5.1	Fire Protection System
	Waste Water	4.6.3 4.6.4 4.7	Domestic Water System Sewage Treatment System Radioactive Waste (Radwaste) and Hazardous Waste Management
	Salt Handling	4.3.5	Underground Mining Operations
	Radwaste	4.7	Radioactive Waste (Radwaste) and Hazardous Waste Management
	Transportation	2.2.7	Land Transportation
	Alarms	4.5.2	Plant Monitoring and Communications
	Maintenance	8.3.5	Maintenance Program

Table 1.3-2, Consultation and Cooperation (C&C) Agreement/FY-95 SAR Correlation 4 of 5

C&C Topic		FY-95 SAR Section	
	Compressed Air	4.6.2	Compressed Air
	Underground Fuel	4.2.3.1	General Design
4.5	Emplacement and Retrieval	4.3	Retrieval Deleted
4.6	Underground Excavation Equipment	Deleted -	Standard Industrial (MSHA) Hazard
Chapter 5 - Process Description			
5.1	Contact-handled (CH) waste handling	4.3.1	CH TRU Waste Handling System
5.2	Remote-handled (RH) waste handling	4.3.2	RH TRU Waste Handling System
5.3	Experimental handling	Deleted - SAR only addresses disposal phase	
5.4	Plant Generated Radwaste	4.7	Radioactive Waste (Radwaste) and Hazardous Waste Management
5.5	General process		
	Instrumentation	4.5.2	Plant Monitoring and Communications
	Criticality Safety	5.1.4	Nuclear Criticality
	Waste Logging	4.3.4	WIPP Waste Information System
5.6	Underground excavation	4.3.5	Underground Mining Operations
5.7	Control room	4.5.2.1	Central Monitoring System
5.8	Analytical Sampling	7.1.4.2.1 7.2.4	Effluent Sampling/Monitoring and Environmental Monitoring Environmental Monitoring
5.9	Retrievability of All Waste Forms	Deleted	
Chapter 6 - Radiation Protection			
6.1	As low as reasonably achievable (ALARA)	7.1.2 7.2.3.1	ALARA Policy and Program ALARA Policy
6.2	Radiation Sources	7.1.3.1.3.2	Direct Radiation Sources
6.3	Radiation protection	7.1.3	Radiological Exposure Control
6.4	On-site dose assessment	7.1.4.1 7.2.2.2	On-site Dose Assessment On-site Exposure Assessment
6.5	Radiological control program	7.1.1	Radiological Control Program and Organization

Table 1.3-2, Consultation and Cooperation (C&C) Agreement/FY-95 SAR Correlation 5 of 5

C&C Topic		FY-95 SAR Section	
6.6	Off-site dose assessment	7.1.4.2 7.2.2.1	Off-site Dose Assessment Off-site Exposure Assessment
Chapter 7 - Accident Analysis			
7.1	Accident classifications	5.2	CH TRU Accident Analysis
7.2	Source terms and analytical methods	5.2	CH TRU Accident Analysis
7.3	Accident descriptions and actual analyses	5.2	CH TRU Accident Analysis
Chapter 8 - Long Term Waste Isolation Assessment		5.4	Long-Term Waste Isolation Assessment
8.1	Identification of potential communication modes	5.4	Long-Term Waste Isolation Assessment
8.2	Modeling methods	5.4	Long-Term Waste Isolation Assessment
8.3	Consequence analyses	5.4	Long-Term Waste Isolation Assessment
Chapter 9 - Conduct of Operations			
9.1	Organizational structure	8.1.3	Organizational Structure, Responsibilities, and Interfaces
9.2	Acceptance tests	8.3.3	Initial Test Program
9.3	Training	8.2.4	Training Program
9.4	Operating procedures	8.2.3	Procedures Program
9.5	Security		Deleted
9.6	Emergencies	8.5	Emergency Preparedness Program
Chapter 10 - Operating Limits and Controls			
10.1	Design limits	Chapter 3	
10.2	Operating limits and surveillance requirements	6.4	Derivation of WIPP TSRs
10.3	Design features	Not Required by 5480.22	
10.4	Administrative controls	6.4.5	Administrative Controls
10.5	Guidelines for the operating organization	6.4.5	Administrative Controls
Chapter 11 - Quality Assurance		Chapter 9 - Quality Assurance	

Table 1.3-3, DOE Order 5480.23/FY-95 SAR Correlation 1 of 1

DOE Order 5480.23 Topic	FY-95 SAR Section
Chapter 1 - Executive Summary	Chapter 1 - Executive Summary
Chapter 2 - Applicable Statutes, Rules, and Departmental Orders	Chapter 1 - Executive Summary
Chapter 3 - Site Characteristics	Chapter 2 - Site Characteristics
Chapter 4 - Facility Description and Operation	Chapter 4 - Facility Design and Operation
Chapter 5 - Hazards Analysis and Classification of the Facility	Chapter 5 - Hazards and Accident Analysis
Chapter 6 - Principal Health and Safety Criteria	Chapter 3 - Principal Design and Safety Criteria
Chapter 7 - Radioactive and Hazardous Material Waste Management	Chapter 4 - Facility Design and Operation
Chapter 8 - Inadvertent Criticality Protection	Chapter 5 - Hazards and Accident Analysis
Chapter 9 - Radiation Protection	Chapter 7 - Radiological and Hazardous Material Protection
Chapter 10 - Hazardous Material Protection	Chapter 7 - Radiological and Hazardous Material Protection
Chapter 11 - Analysis of Normal, Abnormal, and Accident Conditions	Chapter 5 - Hazards and Accident Analysis
Chapter 12 - Management, Organization, Institutional Safety	Chapter 8 - Institutional Programs
Chapter 13 - Procedures and Training	Chapter 8 - Institutional Programs
Chapter 14 - Human factors	Chapter 4 - Facility Design and Operation
Chapter 15 - Initial Testing, In service Surveillance, Maintenance	Chapter 8 - Institutional Programs
Chapter 16 - Technical Safety Requirements	Chapter 6 - Derivation of Technical Safety Requirements
Chapter 17 - Operational Safety	Chapter 8 - Institutional Programs
Chapter 18 - Quality Assurance	Chapter 9 - Quality Assurance
Chapter 19 - Emergency Preparedness	Chapter 8 - Institutional Programs
Chapter 20 - Decontamination and Decommissioning	Chapter 10 - Decontamination and Decommissioning

Table 1.3-4, Summary of Estimated Radiological Consequences From Accidents

Summary of Radiological Consequences for Postulated Accidents for the CH TRU Waste Handling Operations							
Accident	Estimated Frequency/yr	Type of Release	Total Released (PE-Ci)	Receptor Doses (CEDE-Rem)		Offsite Dose Criteria (CEDE-rem)	% of Dose Criteria [(Dose/Criteria)*100]
				Exclusive Use Area Boundary	Site Boundary		Exclusive Use Area Boundary
CH1	Extremely Unlikely						
WHB Spont. Ign		Drums/mitigated	1.9E-08	1.9E-06	1.3E-07	≤ 25	<1.0%
(Ref. 5.2.3.1)		Drums/unmitigated	1.9E-02	1.9E+00	1.3E-01	≤ 25	7.6%
CH2	Unlikely						
Crane Drop		Drums/mitigated	1.4E-08	1.4E-06	9.6E-08	≤ 6.5	<1.0%
(Ref. 5.2.3.2)		Drums/unmitigated	1.4E-02	1.4E+00	9.6E-02	≤ 6.5	21.8%
		SWBs/mitigated	1.3E-09	1.3E-07	8.9E-09	≤ 6.5	<1.0%
		SWBs/unmitigated	1.3E-03	1.3E-01	8.9E-03	≤ 6.5	2.0%
CH3	Unlikely						
WHB Punct/Drop		Drums/mitigated	5.6E-09	5.7E-07	3.9E-08	≤ 6.5	<1.0%
(Ref. 5.2.3.3)		Drums/unmitigated	5.6E-03	5.7E-01	3.9E-02	≤ 6.5	8.7%
		SWBs/mitigated	2.6E-09	2.6E-07	1.8E-08	≤ 6.5	<1.0%
		SWBs/unmitigated	2.6E-03	2.6E-01	1.8E-02	≤ 6.5	4.0%
CH4	Anticipated						
WHB Drop		Drums/mitigated	8.0E-09	8.1E-07	5.5E-08	≤ 2.5	<1.0%
(Ref. 5.2.3.4)		Drums/unmitigated	8.0E-03	8.1E-01	5.5E-02	≤ 2.5	32.4%
		SWBs/mitigated	2.6E-09	2.6E-07	1.8E-08	≤ 2.5	<1.0%
		SWBs/unmitigated	2.6E-03	2.6E-01	1.8E-02	≤ 2.5	10.5%
CH5	Incredible	no release					
Hoist Failure			-	-	-	-	
(Ref. 5.2.3.5)							

Table 1.3-4, Summary of Estimated Radiological Consequences From Accidents

Summary of Radiological Consequences for Postulated Accidents for the CH TRU Waste Handling Operation							
Accident	Estimated Frequency/yr	Type of Release	Total Released (PE-Ci)	Receptor Doses (CEDE-Rem)		Offsite Dose Criteria (CEDE-rem)	% of Dose Criteria [(Dose/Criteria)*100]
				Exclusive Use Area Boundary	Site Boundary		Exclusive Use Area Boundary
CH6	Incredible	no release					
DBE			-	-	-	-	
(Ref. 5.2.3.6)							
CH7	Extremely Unlikely						
U/G Spont. Ign		Drums/mitigated	9.4E-09	1.2E-06	6.4E-08	≤ 25	<1.0%
(Ref. 5.2.3.7)		Drums/unmitigated	9.4E-03	1.2E+00	6.4E-02	≤ 25	5.0%
CH8	Incredible	no release					
WHB Aircraft Crash			-	-	-	-	-
(Ref. 5.2.3.8)							
CH9	Unlikely						
U/G Drop		Drums/mitigated	7.0E-09	9.2E-07	4.7E-08	≤ 2.5	<1.0%
(Ref. 5.2.3.9)		Drums/unmitigated	7.0E-03	9.2E-01	4.7E-02	≤ 2.5	36.8%
		SWBs/mitigated	6.5E-10	8.5E-08	4.4E-09	≤ 2.5	<1.0%
		SWBs/unmitigated	6.5E-04	8.5E-02	4.4E-03	≤ 2.5	3.4%
CH10	Incredible	no release					
DBT							
(Ref. 5.2.3.10)							
CH11	Unlikely						
U/G Roof Fall		Drums/mitigated	2.1E-08	2.8E-06	1.4E-07	≤ 6.5	<1.0%
(Ref. 5.2.3.9)		Drums/unmitigated	2.1E-02	2.8E+00	1.4E-01	≤ 6.5	42.4%
		SWBs/mitigated	3.3E-09	4.3E-07	2.2E-08	≤ 6.5	<1.0%
		SWBs/unmitigated	3.3E-03	4.3E-01	2.2E-02	≤ 6.5	6.6%

Table 1.3-5, Summary of Estimated Toxicological Consequences From Accidents

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations

Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria	Exclusive Use Area Boundary
CH1	Extremely Unlikely							
WHB Spont. Ign.		Drums/unmitigated						
(Ref. 5.2.3.1)			Asbestos	7.1E+01	3.6E-04 f/cc	2.5E-05 f/cc	TLV-TWA	<1.0%
			Beryllium	5.5E+00	3.6E-06	2.5E-07	TLV-TWA	<1.0%
			Cadmium	7.8E-02	5.2E-08	3.5E-09	TLV-TWA	<1.0%
			Lead	2.1E+02	1.4E-04	9.7E-06	TLV-TWA	<1.0%
			Butyl Alcohol	7.8E+01	5.2E-05	3.5E-06	PEL C	<1.0%
			Carbon Tetrachloride	1.6E+02	1.1E-04	7.3E-06	TLV-TWA	<1.0%
			Mercury	9.2+01	6.1E-05	4.1E-06	PEL C	<1.0%
			Methyl Alcohol	2.1E-01	1.4E-07	9.4E-09	EEGL	<1.0%
			Methyl Chloride	1.0E+01	6.9E-06	4.7E-07	TLV-TWA	<1.0%
			Polychlorinated Biphenyl (PCB)	2.2E+02	1.5E-04	1.0E-05	TLV-TWA	<1.0%
			Trichloroethylene	1.0E+02	6.8E-05	4.6E-06	EEGL	<1.0%

Table 1.3-5, Summary of Estimated Toxicological Consequences From Accidents

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria	Exclusive Use Area Boundary
CH2	Unlikely							
Crane Drop		Drums/unmitigated						
(Ref. 5.2.3.2)			Methylene Chloride	295.92	1.8E-01	1.2E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	439.25	2.6E-01	1.8E-02	TLV-STEL	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	380.47	2.3E-01	1.5E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	564.75	3.4E-01	2.3E-02	TLV-STEL	1.0%
CH3	Unlikely							
WHB Punct/Drop		Drums/unmitigated						
(Ref. 5.2.3.3)			Methylene Chloride	169.10	1.0E-01	6.8E-03	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	251.00	1.5E-01	1.0E-02	TLV-STEL	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	718.66	4.3E-01	2.9E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	1066.76	6.4E-01	4.3E-02	TLV-STEL	1.0%

Table 1.3-5, Summary of Estimated Toxicological Consequences From Accidents

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria	Exclusive Use Area Boundary
CH4	Anticipated							
WHB Drop		Drums/unmitigated						
(Ref. 5.2.3.4)			Methylene Chloride	169.10	1.0E-01	6.8E-03	TLV-TWA	<1.0%
			Carbon Tetrachloride	251.00	1.5E-01	1.0E-02	PEL-TWA	1.2%
		SWBs/unmitigated						
			Methylene Chloride	718.66	4.3E-01	2.9E-02	TLV-TWA	<1.0%
			Carbon Tetrachloride	1066.76	6.4E-01	4.3E-02	PEL-TWA	5.0%
CH5	Incredible							
Hoist Failure				-	-	-	-	-
(Ref. 5.2.3.5)								
CH6	Incredible							
DBE				-	-	-	-	-
(Ref. 5.2.3.6)								

Table 1.3-5, Summary of Estimated Toxicological Consequences From Accidents

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria	Exclusive Use Area Boundary
CH7								
U/G Spont. Ign	Extremely Unlikely							
(Ref. 5.2.3.7)		Drums/unmitigated						
			Asbestos	3.6E+01	1.8E-04 f/cc	1.2E-05 f/cc	TLV-TWA	<1.0%
			Beryllium	2.7E+00	1.8E-06	1.2E-07	TLV-TWA	<1.0%
			Cadmium	3.9E-02	2.6E-08	1.8E-09	TLV-TWA	<1.0%
			Lead	1.1E+02	7.1E-05	4.8E-06	TLV-TWA	<1.0%
			Butyl Alcohol	3.9E+01	2.6E-05	1.8E-06	PEL C	<1.0%
			Carbon Tetrachloride	8.2E+01	5.4E-05	3.7E-06	TLV-TWA	<1.0%
			Mercury	4.6E+01	3.1E-05	2.1E-06	PEL C	<1.0%
			Methyl Alcohol	1.0E-01	6.9E-08	4.7E-09	EEGL	<1.0%
			Methyl Chloride	5.2E+00	3.5E-06	2.3E-07	TLV-TWA	<1.0%
			Polychlorinated Biphenyl (PCB)	1.1E+02	7.4E-05	5.0E-06	TLV-TWA	<1.0%
			Trichloroethylene	5.1E+01	3.4E-05	2.3E-06	EEGL	<1.0%
CH8	Incredible							
Aircraft Crash				-	-	-	-	-
(Ref. 5.2.3.8)								

Table 1.3-5, Summary of Estimated Toxicological Consequences From Accidents

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria	Exclusive Use Area Boundary
CH9	Unlikely							
U/G Drop		Drums/unmitigated						
(Ref. (5.2.3.9)			Methylene Chloride	295.92	2.3E-01	1.2E-02	TLV-TWA	<1.0%
			Carbon Tetrachloride	439.25	3.4E-01	1.8E-02	PEL-TWA	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	380.47	2.9E-01	1.5E-02	TLV-TWA	<1.0%
			Carbon Tetrachloride	564.75	4.4E-01	2.3E-02	PEL-TWA	<1.0%
CH10	Incredible	no release						
DBT				-	-	-	-	-
(Ref. 5.2.3.10)								
CH11	Unlikely							
UG Roof Fall		Drums/unmitigated						
(Ref. 5.2.3.11)			Methylene Chloride	887.76	6.9E-01	3.5E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	1317.76	1.0E+00	5.3E-02	TLV-STEL	1.6%
		SWBs/unmitigated						
			Methylene Chloride	1817.79	1.4E+00	7.3E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	2698.27	2.1E+00	1.1E-01	TLV-STEL	3.3%

NOTE: No credit is taken for mitigation of solid, liquid chemicals or volatile organic compounds (VOC) by HEPA filtration.

1.4 Organizations

The overall responsibility for the design, construction, operation, and decommissioning of the WIPP rests solely with the DOE. Within the DOE, the Assistant Secretary for Environmental Restoration and Waste Management (EM) is responsible for implementing the radioactive waste disposal policy. In 1993, the DOE Carlsbad Area Office (CAO) was created to be directly responsible for the WIPP Project. The CAO reports programmatically to the DOE-EM and administratively to the DOE-AL.

During the construction phase, DOE-AL contracted with the following organizations to participate in the WIPP Project:

- Sandia National Laboratories (SNL), Department of Waste Management Technology, Albuquerque, New Mexico, to serve as the Scientific Advisor

- Bechtel National Incorporated, Advanced Technology Division, San Francisco, California, to serve as the Architect/Engineer

- Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, New Mexico, to serve first as the Technical Support Contractor (1978-1985) and later as the Management and Operating Contractor (1985-present)

  NOTE: The U.S. Army Corps of Engineers was the construction manager under provisions of an Interagency Agreement prior to transfer of this responsibility to the Management and Operating Contractor (MOC).

SNL, as the Scientific Advisor, has been responsible for developing the conceptual design of the WIPP facility, preparing the Draft and Final Environmental Impact Statements, and performing the site selection and characterization studies. SNL is also responsible for completing the performance assessment of the WIPP facility in compliance with 40 CFR 191 Subparts B and C.[1]

Bechtel, the Architect/Engineer, was responsible for developing the detailed design of the facility, including construction bid package development and design related geotechnical explorations. Bechtel engaged the services of Rockwell International as consultant for the design of special waste handling equipment.

As the Technical Support Contractor (TSC) (from 1978-1985), Westinghouse was responsible for providing general management and procurement support. In this role, Westinghouse performed technical reviews of the design, prepared the Safety Analysis Report, supported preparation of the Final Environmental Impact Statement, and provided support in operational planning and quality assurance. In 1985, the DOE-AL contracted with Westinghouse to provide management and operating services as the MOC. In this capacity, Westinghouse is solely responsible for general management and operating services, including operational safety, engineering management, quality assurance and control, project control, construction management, and environmental services. As part of its responsibility as MOC, Westinghouse ensures that all inputs to facility operations are properly reviewed for health, safety, and environmental implications.

The DOE has entered into a formal agreement with the State of New Mexico for the purpose of consultation and cooperation (WACC[2]). This agreement, including its associated working agreement and subsequent modifications, provides a basis for the Governor of New Mexico to exercise the state's right, granted under Public Law 96-164,[3] to comment on and make recommendations regarding the public health and safety aspects of the WIPP Project. The WACC designates key events, sets time frames for review, provides for comments and resolution of comments, and establishes procedures for review of the WIPP Project activities and for resolving conflicts.

References for Section 1.4

1. 40 CFR 191, U.S. Environmental Protection Agency, Environmental Radiation Protection for Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Wastes, Subpart B, Environmental Standards for Disposal, July 1994.

2. Working Agreement for Consultation and Cooperation, signed by the U.S. DOE and the State of New Mexico, July 1981 and subsequent revisions.

3. Public Law 96-164, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, December 29, 1979.

1.5 Statutes, Federal Rules, and DOE Directives Applicable to the Preclosure WIPP CH TRU Waste Operational Safety

Public Law 83-703	Atomic Energy Act of 1954
Public Law 90-148	Clean Air Act
Public Law 91-190	National Environmental Policy Act
Public Law 94-580	Resource Conservation and Recovery Act
Public Law 95-164	Federal Mine Safety and Health Act of 1977
Public Law 96-164	Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
Public Law 96-510	Comprehensive Environmental Response, Compensation, and Liability Act
Public Law 102-579	Waste Isolation Pilot Plant Land Withdrawal Act
10CFR Part 830	Nuclear Safety Management, April 5, 1994
10CFR Part 835	Occupational Radiation Protection, December 14, 1993
29 CFR Part 1910	Occupational Safety and Health Standards, June 27, 1974
30 CFR Part 57	Safety and Health Standards - Underground Metal and Nonmetal Mines, January 29, 1985
40 CFR Part 61, Subpart H	Subpart H - National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities; 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants, December 15, 1989
40 CFR Part 191, Subpart A	Subpart A - Environmental Standards for Management and Storage; 40 CFR 191, Environmental Radiation Protection for Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes, November 18, 1985
40 CFR Part 261	Identification and Listing of Hazardous Waste, May 19, 1980
40 CFR Part 262	Standards Applicable to Generators of Hazardous Waste, May 19, 1980
40 CFR Part 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, May 19, 1980
40 CFR Part 265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, May 19, 1980
40 CFR Part 268	Land Disposal Restrictions, May 19, 1980
40 CFR Part 270	EPA Administered Permit Programs: The Hazardous Waste Permit Program, April 1, 1983
40 CFR Part 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks, September 23, 1988
DOE Order 4330.4B	Maintenance Management Program, February 10, 1994
DOE Order 4700.1	Project Management Systems, June 2, 1992
DOE Order 5000.3B	Occurrence Reporting and Processing of Operations Information, January 19, 1993
DOE Order 5400.1	General Environmental Protection Program, June 29, 1990
DOE Order 5400.4	Comprehensive Environmental Response, Compensation, and Liability Act Requirements, June 6, 1989
DOE Order 5400.5	Radiation Protection of the Public and the Environment, January 7, 1993
DOE Order 5440.1E	National Environmental Policy Act Compliance Program, November 10, 1992
DOE Order 5480.4	Environmental Protection, Safety, and Health Protection Standards, January 7, 1993
DOE Order 5480.18B	Nuclear Facility Training Accreditation Program, August 31, 1994

DOE Order 5480.19	Conduct of Operations Requirements for DOE Facilities, May 18, 1992
DOE Order 5480.20A	Personnel Selection, Qualification, Training Requirements for DOE Nuclear Facilities, November 15, 1994
DOE Order 5480.21	Unreviewed Safety Questions, May 12, 1994
DOE Order 5480.22	Technical Safety Requirements, September 15, 1992
DOE Order 5480.23	Nuclear Safety Analysis Reports, April 30, 1992
DOE Order 5480.24	Nuclear Criticality Safety, August 12, 1992
DOE Order 5480.28	Natural Phenomena Hazards Mitigation, January 15, 1993
DOE Order 5500.1B	Emergency Management System, April 30, 1991
DOE Order 5500.2B	Emergency Categories, Classes, and Notification and Reporting Requirements, February 27, 1992
DOE Order 5500.3A	Planning and Preparedness for Operational Emergencies, February 27, 1992
DOE Order 5500.3B	Occurrence Reporting and Processing of Operations Information, January 19, 1993
DOE Order 5500.7B	Emergency Operation Records Protection Program, October 23, 1991
DOE Order 5500.10	Emergency Readiness Assurance Program, February 27, 1992
DOE Order 5820.2A	Radioactive Waste Management, September 1988
DOE Order 6430.1A	General Design Criteria, 1989

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SITE CHARACTERISTICS

This Chapter provides information on the location of the WIPP facility and the site characteristics to support and clarify assumptions used in the hazards and accident analysis to identify and analyze potential external and natural phenomena accident indicators and accident consequences external to the facility.

2.1 Geography and Demography of the Area Around the WIPP Facility

2.1.1 WIPP Facility Location and Description

The Waste Isolation Pilot Plant (WIPP) Facility is located in Eddy County in southeastern New Mexico (Figure 2.1-1). The center of the WIPP facility is approximately 103°47'27" W longitude and 32°22'11" N latitude.

Prominent natural features within five miles of the center of the WIPP facility are described in detail in Section 2.7 and include Livingston Ridge and Nash Draw, which are located about five miles west. Livingston Ridge, the most prominent physiographic feature near the WIPP facility, is a northwest facing bluff (about 75 feet high) that marks the east edge of Nash Draw (a shallow drainage course about five miles wide). Descriptions of Nash Draw and Livingston Ridge are presented in Section 2.7.

Other prominent natural features are the Pecos River which is about 12 miles west at its nearest point, and Carlsbad Caverns National Park which is more than 42 miles west southwest. The nearest prominent man-made features are the city of Loving (with a 1990 population of 1243) which is 18 miles west southwest, and the city of Carlsbad (with a 1990 population of 24,896) which is 26 miles west.

2.1.1.1 WIPP Facility Area

The area of land that lies within the WIPP Site Boundary and committed to the WIPP facility is a square four miles on a side. It contains 10,240 acres (16 mi^2) including Sections 15-22 and 27-34 in township T22S, R31E. The area containing the WIPP facility surface structures is surrounded with a chain link fence and covers about 35 acres in Sections 20 and 21 of T22S, R31E. This fenced area is known as Property Protection Area. The location and orientation of the WIPP facility surface structures are shown in Figure 2.1-2. These structures include the Waste Handling Building (WHB) where radioactive waste is received and prepared for underground disposal, four shafts to the underground area, a Support Building containing laboratory and office facilities, showers, change rooms and equipment disposal areas for underground workers, an Exhaust Filter Building (EFB), and a water supply system. Support structures outside of the chain link fence include sewage stabilization ponds, other auxiliary buildings, two mined-rock (salt) piles, and an evaporation pond for collecting salt pile runoff.

There are no industrial, commercial, institutional, recreational or residential structures within the WIPP Site Boundary and no through public highways, railways or waterways traverse the WIPP Site Boundary. County Road 802 crosses the WIPP Site Boundary as the south access road. There are four natural gas pipelines that traverse the vicinity of the WIPP facility. One pipeline that is within the WIPP Site Boundary is oriented northeast southwest and is about 1.2 miles north of the center of the WIPP surface structures at its closest point. This pipeline, along with other pipelines in the area of the WIPP facility, are discussed in Section 2.2.3.

The areas that have been designated as subdivisions within the WIPP Site Boundary are defined below and depicted in Figure 2.1-3.

The Property Protection Area is an area of approximately 35 acres surrounded by a chain link fence. Most of the WIPP facility surface structures are located within this area. Except for the salt storage piles, and the wastewater stabilization ponds.

The Exclusive Use Area is an area of approximately 424 acres surrounded by a barbed wire fence and posted no trespassing. Review of the WIPP Land Management Plan indicates that public access to the WIPP 16 section area up to the Off-limits Area (WIPP Secured Area) is allowed for grazing purposes and up to the DOE "Exclusive Use Area" for recreational purposes.

The Off-limits Area (shown in Figure 2.1-3) is an area of approximately 1,450 acres and is posted no trespassing. Access to this area will be restricted.

The WIPP Site Boundary encompasses an area of 10,240 acres (16 sections). The DOE will not permit subsurface mining, drilling, or resource exploration unrelated to the WIPP Project within the WIPP Site Boundary during facility operation or after decommissioning. This prohibition precludes slant drilling under the WIPP facility from within or outside the WIPP facility. With the exception of existing rights under federal oil and gas leases No. NMNM 02953 and NMNM 02953C, which shall not be affected unless a determination is made to require the acquisition of such leases to comply with final disposal regulations or with the solid waste disposal act (42 U.S.C. 6901 et seq).[2]

Within the Property Protection Area, public access is restricted to employees and approved visitors. Within the Exclusive Use Area access is restricted to authorized personnel and vehicles. Mining and Drilling for purposes other than those which support the WIPP project are prohibited within the 16-section (4,146 ha) Land Withdrawal Act (LWA). In addition, small areas have been fenced to control access to material storage areas, borrow pits, the sewage stabilization ponds, and biological study plots.

A zone, provided between the mined area underground and the WIPP Site Boundary is a minimum of one mile wide. This thickness was specified based on recommendations made by Oak Ridge National Laboratory (ORNL). The ORNL recommendation of one to five miles for the size of the buffer zone was to preclude unacceptable penetration of the salt formation. The ORNL stated that the actual size of the buffer must be based on site dependent factors including drilling operations, mining operations and salt dissolution rates. This was addressed in the Geological Characterization Report[1] where the authors state that the one mile buffer should provide more than 250,000 years of isolation using very conservative flow assumptions.

2.1.2 Exclusion Area Land Use and Control

2.1.2.1 Authority

The 10,240 acres that lie within the WIPP Site Boundary are on federal land. During construction all the federal lands within the WIPP Site Boundary were managed in accordance with the terms of Public Land Order 6403 and a DOE/Bureau of Land Management (BLM) Memorandum of Understanding (MOU) and the BLM Resource Management Plan.

During operations, the area within the WIPP Site Boundary will remain under federal control. This includes all facility areas described in Section 2.1.1.1

On October 30, 1992, the WIPP Land Withdrawal Act (LWA), Public Law 102-579, was signed by President Bush transferring the land from the Department of the Interior (DOI) to the DOE. Consistent with the mission of the WIPP facility, lands within and around the WIPP Site Boundary are administered according to a multiple land use policy. Mining and Drilling for purposes other than those which support the WIPP project are prohibited within the 16-section (4,146 ha) LWA subject such conditions and restrictions as may be necessary to permit the conduct of WIPP-related activities.[1]

2.1.2.1.1 Agricultural Uses

All the land within the WIPP Site Boundary up to the Exclusive Use Area has been leased for grazing, which is the only significant agricultural activity in the vicinity of the WIPP facility. There are two leaseholders as shown in Figure 2.1-4. The Smith Ranch, owned by Kenneth Smith, Inc. of Carlsbad, New Mexico, has lease rights to 2880 acres within the northern portion of the WIPP Site Boundary. J. C. Mills of Abernathy, Texas, owner of the Mills Ranch, has lease rights to 7,360 acres within the southern portion of the WIPP Site Boundary.

2.1.2.1.2 Water Use

There are no significant uses of surface or groundwater in the vicinity of the WIPP facility. Several windmills have been erected throughout the area to pump groundwater for livestock watering. Additionally, several ponds have been created to capture runoff for livestock.

2.1.2.1.3 Industrial and Commercial Facilities

There are no industrial facilities within a five-mile radius of the WIPP facility. Ranching is the only commercial operation within five miles of the facility, with the exception of oil and gas related activities. The five-mile radius encompasses grazing allotments of three separate ranches; however, only one ranch house is located in the area. It is about 3.5 miles from the center of the WIPP facility in the south southwest sector. There are three potash mines and two chemical processing plants (adjacent to the mines) between five and 10 miles of the WIPP facility.

References for Section 2.1

1. SAND 78-1596, Geological Characterization Report for the WIPP Site, Southeastern New Mexico. Sandia National Laboratories, Albuquerque, NM, 1978.

2. Public Law 102-579, 102nd Congress, Waste Isolation Pilot Plant Land Withdrawal Act, October 30, 1992.

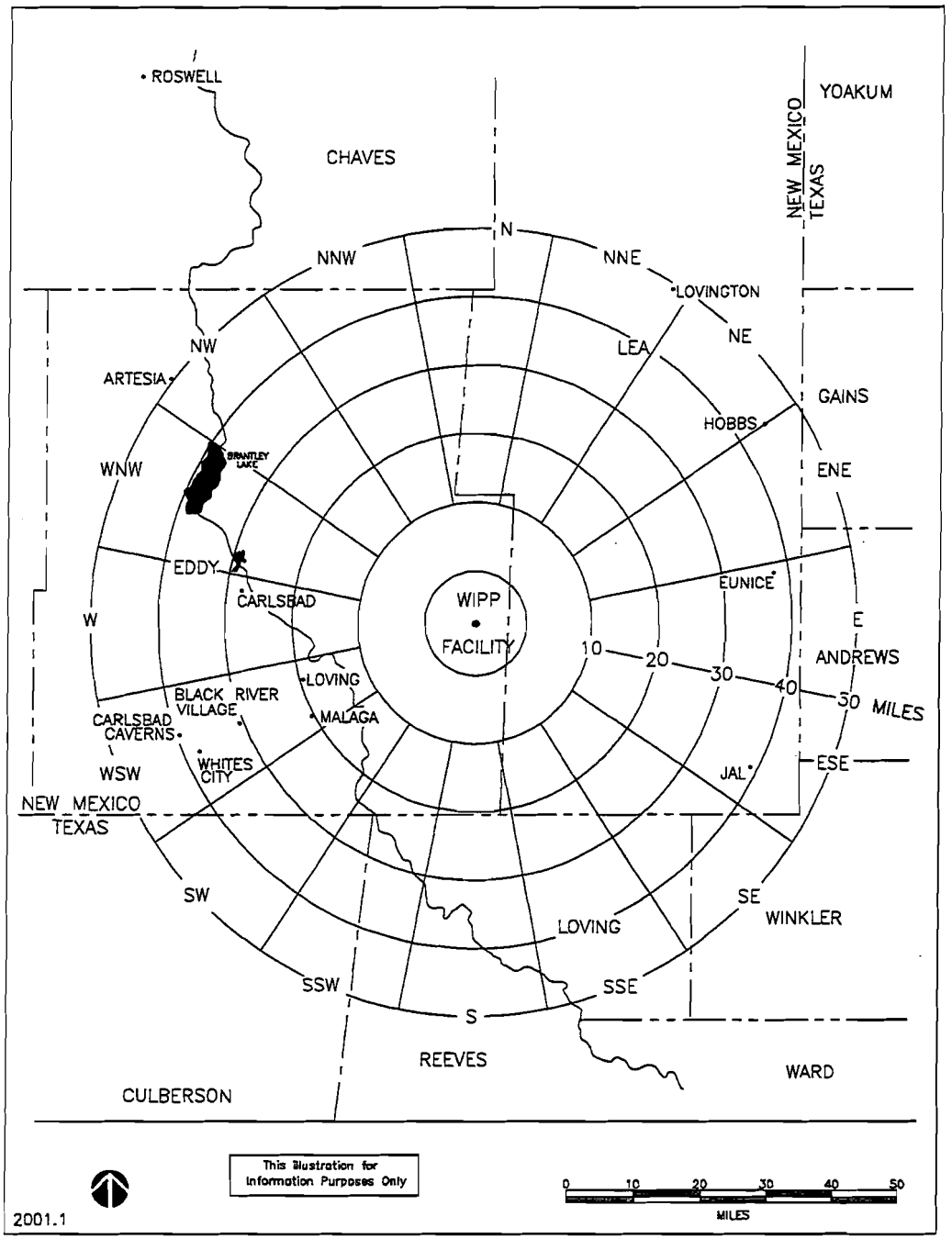

Figure 2.1-1, Region Surrounding the WIPP Facility

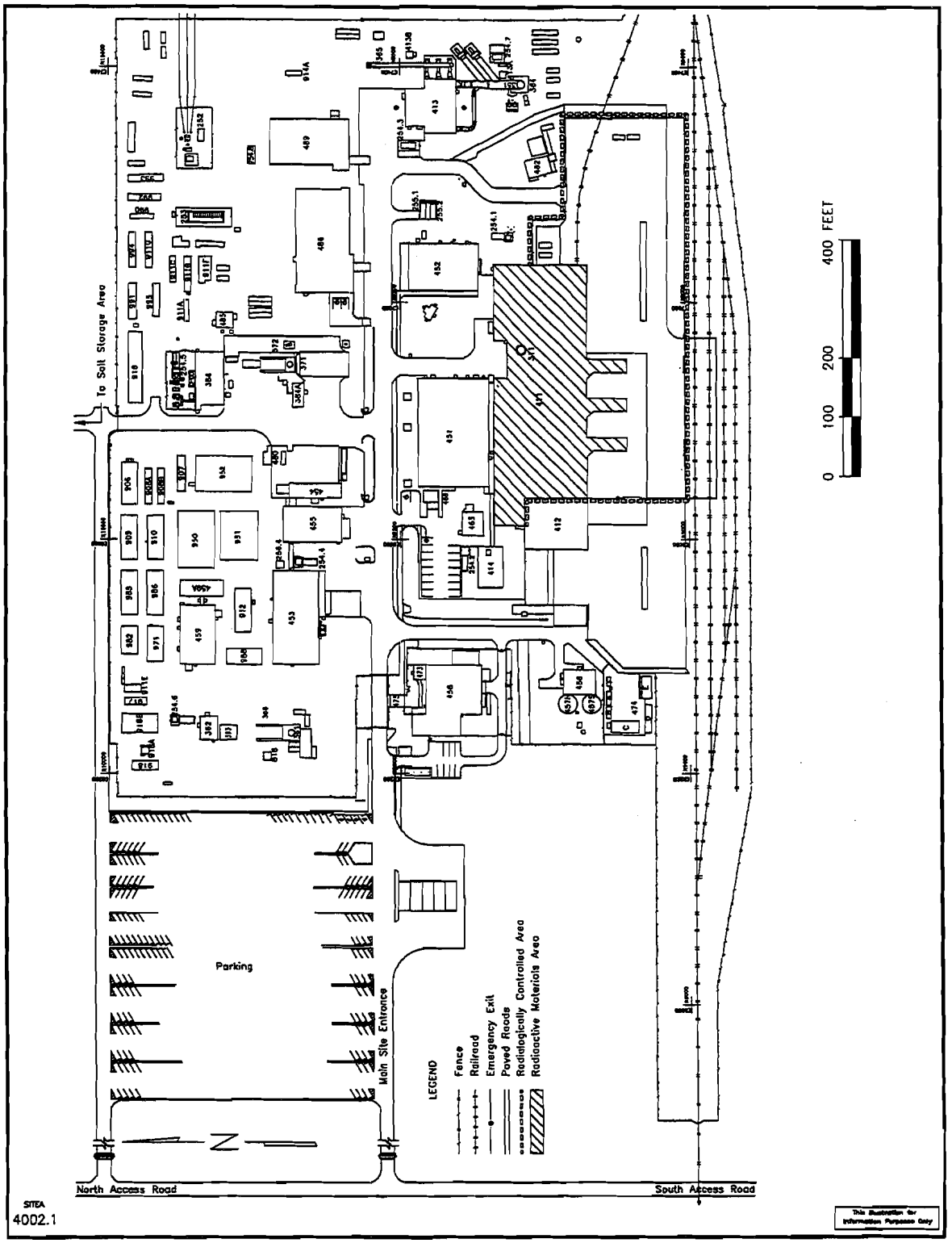

Figure 2.1-2a, WIPP Surface Structures

4003.3

BLDG./ FAC. #	DESCRIPTION
252	SPS UTILITY SUBSTATION
253	13.8 KV SWITCHGEAR 25P-SWG15/1
254.1	AREA SUBSTATION NO.1 25P-SW15.1
254.2	AREA SUBSTATION NO.2 25P-SW15.2
254.3	AREA SUBSTATION NO.3 25P-SW15.3
254.4	AREA SUBSTATION NO.4 25P-SW15.4
254.5	AREA SUBSTATION NO.5 25P-SW15.5
254.6	AREA SUBSTATION NO.6 25P-SW15.6
254.7	AREA SUBSTATION NO.7 25P-SW15.7
254.8	AREA SUBSTATION NO.8 25P-SW15.8
255.1	EMERGENCY GENERATOR #1 25-PE 503
255.2	EMERGENCY GENERATOR #2 25-PE 504
311	WASTE SHAFT
351	EXHAUST SHAFT
361	AIR INTAKE SHAFT
362	AIR INTAKE SHAFT/HOIST HOUSE
363	AIR INTAKE SHAFT/WINCH HOUSE
364	EFFLUENT MONITORING INSTRUMENT SHED A
365	EFFLUENT MONITORING INSTRUMENT SHED B
366	AIR INTAKE SHAFT HEADFRAME
371	SALT HANDLING SHAFT
372	SALT HANDLING SHAFT HEADFRAME
384	SALT HANDLING SHAFT HOISTHOUSE
384A	SALT HOIST OPERATIONS
411	WASTE HANDLING BUILDING
412	TRUPACT MAINTENANCE BUILDING
413	EXHAUST FILTER BUILDING
413A	EFFLUENT MONITORING ROOM A
413B	EFFLUENT MONITORING ROOM B
414	WATER CHILLER FACILITY & BLDG
451	SUPPORT BUILDING
452	SAFETY & EMERGENCY SERVICES FACILITY
453	WAREHOUSE/SHOPS BUILDING
454	VEHICLE SERVICE BUILDING
455	AUXILLIARY WAREHOUSE BUILDING

BLDG./ FAC. #	DESCRIPTION
456	WATER PUMPHOUSE
457N	WATER TANK 25-D-001A
457S	WATER TANK 25-D-001B
458	GUARD AND SECURITY BUILDING
459	CORE STORAGE BUILDING
459A	SANDIA ANNEX
463	COMPRESSOR BUILDING
465	AUXILIARY AIR INTAKE
468	TELEPHONE HUT
473	ARMORY BUILDING
474	HAZARDOUS WASTE STORAGE FACILITY
474A	HAZARDOUS WASTE STORAGE BUILDING
474B	HAZARDOUS WASTE STORAGE BUILDING
474C	OIL & GREASE STORAGE BUILDING
474D	GAS BOTTLE STORAGE BUILDING
474E	HAZARD MATERIAL STORAGE BUILDING
474F	WASTE OIL RETAINER
475	GATEHOUSE
480	VEHICLE FUEL STATION
482	EXHAUST SHAFT HOIST EQUIP. WAREHOUSE
485	SULLAIR COMPRESSOR BUILDING
486	ENGINEERING BUILDING
489	TRAINING BUILDING
816	SANDIA TEST WELL (NOT IDENTIFIED)
906	UNDERGROUND OPERATIONS TRAILER
907	TRANS. & HAZ. MATERIAL HANDLING TRAILER
908A	ENVIRONMENTAL MONITORING LAB TRAILER
908B	UNIVERSITY CONSORTIUM TRAILER
909	PROJECT CONTROL TRAILER
910	ENVIRONMENTAL MONITORING TRAILER
911A	SITE LOCKSMITH TRAILER
911B	SANDIA M101 TRAILER
911C	SANDIA OFFICES TRAILER
911E	SANDIA TRAILER
911F	SANDIA B49 AND B49 ANNEX

BLDG./ FAC. #	DESCRIPTION
911G	SANDIA LABS TRAILER
912	TRAINING TRAILER
914A	TRAINING TRAILER
915	NEW MEXICO ENVIR. DEPT. TRAILER
916	SANDIA OFFICES TRAILER
917	AIS MONITORING
918	VOC TRAILER
918A	VOC AIR MONITORING STATION
918B	VOC LAB TRAILER
950	WORK CONTROL TRAILER
951	PROCUREMENT / PURCHASING
952	TRAILER (7-PLEX)
971	HUMAN RESOURCES TRAILER
982	MAINTENANCE TRAILER
985	QA TRAILER
986	PUBLICATIONS & PROCEDURES TRAILER
988	TRAINING TRAILER
991	SANDIA OFFICES TRAILER
992	SANDIA CALIBRATION LAB TRAILER
993	SANDIA OFFICES TRAILER
994	SANDIA LAB TRAILER
995	SANDIA QA RECORDS TRAILER
SWR NO.1	SWITCHRACK NO. 1
SWR NO.2	SWITCHRACK NO. 2
SWR NO.3	SWITCHRACK NO. 3
SWR NO.4	SWITCHRACK NO. 4
SWR NO.6	SWITCHRACK NO. 6
SWR NO.7,7A,7B	SWITCHRACK NO. 7, 7A, 7B
SWR NO.7C	SWITCHRACK NO. 7C
SWR NO.8	SWITCHRACK NO. 8
SWR NO.9	SWITCHRACK NO. 9
SWR NO.10	SWITCHRACK NO. 10
SWR NO.11	SWITCHRACK NO. 11
--	SANDIA GENERATOR NO.1
--	SANDIA GENERATOR NO.2

Figure 2.1-2b, Legend for Figure 2.1-2a

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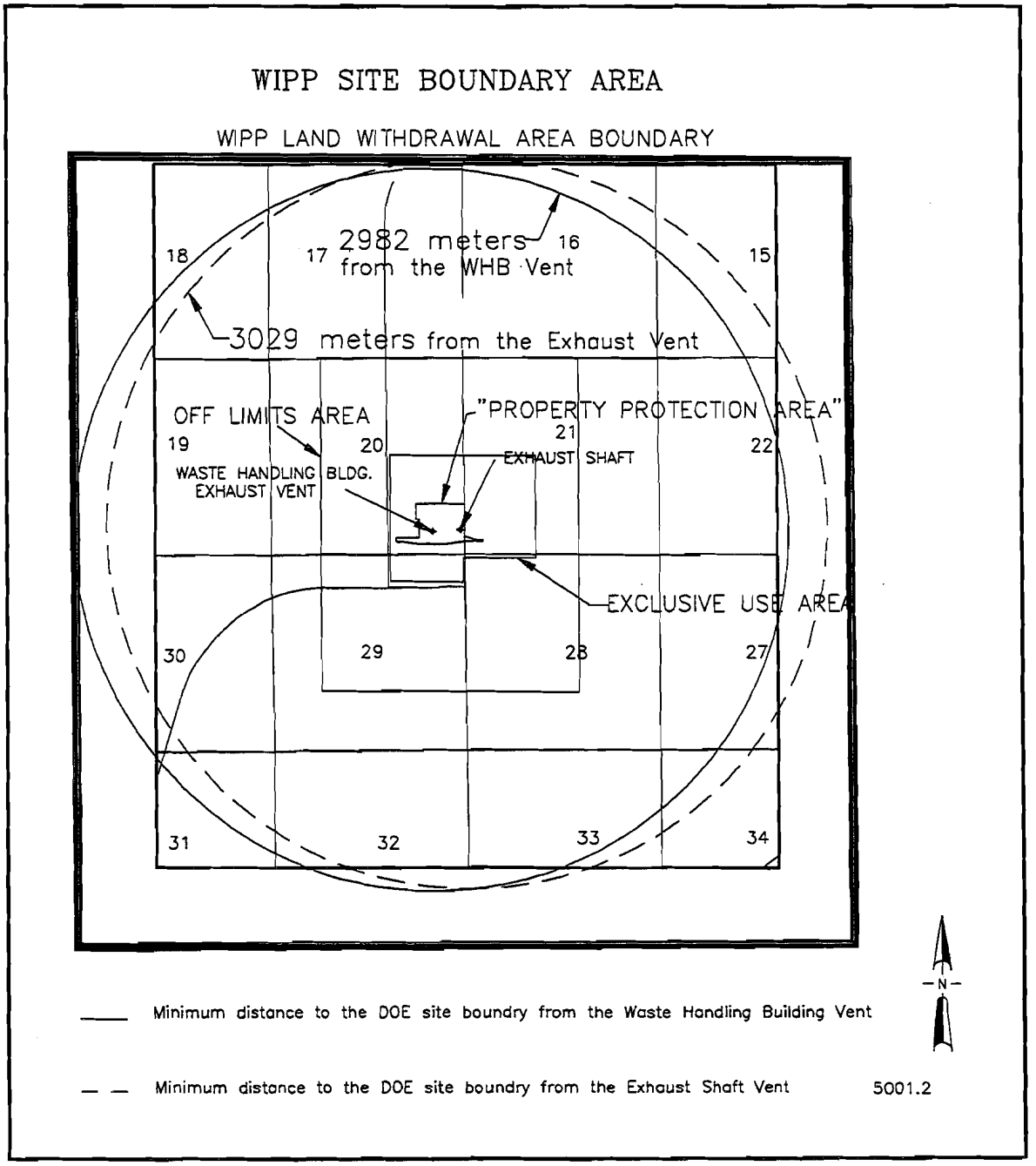

Figure 2.1-3, WIPP Facility Boundaries

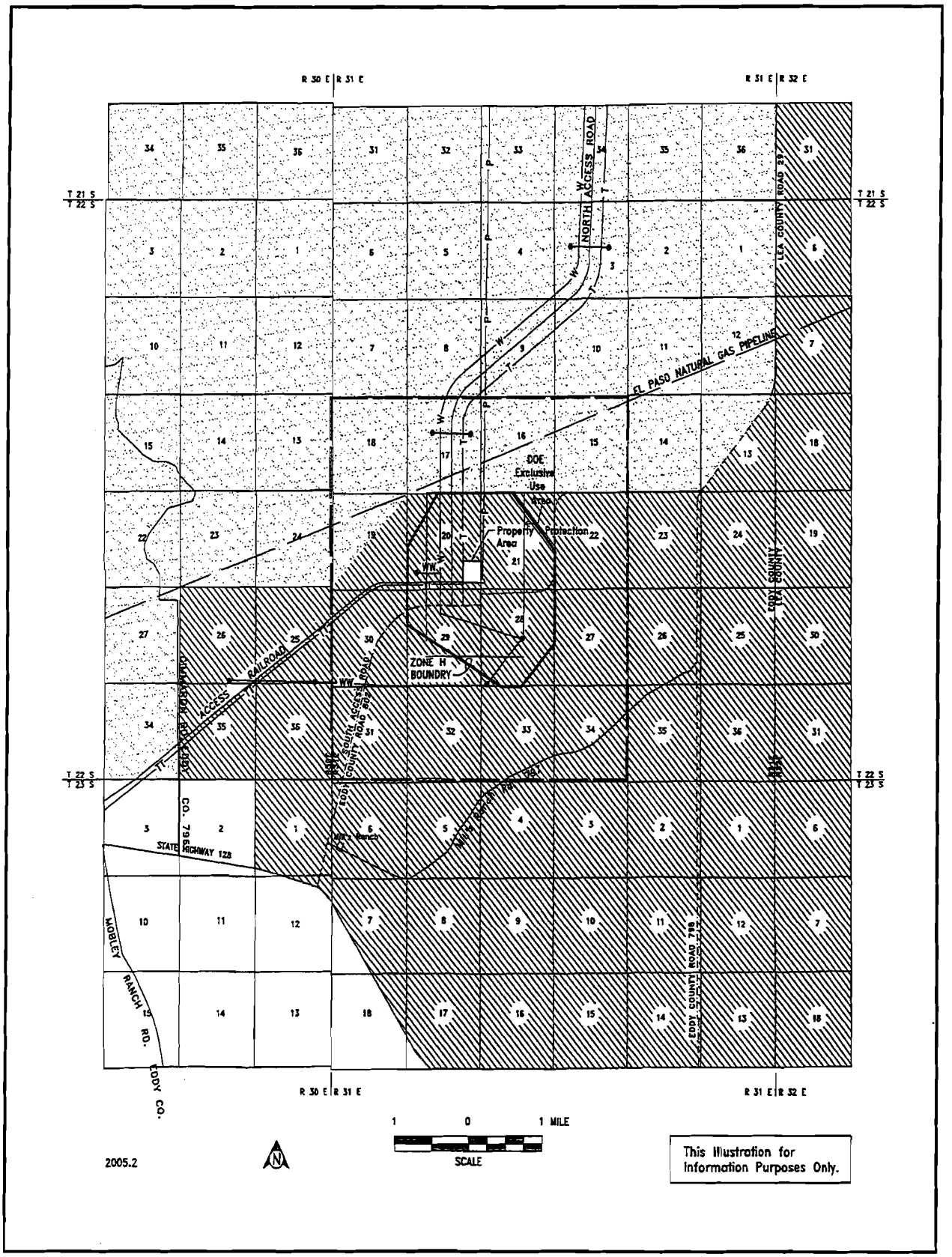

Figure 2.1-4, Grazing Leases Within the WIPP Site Boundary

LEGEND

WIPP SITE BOUNDARY 10,240 ACRES.

U.S. DOE RIGHT OF WAY NUMBER NM-53809, FOR WATERLINE. 50 FEET WIDE. THE DOE HAD AGREED WITH THE CITY OF CARLSBAD TO ALLOW THE INDIVIDUALS TO TAP THIS LINE LOCATED WITHIN THE NORTH ACCESS ROAD RIGHT OF WAY.

STOCK WATER TANKS AND TAP LINES CONNECTED TO THE MAIN WIPP WATERLINE.

SOUTHWESTERN PUBLIC SERVICE COMPANY RIGHT OF WAY NUMBER NM-43203 FOR POWERLINE 60 FEET WIDE.

GENERAL TELEPHONE OF THE SOUTHWEST RIGHT OF WAY FOR TELEPHONE LINE, 30 FEET WIDE, LOCATED WITHIN THE NORTH ACCESS ROAD RIGHT OF WAY.

GENERAL TELEPHONE OF THE SOUTHWEST RIGHT OF WAY NUMBER NM-60174 FOR TELEPHONE LINE, 30 FEET WIDE, LOCATED WITHIN THE RAILROAD RIGHT OF WAY.

U.S. DOE RIGHT OF WAY NUMBER NM-55675 FOR NORTH ACCESS ROAD, 170 FEET WIDE.

EL PASO NATURAL GAS COMPANY RIGHT OF WAY FOR GAS PIPELINE. 30 FEET WIDE IN SECTION 16, 50 FEET WIDE ELSEWHERE.

U.S. DOE RIGHT OF WAY NUMBER NM-55699 FOR ACCESS RAILROAD, 150 FEET WIDE.

EDDY COUNTY RIGHT OF WAY FOR ACCESS ROADS INCLUDES RIGHT OF WAY NUMBER NM-4130 FOR THE SOUTH ACCESS ROAD WHICH IS 150 FEET WIDE.

J.C. MILLS, ABERNATHY, TEXAS. GRAZING LEASE.

KENNETH SMITH, CARLSBAD, NEW MEXICO. GRAZING LEASE.

W.L. MOBLEY, CARLSBAD, NEW MEXICO. GRAZING LEASE.

NOTES

1. ZONE I IS A FENCED AREA OF APPROXIMATELY 35 ACRES. IT CONTAINS ALL SURFACE FACILITIES WITH THE EXCEPTION OF SALT STORAGE PILES, PARKING LOT, LANDFILL AND WASTE WATER STABILIZATION LAGOONS.
2. ZONE II OVERLIES THE MAXIMUM EXTENT OF THE AREA AVAILABLE FOR UNDERGROUND DEVELOPMENT. THE PORTION OF ZONE II LOCATED OUTSIDE THE DOE EXCLUSIVE USE AREA IS PRESENTLY MANAGED BY THE BLM.
3. WIPP SITE BOUNDARY (WSB) PROVIDES A ONE MILE BUFFER AREA AROUND THE AREA AVAILABLE FOR UNDERGROUND DEVELOPMENT. PORTIONS OF WSB ARE PRESENTLY MANAGED BY THE BLM.

2806.1

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Figure 2.1-4b, Legend

2.2 Nearby Industrial, Transportation and Military Facilities

The extractive activities, transportation routes, and military operations that may have a potential affect on operations at the WIPP facility are discussed in this section.

2.2.1 Industrial and Commercial Facilities

There are no industrial facilities within a five-mile radius of the WIPP facility. Ranching is the only commercial operation within five miles of the facility, with the exception of oil and gas related activities. The five-mile radius encompasses grazing allotments of three separate ranches; however, only one ranch house is located in the area. It is about 3.5 miles from the center of the WIPP facility in the south southwest sector. There are three potash mines and two chemical processing plants (adjacent to the mines) between five and 10 miles of the WIPP facility.

2.2.2 Extractive Activities

Within a five mile radius from the center of the WIPP Land Withdrawal Area (LWA), both oil and gas are extracted from the Salado formation. The majority of the newer wells produce oil and gas from the Brushy Canyon formation of the Delaware Mountain Group. Gas wells typically produce from the deeper Pennsylvanian-age formations (Atoka, Strawn, and Morrow formations). As of April 1995, there were 136 oil wells (some which produce both oil and gas), 21 gas wells, and 21 plugged wells within five miles of the Land Withdrawal Act (LWA) boundary (Figure 2.2-2a). These wells are stratigraphically below the repository horizon. There are likewise an additional 292 oil wells, 47 gas wells, and 83 plugged wells within ten miles of the LWA boundary (Figure 2.2-1). The plugged wells include both wells that are considered "dry holes" and wells that are no longer productive and have been permanently sealed.

Besides the oil and gas extractive activities, there are four active potash mines within ten miles of the WIPP LWA. Potash is extracted from the McNutt Potash member which is stratigraphically above the WIPP repository horizon.

2.2.3 Oil and Gas Pipelines

There are no crude oil pipelines within five miles of the WIPP facility. There are, however, 16 natural gas pipelines located within a five-mile radius of the WIPP facility. Many producing wells within the ten mile radius of the WIPP are connected to tank batteries by gathering systems of flexible, plastic tubing. These lines are typically buried at the time of installation; however, there are areas where these lines rest upon the surface of the ground. They carry a mixture of crude oil, natural gas, and produced waters. At the accumulation tanks, these fluids are separated, and the gas is then fed into pipelines. Thirteen of these pipelines have right-of-way lease permits issued by the U.S. Department of the Interior (DOI), Bureau of Land Management (BLM) for access to federal land, while four have permits issued by the State of New Mexico, State Land Office, for access to state lands. Two pipelines require both federal and state right-of-way lease permits. There is one pipeline located on federal land for which no right-of-way lease permit information is available.

The natural gas pipelines are owned and operated by three companies:

- El Paso Natural Gas Company, El Paso, Texas;
- Natural Gas Pipeline Company of America, Chicago, Illinois;
- Transwestern Pipeline Company, Roswell, New Mexico.

Figure 2.2-2 shows the location of each pipeline within five miles of the WIPP facility, along with pertinent information regarding each pipeline.

One major non-oil or gas pipeline lies within the WIPP Site Boundary. This is a 10 inch City of Carlsbad water pipeline that provides the WIPP facility with potable water.

2.2.4 Waterways

There are no navigable waterways within a five-mile radius of the WIPP facility. The nearest river is the Pecos River which is 12 miles west of the WIPP facility.

2.2.5 Military Facilities

There are no military facilities within a five-mile radius of the WIPP facility. Holloman Air Force Base is the nearest military facility to the WIPP Site and is located 138 miles to the northwest.

2.2.6 Airports and Aviation Routes

There are no airports within a ten-mile radius of the site. The nearest airstrip, 12 miles north of the WIPP facility, is privately operated by Transwestern Pipeline Company. The nearest commercial airport is Cavern City, 28 miles west of the WIPP facility near Carlsbad. Other airports in the area are Eunice (32 miles east), Carlsbad Caverns (42 miles southwest), Hobbs Airport (42 miles northeast), Jal (40 miles southeast), Lovington (50 miles northeast), and Artesia (51 miles northwest). The relationship of these airports to the WIPP facility is shown in Figure 2.2-3.

Portions of two federal airways are within five miles of the WIPP facility. Each airway is 10 miles wide. The centerline of low altitude airway V-102 is three miles northwest of the WIPP facility and high altitude airway J-15 is four miles northeast of the WIPP facility at their nearest points. These airways are shown in Figure 2.2-3. Traffic data for these airways are given in Table 2.2-1. The combined traffic on both routes is about 28 Instrument Flight Rule (IFR) flights per peak day. There are no approach or landing zones within five miles of the WIPP facility.

2.2.7 Land Transportation

2.2.7.1 Roads and Highways

Other than the highways that provide north or south access, only one other highway lies within a five-mile radius. This is New Mexico Highway 128, which is between four and five miles southwest of the WIPP facility (Figure 1.2-1). It connects the small community of Jal with NM 31, which leads into Loving and it provides access to Carlsbad. New Mexico Highway 128 is used by ranchers, school buses, potash miners, and by oil and gas company vehicles occasionally transporting drilling rigs (wide loads) to sites in the area. In 1985, it had an average daily traffic flow of about 400 vehicles. Several dirt roads in the area are maintained for ranching, pipeline maintenance, and access to drilling sites.

2.2.7.2 Railroads

Except for the rail spur that serves the WIPP facility, there are no railroad lines within the five-mile radius of the WIPP facility. Rail lines to Western Ag-Minerals Corp. Nash Draw operation, International Minerals and Chemical Corp., and the New Mexico Potash Corp. plant, all potash mining operations, are located between six and 10 miles of the WIPP facility. All railroad lines within the general vicinity of the WIPP facility are used specifically to transport potash ore.

2.2.8 Projected Industrial Growth

While no industrial activity occurs within five miles of the WIPP facility, active potash mining is occurring. These ores are extracted from the Salado formation but are brought to the surface further than five miles from the WIPP. Other extractive activities are oil and gas production (as detailed in section 2.2.2). No extractive activity is allowed within the LWA with the exception of section 31 (the southwest corner section of the LWA). There is currently one gas well producing from that section below the 6000 foot land withdrawal designation. This well was slant drilled from section 6 of township 23 South. The other fifteen sections of the LWA are withdrawn to the center of the earth. Other permit applications for slant drilling into section 31 from outside sections have been denied by the BLM.

Three potash mining operations located around the WIPP facility were contacted concerning their anticipated growth. If these operations expand, there is a possibility that at least two new shafts will be sunk in the approximate two to five miles radius. Plans for expansion are not firm because they are dictated in most cases by the market conditions for potash. Even if this expansion were to occur, it would not pose a safety risk for the WIPP facility since surface and underground operations would be restricted to areas outside the WIPP Site Boundary.

Except for the possible potash mining expansion discussed above, no significant increase in economic activity is forecast for the future within five miles of the WIPP facility.

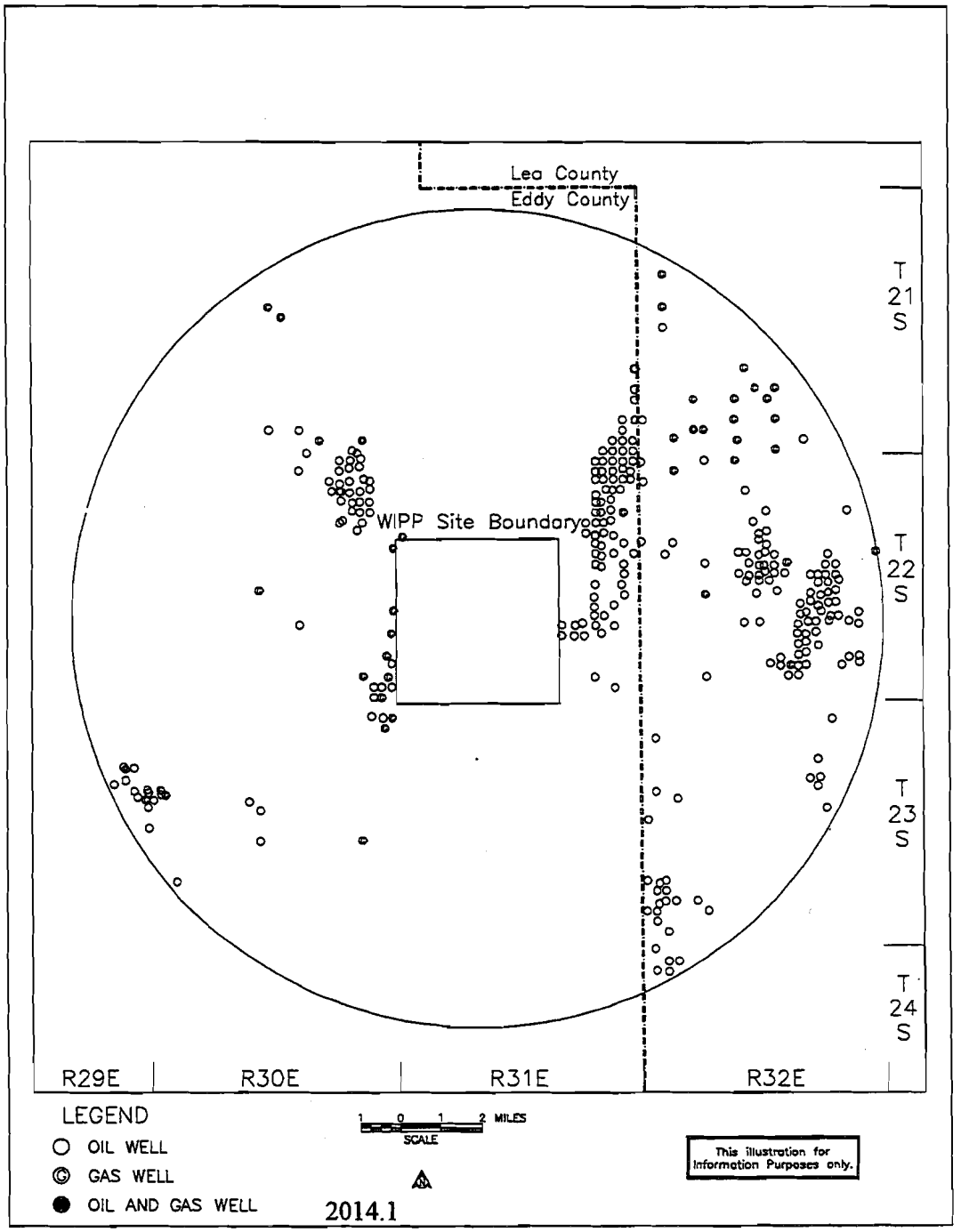

Figure 2.2-1, 1995 Operable Natural Gas and Oil Wells, 10 Mile Radius

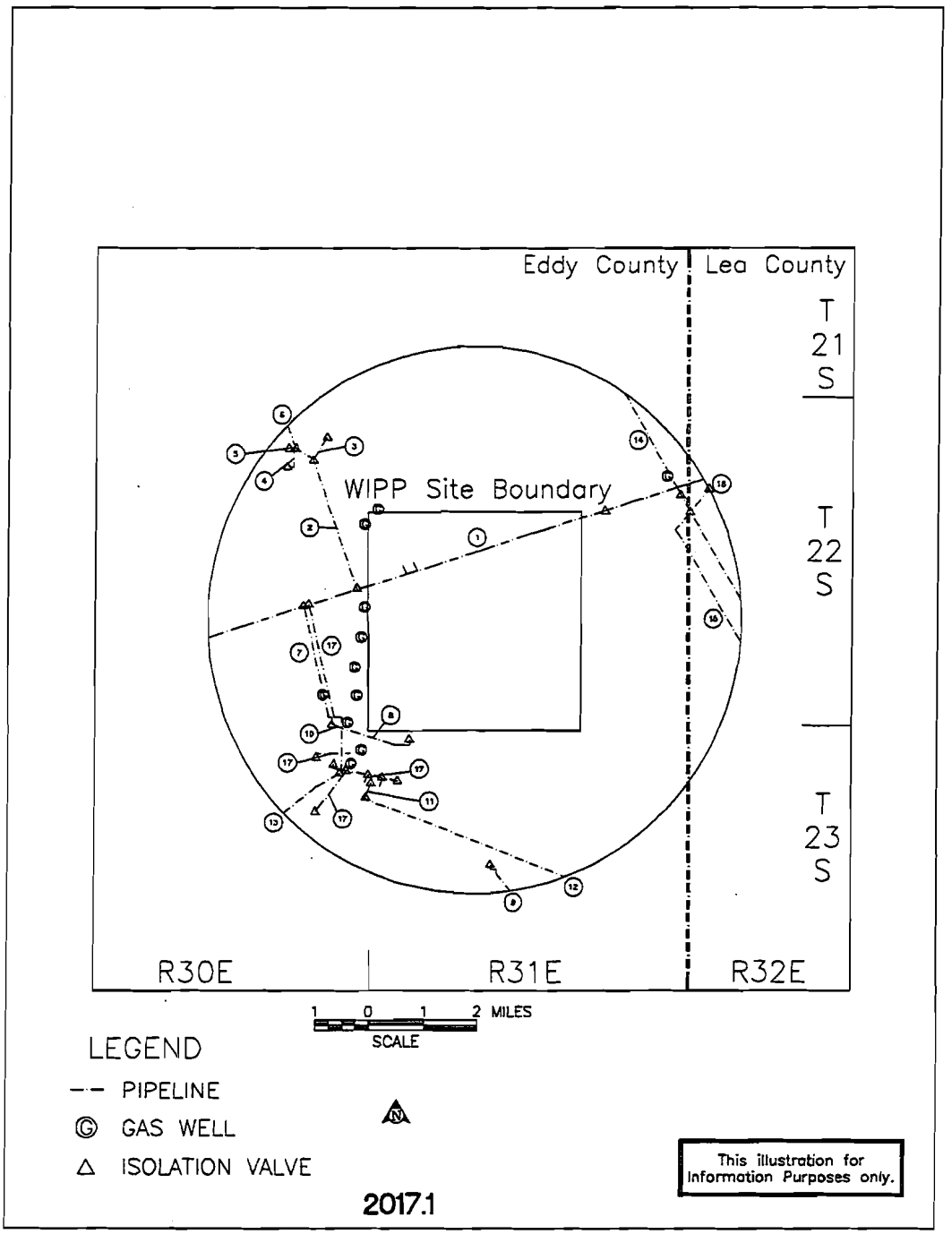

Figure 2.2-2a, 1995 Natural Gas Pipelines and Wells, 5 Mile Radius

Figure 2.2-2b, Explanation to Figure 2.2-2a

1. El Paso Natural Gas Co., Eunice-Carlsbad Line (LC060762) 12.75" Dia Gas Line, Built 1942, Located 1.125 miles NNW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

2. El Paso Natural Gas Co., James "A" No. 1 (NM17321) 4.5"/8.625" Dia Gas Line, Built 1974, Located 2.375 miles WNW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

3. El Paso Natural Gas Co., Cabana No. 1 (NM18432) 4.5" Dia Gas Line, Built 1974, Located 4.25 miles NW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

4. El Paso Natural Gas Co., James "E" No. 1 (NM19974) 4.5" Dia Gas Line, Built 1974, Located 4.25 miles NW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

5. El Paso Natural Gas Co., El Paso "201" Spur Line (NM20125) 4.5" Dia Gas Line, Built 1974, Located 4.625 miles NW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

6. El Paso Natural Gas Co., James "C" No. 1 (RW18344) 6.625" Dia Gas Line, Built 1974, Located 4.625 miles NW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

7. El Paso Natural Gas Co., James Ranch Unit No. 1 (NM046228) (RW14190) 4.5" Dia Gas Line, Built 1958, Located 3.06125 miles WSW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

8. El Paso Natural Gas Co., James Ranch Unit No. 7 (NM26987) 4.5" Dia Gas Line, Built 1976, Located 2.625 miles SW of WIPP. Operating Pressure 721 PSIG, Burial Depth 24".

9. El Paso Natural Gas Co., Arco State No. 1 (RW17822) 6.625" Dia Gas Line, Built 1971, Located 4.625 miles S of WIPP. Operation Pressure 837, Burial Depth 24".

10. El Paso Natural Gas Co., Lateral EE-4 (NM16959/(RW18065) 4.5" Dia Gas Line, Built 1973, Located 3.125 miles SW of WIPP. Operating Pressure 1200 PSIG, Burial Depth 36".

11. Natural Gas Pipeline Co. Of America, Lateral EE-6 Built 1974, 4.5" Dia Gas Line, Built 1974, Located 3.2 miles SSW of WIPP. Operating Pressure 1200 PSIG, Burial Depth 36".

12. Natural Gas Pipeline Co. Of America, Lateral EE-3 (NM16029) 8.625" Dia Gas Line, Built 1972, Located 3.4 miles SSW of WIPP. Operating Pressure 1200 PSIG, Burial Depth 36".

13. Natural Gas Pipeline Co. Of America, Lateral EE-7 (NM22471) 4.5" Dia Gas Line, Built 1974, Located 4.7 miles SW of WIPP. Operating Pressure 1200 PSIG, Burial Depth 36".

14. Transwestern Pipeline Co., West Texas Lateral (NM070224) 24" Dia Gas Line, Built 1960, Located 4.5 miles ENE of WIPP. Operating Pressure 1200 PSIG, Burial Depth 30".

15. Transwestern Pipeline Co., West Texas Lateral (NM8722) 30" Dia Gas Line, Built 1969, Located 4.25 miles ENE of WIPP. Operating Pressure 930 PSIG, Burial Depth 30".

16. Transwestern Pipeline Co., Monument Lateral (NM073482) 10" Dia Gas Line, Built 1960, Located 4.5 miles ENE of WIPP. Operating Pressure 930 PSIG, Burial Depth 30".

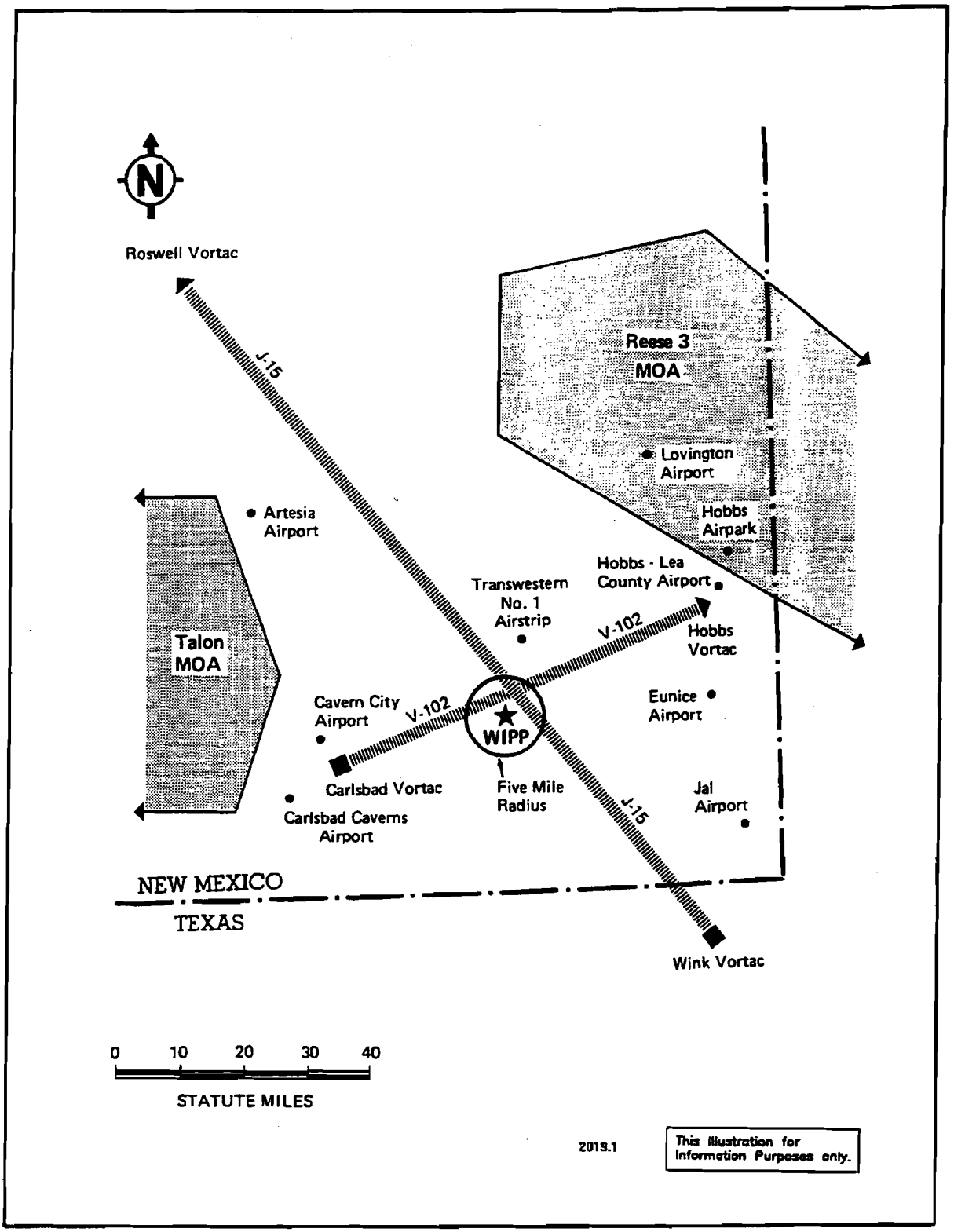

Figure 2.2-3, Airports and Aviation Routes Adjacent to the WIPP Facility

Table 2.2-1, Aviation Routes Within 5 Miles of the Wipp Facility*

Name of Route	Altitude	Destination	Minimum Type	Origin and Flights/Day	Aircraft Flight Rule
FAA V-102	3,000 ft AGL	Carlsbad VORTAC Hobbs VORTAC	Commercial, military, and private	5**	IFR
FAA J-15	18,000 ft MSL	Wink VORTAC Roswell VORTAC	Commercial military, and private	23	IFR

*U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Service, "En Route IFR Peak Day Charts, FY 1976."

**Flights per day on V-102 does not include aircraft operating under Visual Flight Rules.

NOTE: 1976 was the last year day charts were logged by FAA. Local airfield does not monitor this information.

2.3 Resources

The topic of resources is used to broadly define both economic (mineral and non-mineral) and cultural resources associated with the WIPP site. These resources are important since they (1) provide evidence of past uses of the area, and (2) indicate potential future use of the area with the possibility that such use could lead to disruption of the closed repository. Because of the depth of the disposal horizon, it is believed that only the mineral resources are of significance in predicting the long-term performance of the disposal system. However, the non-mineral and cultural resources are presented for completeness.

Mineral resource discussions are focused principally on hydrocarbons and potassium salts, both of which have long histories of development in the region and the exploration for and production of which could be disruptive to the disposal system. The information regarding the mineral resources concentrates on the following factors:

- Number, location, depth, and present state of development including penetrations through the disposal horizon
- Type of resource
- Accessibility, quality, and demand
- Mineral ownership in the area.

The discussion of cultural and economic resources is focused on describing past and present land uses unrelated to the development of minerals. The archaeological record supports the observation that changes on land use are principally associated with climate and the availability of forage for wild and domestic animals. In no case does it appear that past or present land use has had an impact on the subsurface beyond the development of shallow groundwater wells to water livestock.

2.3.1 Extractable Resources

Geologic studies of the WIPP site have included an investigation of potential natural resources to evaluate the impact of denying access to these resources as well as other consequences of their occurrence. Studies were conducted in support of the Final Environmental Impact Statement (FEIS)[1] to assure knowledge of minerals and resources and the impacts of their denial was included in the decision-making process for WIPP. Of the mineral resources expected to occur beneath the site, five are of practical concern: the potassium salts sylvite and langbeinite, which occur in strata above the repository horizon, and hydrocarbons (crude oil, natural gas, and distillate liquids associated with natural gas), which occur in strata below the repository horizon. Other mineral resources beneath the site are caliche, salt, gypsum (Open-file Report 87),[2] and lithium (SAND77-0946);[3] enormous deposits of these minerals near the site and elsewhere in the country are more than adequate (and more economically attractive) to meet future requirements for these materials (SAND78-1596).[4] The NMBMMR[5] recently completed a comprehensive reevaluation of the mineral resources within the first mile immediately adjacent to the WIPP site.

2.3.1.1 Potash Resources at the WIPP Site

Throughout the Carlsbad Potash Mining District, commercial quantities of potassium salts are restricted to the middle portion of the Salado, the McNutt Potash Member. A total of 11 zones (or distinct ore layers) have been recognized in the McNutt. Horizon Number 1 is at the base, and Number 11 is at the top. The 11th ore zone is not mined.

The United States Geological Survey (USGS) uses three established standard grades: low, lease, and high, to quantify the potash resources at the site (USGS Open-file Report).[6] The USGS assumes that the "lease" and "high" grades comprise reserves because some lease-grade ore is mined in the Carlsbad district. Most of the potash that is mined, however, is better typified by the high grade. Even the high-grade resources may not be reserves, however, if their properties make processing uneconomic.

Griswold NMBMMR[5] used 40 existing drill holes on and around the WIPP site to perform a re-evaluation of potash resources. He selected holes that were drilled using brine so that the dissolution of potassium salts was inhibited. The DOE has concluded that only the 4th and 10th ore zones contain economically attractive potash reserves based on NMBMMR.[5] The quantities are summarized in Table 2.3-1.

2.3.1.2 Potash Mining in the Carlsbad Resource Area

There are five operating potassium mineral operations in Eddy and Lea Counties. These mines lease about 120,000 acres of Federal mineral rights and 89,697 acres in State mineral rights. The closest mine to the WIPP site is approximately 10 miles (16 kilometers). During the 1994 fiscal year for potash mines, 13,040,000 tons of ore were mined to produce 2,449,000 tons of potassium mineral fertilizers. This is approximately 81 percent of United States' production. This industry employs about 1,800 persons in the direct mining and recovery of minerals, making it the area's major employer (U.S. Bureau of Mines [USBM];[7] Energy, Mineral, Resource Department [EMRD] of New Mexico).[8]

2.3.1.3 Hydrocarbon Resources at the WIPP Site

In 1974 Foster of the NMBMMR conducted a hydrocarbon resource study in southeastern New Mexico under contract to the ORNL. The study included an area of 1,512 square miles (3,914 square kilometers). At the time of that study, the proposed repository site was about 5 miles (8 kilometers) northeast of the current site. The 1974 NMBMMR evaluation included a more detailed study of a four-township area centered on the old site; the present site is in the southwest quadrant of that area. The 1974 NMBMMR hydrocarbon resources study is presented in more detail in the FEIS (DOE/EIS-0026).[9] The reader is referred to the FEIS or the original study (AF[40-1]-4423)[10] for additional information.

The NMBMMR[5] mineral resource re-evaluation contains a comprehensive summary of all previous evaluations.

Broadhead et al. NMBMMR[5] provided a reassessment of hydrocarbon reserves within the WIPP site boundary and within the first mile adjacent to the boundary. Calculations were made for reserves that are extensions of known, currently productive oil and gas reserves that are thought to extend beneath the study area with reasonable certainty (called probable resources in the report). Qualitative estimates are also made concerning the likelihood that oil and gas may be present in undiscovered pools and fields in the area (referred to as possible reserves). Possible resources were not quantified in the study. The results of the study are shown in Tables 2.3-2 and 2.3-3.

2.3.2 Demographics

The WIPP is located in the Southeastern part of Eddy County, near Lea County. The population density of Eddy County is 11.63 persons per square mile; the Lea County population density is 12.69 persons per square mile (Census of Population).[11]

Demographics for the communities surrounding the WIPP site are listed below, by county.

EDDY COUNTY

Community	Population	Location Relative to the WIPP Site
Artesia	10,610	53 miles (86 kilometers) northwest
Carlsbad	24,896	26 miles (42 kilometers) west
Loving	1,243	18 miles (29 kilometers) west-southwest
Total Eddy County	48,605	

LEA COUNTY

Community	Population	Location. Relative to the WIPP Site
Eunice	2,731	40 miles (64 kilometers) east
Hobbs	29,115	40 miles (64 kilometers) east
Jal	2,153	45 miles (72 kilometers) southeast
Lovington	9,322	50 miles (80.5 kilometers) northeast
Total Lea County	55,765	

2.3.2.1 Land Use at the WIPP Site

At present, land within 10 miles (16 kilometers) of the site is used for potash-mining operations, active oil and gas wells, and grazing. This pattern is expected to change little in the future.

The *Waste Isolation Pilot Plant Land Withdrawal Act* (LWA) (Public Law 102-579),[12] provides the DOE with lands for operation of the WIPP project. The law provides for the transfer of the WIPP site lands from the Department of the Interior (DOI) to the DOE and effectively withdraws the lands, subject to existing rights, from entry, sale, or disposition; appropriation under mining laws; and operation of the mineral and geothermal leasing laws. The LWA directed the Secretary of Energy to produce a management plan to provide for grazing, hunting and trapping, wild life habitat, the disposal of salt, and tailings and mining (PTB).[13]

There are no hydrocarbon production wells within the volumetric boundary defined by the LWA. One active well, referred to as James Ranch 13, was drilled in 1982 to tap gas resources beneath Section 31. This well was initiated in Section 6, outside the WIPP site boundary. The well enters Section 31 below a depth of 6,000 feet (1,829 meters) beneath ground level (PTB).[13]

Grazing leases have been issued for all land sections immediately surrounding the WIPP (PTB).[13] Grazing within the WIPP site lands operates within the authorization of the Taylor Grazing Act of 1934, the Federal Land Policy and Management Act (FLPMA), the Public Rangelands Improvement Act of 1978, and the Bankhead-Jones Farm Tenant Act of 1973. The responsibilities of the DOE include supervision of ancillary activities associated with grazing (e.g., wildlife access to livestock water development, assure water developments inside WIPP lands are configured according to the regulatory requirements, etc.) and ongoing coordination with respective allottees. Administration of grazing rights shall be in cooperation with the BLM in accordance with an existing Memorandum of Understanding (MOU) and the coinciding Statement of Work through guidance established in the East Roswell Grazing Environmental Impact Statement (DOE/WIPP 94-2033).[14] Two grazing allotments administered by the BLM fall within the land withdrawal area: Livingston Ridge (No. 77027), and Antelope Ridge (No. 77032) (DOE/WIPP 93-004).[15]

2.3.2.2 Land Use in the Carlsbad Resource Area

Major land uses in the Carlsbad resource area include potash mining and oil and gas recovery (discussed previously), and ranching, farming, and tourism.

2.3.2.2.1 Ranching

There are 286 ranching units in the Carlsbad resource area (New Mexico Agricultural Statistics).[16] The approximate areas, in acres, are as follows:

County	Total	Federal	State	Deeded
Eddy	2,675,000	1,627,827	577,225	470,149
Lea	2,812,160	416,960	1,199,221	1,195,979

The number of livestock located on these ranching units will vary depending upon grazing conditions. However, the number of livestock (in heads) for the Carlsbad resource area as reported in the 1993 *New Mexico Agricultural Statistics*[16] are:

County	Cattle	Dairy Herd	Sheep	Goats/ Horses/Pigs
Eddy	25,000	9,100	12,000	1,200
Lea	22,000	7,200	5,800	1,560

2.3.2.2.2 Farming

There are approximately 160,000 acres of farmland in the Carlsbad resource area. The principal crops grown include cotton, alfalfa, and chile. There are also significant quantities of pecans grown in this area, and minor amounts of truck vegetables.

2.3.2.2.3 Tourism

There are two national parks (Guadalupe Mountains and Carlsbad Caverns), a national forest (Lincoln), and two state parks (Living Desert Zoo and Gardens, and Brantley) located within or near the Carlsbad resource area. The Carlsbad Caverns National Park, which is 36 miles (58 kilometers) southeast of the WIPP site, has approximately 1 million visitors per year. There are three dams on the Pecos River that provide recreational activities during the summer months. The closest surface water to WIPP (the Pecos River) is located about 12 miles (19 kilometers) away.

2.3.2.3 History and Archaeology

The WIPP site boundary consists of a 16-square-mile (10,240-acre) area located in southeastern New Mexico. From about 10,000 B.C. to the late 1800s, this region was inhabited by nomadic aboriginal hunters and gatherers who subsisted on various wild plants and animals (DOE/WIPP 94-026).[17] From about A.D. 600 onward, as trade networks were established with Puebloan peoples to the west, domesticated plant foods and materials were acquired in exchange for dried meat, hides and other products from the Pecos Valley and Plains. In the mid-1500s, the Spanish Conquistadors encountered Jumano and Apachean peoples in the region practicing hunting and gathering and engaging in trade with Puebloans (DOE/WIPP 93-017).[18] After the Jumanos abandoned the southern Plains region, the Comanches became the major population of the area. Neighboring populations, with whom the Comanches maintained relationships ranging from mutual trade to open warfare, included the Lipan, or Southern Plains Apache; several Puebloan groups; Spaniards; and the Mescalero Apaches (Report of Class II Survey and Testing).[19]

The best documented indigenous culture in the WIPP region is that of the Mescalero Apaches, who lived west of the Pecos. Their lifestyle represents a transition between the full sedentism of the Pueblos and the nomadic hunting and gathering of the Jumanos and Sumas. In 1763 the San Saba expedition encountered and camped with a group of Mescaleros in Los Medaños. Expedition records indicate the presence of both Lipan and Mescalero Apaches in the region (Report of Class II Survey and Testing).[19]

A peace accord reached between the Comanches and the Spaniards in 1768 resulted in two historically important economic developments: (1) organized buffalo hunting by Hispanic and Puebloan "ciboleros"; and (2) renewal and expansion of the earlier extensive trade networks by Comancheros. These events placed eastern New Mexico in a position to receive a wide array of both physical and ideological input from the Plains culture area to the east and north and from Spanish-dominated regions to the west and south. Comanchero trade began to mesh with the Southwest American trade influence in the early nineteenth century. However, Comanchero trade was cut short when the Lincoln County War erupted, after which, the region was dominated by Texan influence (Report of Class II Survey and Testing).[19]

The first cattle trail in the area was established along the Pecos river in 1866 by Charles Goodnight and Oliver Loving. By 1868, Texan John Chism dominated much of the area by controlling key springs along the river. Overgrazing, drought, and dropping beef prices led to the demise of open range cattle ranching by the late 1880s (Mariah Associates, Inc. 1987, §3.2.2).[19]

The transition from open range livestock production to ranching, which involved fenced grazing areas and production of hay crops for winter use, is an important historical issue in the arid west. Herd grazing patterns were influenced by the availability of water supplies as well as by the storage of summer grasses as hay for winter use.

The town now called Carlsbad was founded as "Eddy" in 1888 as a health spa. In addition to ranching, the twentieth century brought the development of the potash, oil, and gas industries that have increased the population eightfold in the last 50 years.

Although technological change has altered some of the aspects, ranching remains an important economic activity in the WIPP region. This relationship between people and the land is still an important issue in the area. Ranch-related sites which date to the 1940s and 50s are common in parts of the WIPP area. These will be considered historical properties within the next several years, and thus will be treated as such under current law (DOE/WIPP 93-017).[18]

The National Historic Preservation Act (NHPA; 16 USC 470 et seq.) was enacted to protect the nation's cultural resources in conjunction with the states, local governments, Indian tribes, and private organizations and individuals. The policy of the federal government includes (1) providing leadership in preserving the prehistoric and historic resources of the nation; (2) administering federally owned, administered, or controlled prehistoric resources for the benefit of present and future generations; (3) contributing to the preservation of non-federally owned prehistoric and historic resources; and (4) assisting state and local governments and the national trust for historic preservation in expanding and accelerating their historic preservation programs and activities. The act also established the National Register of Historic Places ("National Register"). At the state level, the State Historic Preservation Officer (SHPO) coordinates the state's participation in implementing the NHPA. The NHPA has been amended by two acts: the Archaeological and Historic Preservation Act (16 USC 469 et seq.), and the Archaeological Resource Protection Act (16 USC 470aa et seq.).

In order to protect and preserve cultural resources found within the WIPP site boundary, the WIPP submitted a mitigation plan to the New Mexico SHPO describing the steps to be taken to either avoid or excavate archaeological sites. A "site" was defined as a place used and occupied by prehistoric people (DOE/EIS-0026-FS).[20] In May 1980, the SHPO made a determination of "no adverse effect from WIPP activities" on cultural resources. The National Advisory Council on Historic Preservation concurred that the WIPP Mitigation Plan is appropriate to protect cultural resources (DOE/EIS-0026-FS).[20]

Known historical sites (more than 50 years old) in southeastern New Mexico consist primarily of early twentieth century homesteads that failed, or isolated features from late nineteenth century and early twentieth century cattle or sheep ranching and military activities. To date, no Spanish or Mexican conquest or settlement sites have been identified. Historic components are rare but are occasionally noted in the WIPP area. These include features and debris related to ranching.

Since 1976, cultural resource investigations have recorded 98 archaeological sites and numerous isolated artifacts within the 16-square-mile (41.4-square-kilometer) area enclosed by the WIPP site boundary (PTB).[13] In the central 4-square-mile (10-square-kilometer) area, 33 sites were determined to be eligible for inclusion on the National Register as an archaeological district. Investigations since 1980 have recorded an additional 14 individual sites outside the central 4-square-mile area that are considered eligible for inclusion on the National Register (PTB).[13] The major cultural resource investigations to date are broken out as follows:

1977 The first survey of the area was conducted by J. Nielson[21] of the Agency for Conservation Archaeology (ACA) for Sandia. This survey resulted in the location of 33 sites and 64 isolated artifacts.

1979 R. MacLennan and S. Schermer[22] of ACA performed the next survey. It was conducted for access roads and a railroad right-of-way for Bechtel, Inc. The survey encountered two sites and 12 isolated artifacts.

1980 Schermer[23] performed another survey to relocate the sites originally recorded by Nielson. This survey redescribed 28 of the original 33 sites.

1981 P. Hicks[24,25] directed the excavation of nine sites in the WIPP core-area.

1982 B. Bradley[26] recorded one site and four isolated artifacts in an archaeological survey for a proposed water pipeline.

1985 K. Lord and W. Reynolds[26] examined three sites within the WIPP core area. These sites consisted of two plant-collecting and processing sites and one base camp used between 1000 B.C. and A.D.1400. The artifacts recovered from the excavations have been placed in the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe.

1987 Mariah Associates, Inc.[19] identified 40 sites and 75 isolates in an inventory of 2,460 acres in 15 quarter-section units surrounding the WIPP site. In this investigation, 19 of the sites were located within the WIPP site's boundary. Sites encountered in this investigation tended to lack evident or intact features. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register, 24 were identified as having insufficient data to determine eligibility, and two were determined to be ineligible for inclusion. The eligible and potentially eligible sites have been mapped and are being avoided by the DOE in its current activities at the WIPP site. Figure 2-32 maps out the 40 archaeological sites identified by the Mariah study.

1988 to 1992 Several archaeological clearance reports have been prepared for seismic testing lines on public lands in Eddy County, New Mexico during this period.

The Delaware Basin has been used in the past for an isolated nuclear test, Project Gnome.[27] This test took place in 1961 at a location approximately 8 miles (13 kilometers) southwest of the WIPP (Project Gnome).[27] The primary objective of Project Gnome[27] was to study the effects of an underground nuclear explosion in salt. The Gnome experiment involved the detonation of a 3.1 kiloton nuclear device at a depth of 1200 feet (361 meters) in the bedded salt of the Salado. The explosion created a cavity of approximately 1,000,000 cubic feet (27,000 cubic meters), and caused surface displacements over an area of about 1200 foot (360 meter) radius. Fracturing and faulting caused measurable changes in rock permeability and porosity at distances up to approximately 330 feet (100 meters) from the cavity. No earth tremors were reported at distances over 25 miles (40 kilometers) from the explosion. Project Gnome[27] was decommissioned in 1979.

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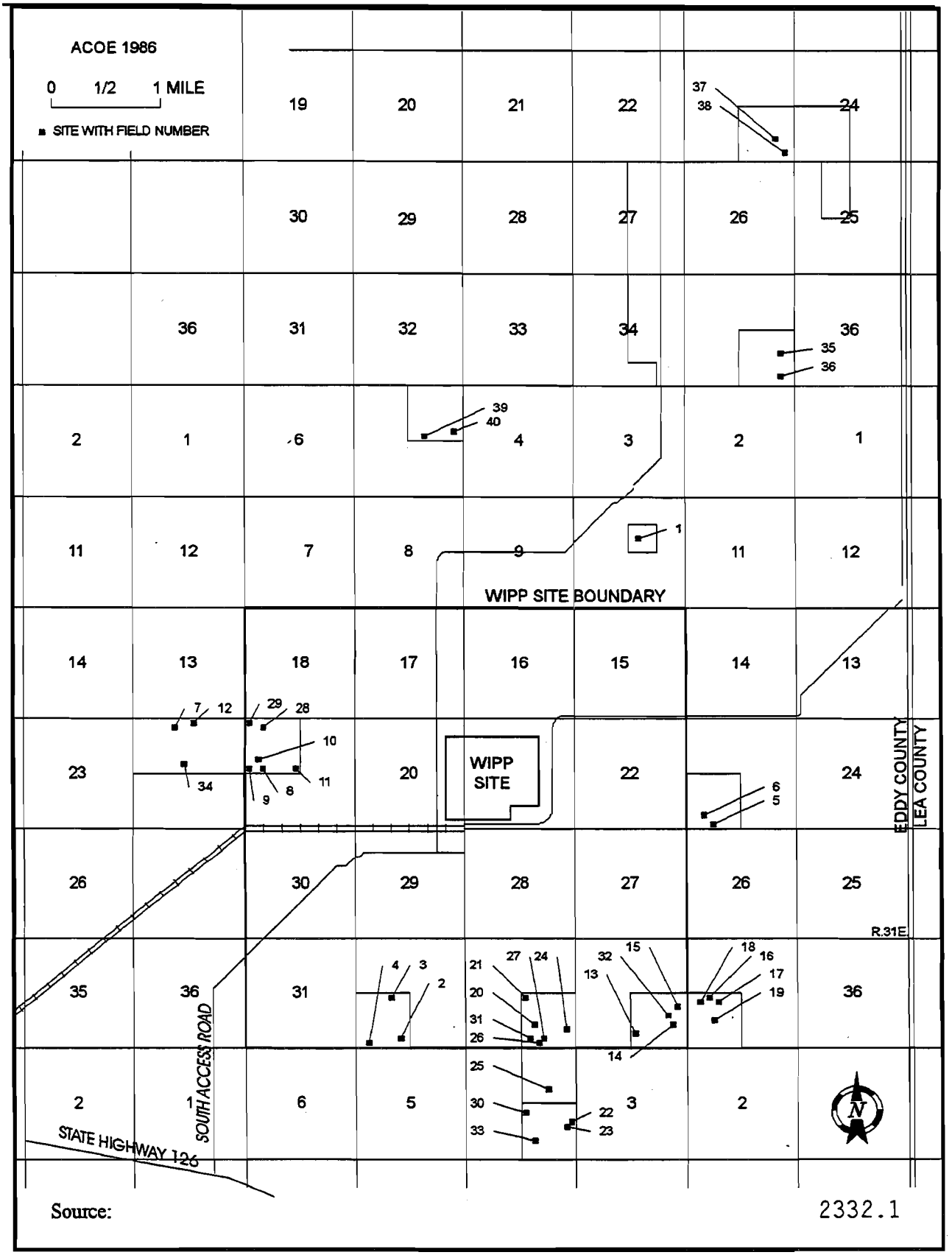

Figure 2.3-1, Mariah Study Archeological Sites

Table 2.3-1, U.S. Bureau of Mines Estimates of Potash Resources Within the Study Area

Mining Unit	Product	Recoverable Ore (10^6 tons)	
		Within WIPP Site	Outside WIPP Site
4th Ore Zone	Langbeinite	40.5 @ 6.99%	126.0 @ 7.30%
10th Ore Zone	Sylvite	52.3 @ 13.99%	105.0 @ 14.96%

Table 2.3-2, In-Place Oil Within Study Area

Formation	Within WIPP Site (10^6 bbl)*	Outside WIPP Site (10^6 bbl)	Total (10^6 bbl)
Delaware	10.33	20.8	31.13
Bone Spring	0.44	0.8	1.25
Strawn	0.4	0.4	0.8
Atoka	1.1	0.1	0.2
Total	**12.3**	**22.9**	**35.3**

Source: NMBMMR,[5] 1995, Ch. XI

* bbl = barrel = 42 gallons

Table 2.3-3, In-place Gas Within Study Area

Formation	Gas Reserves Mcf*	
	Within WIPP Site Boundary	Adjacent to the WIPP Site Boundary
Delaware	18,176	32,873
Bone Springs	956	1,749
Strawn	9,600	9,875
Atoka	123,336	94,410
Morrow	32,000	28,780

Source: NMBMMR,[5] 1995, Ch. XI

*Mcf = thousand cubic feet

2.4 Background Environmental Conditions

Background environmental conditions[1] are provided in this SAR as part of the complete description of the WIPP and its vicinity. Background environmental conditions form the baseline for determining if releases to the environment have occurred during the operational period or during any post-operational monitoring period. Emphasis is placed on ecological conditions and water quality and includes the following:

Ecological Conditions

- Vegetation
- Mammals
- Reptiles and amphibians
- Birds
- Arthropods
- Aquatic ecology
- Endangered species

Quality of Environmental Media

- Surface-water
- Groundwater
- Air

Pathways

- Atmospheric radiation
- Ambient radiation
- Terrestrial radiation
- Hydrologic radiation
- Biotic radiation.

2.4.1 Terrestrial and Aquatic Ecology

2.4.1.1 Vegetation

The WIPP site is in an area characterized by stabilized sand dunes. The vegetation is dominated by shinnery oak, mesquite, sand sage, dune yucca, smallhead snakeweed, three-awn, and numerous species of forbs and perennial grasses. The dominant shrubs are deep-rooted species with extensive root systems. The shrubs not only stabilize the dune sand but serve as food, shelter, and nesting sites for many species of wildlife inhabiting the area (DOE/EIS-0026-FS).[2]

The vegetation in the vicinity of the WIPP site is not a climax vegetation, at least in part because of past grazing management. The composition of the plant life at the site is heterogeneous because of variations in terrain and in the type and the depth of soil. Shrubs are conspicuous members of all plant communities. The site lies within a region of transition between the northern extension of the Chihuahuan Desert (desert grassland) and the southern Great Plains (Short Grass Prairie); it shares the floral characteristics of both.

Grazing, primarily by domestic livestock, and fire control are largely responsible for the shrub-dominated seral communities of much of southeastern New Mexico. A gradual retrogression from the tall- and mid-grass-dominated vegetation of 100 years ago has occurred throughout the region.[2] The cessation of grazing would presumably not alter the domination by shrubs, but it would result in an increase in grasses. Experimental exclosures have been established to study site-specific patterns of succession in the absence of grazing, but long-term results are not yet available (DOE/EIS-0026).[3]

The semiarid climate makes water a limiting factor in the entire region. The amount and timing of rainfall greatly influence plant productivity and, therefore, the food supply available for wildlife and livestock. The seeds of desert plants are often opportunistic: they may lie dormant through long periods of drought to germinate in the occasional year of favorable rainfall. Significant fluctuations in the abundance and distribution of plants and wildlife are typical of this region. Several examples of such fluctuations have been documented in the area within 5 miles (8 kilometers) of the center of the WIPP site, which has been intensively studied.[3]

Two introduced species of significance in the region are the Russian thistle, or tumbleweed, a common invader in disturbed areas, and the salt cedar, which has proliferated along drainage ways.

Several distinct biological zones occur on or near the site: the mesa, the central dunes complex, the creosote-bush flats, the Livingston Ridge escarpment, and the Tobosa Flats in Nash Draw west of the ridge. A low, broad mesa named the Divide lies on the eastern edge of the study area and supports a typical desert-grassland vegetation. The dominant shrub and subshrub are mesquite and snakeweed, respectively. The most abundant grasses are black grama, bush muhly, ring muhly, and fluffgrass. Cacti, especially varieties of prickly pear, are present.[3]

Where the ground slopes down from the Divide to the central dune plains, the soil becomes deep and sandy. Shrubs like shinnery oak, mesquite, sand sagebrush, snakeweed, and dune yucca are dominant. In some places, all of these species are present; in others, one or more are either missing or very low in density. These differences appear to be due to localized variations in the type and depth of soil. Thus, a number of closely related but distinct plant associations form a "patchwork" complex, or mosaic, across the stabilized dunes in the central area. Hummocky, partially stabilized sand dunes occur, and large, active dunes are also present. The former consist of "islands" of vegetation, primarily mesquite, separated by expanses of bare sand. The mesquite-anchored soil is less susceptible to erosion, mainly by wind, than is the bare sand. The result is a series of valley-like depressions, or blowouts, between vegetated hummocks. Active dunes running east to west are found 10 miles (16 kilometers) south and east of the site.[3]

To the west and southwest, the soil changes again, becoming more dense and shallow (less than 10 inches [25 centimeters] to caliche) than in the dune area. The composition of the plant life is radically altered, and creosote bushes become dominant. Toward Livingston Ridge to the west and northwest, creosote bushes gradually give way to an acacia-dominated association at the top of the escarpment. The western face of the ridge drops sharply to a valley floor (flats) that is densely populated with tobosa grass, which is rare elsewhere in the study area.[3]

2.4.1.2 Mammals

The most conspicuous mammals at the site are the black-tailed jack rabbit (*Lepus californicus*) and the desert cottontail (*Sylvilagus auduboni*). Common small mammals found at the WIPP site include the Ord's kangaroo rat (*Dipodomys ordii*), the plains pocket mouse (*Perognathus flavescens*), and the northern grasshopper mouse (*Onychomys leucogaster*). Big-game species, such as the mule deer (*Odocoileus hemionus*) and the pronghorn antelope (*Antilocapra americana*), and carnivores, such as the coyote (*Canis latrans*), are present in small numbers.

2.4.1.3 Reptiles and Amphibians

Commonly observed reptiles in the study area are the side-blotched lizard, the western box turtle, the western whiptail lizard, and several species of snakes, including the bullsnake, the prairie rattlesnake, the western diamondback rattlesnake, the coachwhip, the western hognose, and the glossy snake. Of these, only the side-blotched lizard is found in all habitats. The others are mainly restricted to one or two associations within the central dunes area, although the western whiptail lizard and the western diamondback rattlesnake are found in areas dominated by creosote bush as well. The yellow mud turtle is found only in the limited number of aquatic habitats in the study area (i.e., dirt stock ponds and metal stock tanks), but it is common in these locales.[3]

Amphibians are similarly restricted by the availability of aquatic habitat. Aquatic habitats near the WIPP site include stock-watering ponds and tanks. These may be frequented by yellow mud turtles (*Kinosternon flarescens*), tiger salamanders (*Ambystoma tigrinum*), and occasional frogs and toads. Fish are sometimes stocked in the ponds and tanks.[3]

2.4.1.4 Birds

Numerous birds inhabit the area either as transients or year-long residents. Loggerhead shrikes (*Lanius ludovicianus*), pyrrhuloxias (*Cardinalis sinuata*) and black-throated sparrows (*Amphispiza bilineata*) are examples of common residents. Migrating or breeding waterfowl species do not frequently occur in the area. Some raptors (e.g., Harris Hawks [*Parabuteo unicinctus*]) are residents. The density of large avian predators' nests has been documented as among the highest recorded in the scientific literature.[3]

2.4.1.5 Arthropods

About 1,000 species of insects have been collected in the study area. Of special interest are subterranean termites. Vast colonies of these organisms are located across the study area; they are detritivores and play an important part in the recycling of nutrients in the study area.[3]

2.4.1.6 Aquatic Ecology

Aquatic habitats within a 5-mile (8-kilometer) radius of the WIPP site are limited. Stock-watering ponds and tanks constitute the only permanent surface waters. Ephemeral surface-water puddles form after heavy thunderstorms. At greater distances, seasonally wet, shallow lakes (playas) and permanent salt lakes are found.[3]

Laguna Grande de la Sal is a large, permanent salt lake at the south end of Nash Draw. Natural brine springs, effluent brine from nearby potash refineries, and surface and subsurface runoff discharge into the lake. One of the natural brine springs at the northern margin of the lake has been found to support a small population of the Pecos River pupfish. This species is among the species recognized as threatened by the State of New Mexico. The spring, now called Pupfish Spring, is about 11 miles (18 kilometers) west-southwest of the WIPP site.[3]

Several marine organisms are present in the lower Pecos and in the Red Bluff Reservoir. They include small, shelled protozoans (Foraminifera), a Gulf Coast shrimp, an estuarine oligochaete and a dragonfly, and several species of marine algae. These species have presumably been introduced. Salt-tolerant species of insects, oligochaetes, and nematodes and unusual algal assemblages characterize this stretch of the river. The combination of high salinity, elevated concentrations of heavy metals, and salt-tolerant and marine fauna makes the lower Pecos a unique river system.[3]

2.4.1.7 Endangered Species

The DOE consulted with the U.S. Fish and Wildlife Service (FWS) in 1979 to determine the presence of threatened and endangered species at the WIPP site.[3] At that time the FWS listed the Lee pincushion cactus (*Coryphantha sneedi* var *leei*), the black-footed ferret (*Mustela nigripes*), the American peregrine falcon (*Falco peregrinus anatum*), the bald eagle (*Haliaeetus leucocephalus*), and the Pecos gambusia (*Notropis simus pecosensis*) as threatened or endangered and as occurring or having the potential to occur on lands within or outlying the WIPP site. The U.S. Fish and Wildlife Services (FWS) advised the DOE that the list of species provided in 1979 is still valid except that the black-footed ferret (*Mustela nigripes*) should now be deleted. The DOE believes that the actions described in the Final Supplement, Environment Impact Statement (FSEIS)[4] will have no impact on any threatened or endangered species because these activities do not involve any ground disturbance that was not already evaluated in the Final Environmental Impact Statement (FEIS).[3] In addition, there is no critical habitat for terrestrial species identified as endangered by either the FWS or the New Mexico Department of Game and Fish (NMDG&F) at the site area.

Also in 1989, the DOE consulted with the NMDG&F regarding the endangered species listed by the state in the vicinity of the WIPP site. The NMDG&F (based on NMDG&F Regulation 657, dated January 9, 1988)[5] currently lists seven birds and one reptile that are in one of two endangerment categories and occur or are likely to occur at the site.[1] The NMDG&F agreed that the proposed WIPP activities would probably not have appreciable impacts on endangered species listed by the state in the area.[1] A Handbook of Rare and Endemic Plants of New Mexico,[6] which lists the plants in New Mexico classified as threatened, endangered, or sensitive, includes 20 species, representing 14 families, that are found in Eddy County and could occur at or near the WIPP site.

2.4.2 Water Quality

2.4.2.1 Groundwater Quality

Based on the major solute compositions described in SAND88-0196,[7] four hydrochemical facies are delineated for the Culebra.

Zone A. A sodium chloride brine (approximately 3.0 molar) with a magnesium/calcium (Mg/Ca) mole ratio between 1.2 and 2.0. This water is found in the eastern third of the WIPP site. The zone is roughly coincident with the region of low transmissivity described in SAND88-7002.[8] On the western side of the zone, halite in the Rustler has been found only in the unnamed lower member. In the eastern portion of the zone, halite has been observed throughout the Rustler.

Zone B. A dilute anhydrite-rich water (ionic strength < 0.1 molar) occurs in the southern part of the site. The Mg/Ca mole ratios are uniformly low (0.0–0.5). This zone is coincident with a high-transmissivity region and halite is not found in the Rustler in this zone.

Zone C. Waters of variable composition with low to moderate ionic strength (0.3–1.6 molar) occur in the western part of the WIPP site and along the eastern side of Nash Draw. Mg/Ca mole ratios range from 0.5 to 1.2. This zone is coincident with a region of variable transmissivity. In the eastern part of this zone, halite is present in the lower member of the Rustler. Halite is not observed in the formation on the western side of the zone. The most halite-rich water is found in the eastern edge of the zone, close to core locations where halite is observed in the Tamarisk member.

Zone D. A fourth zone can be defined based on inferred contamination related to potash refining operations in the area. Waters from these wells have anomalously high solute concentrations (3–6 molar) and potassium/sodium (K/Na) weight ratios (0.22) compared to waters from other zones (K/Na = 0.01–0.09). In the extreme southwestern part of this zone, the composition of the Culebra well water has changed over the course of a 7-year monitoring period. The Mg/Ca mole ratio at WIPP-29 is anomalously high, ranging from 10 to 30 during the monitoring period.

This zonation is consistent with that described in EEG31,[9] which defined three zones. The fourth zone (D) was added in SAND88-0196[7] to account for the local potash contamination.

Together, the variations in solutes and the distribution of halite in the Rustler exhibit a mutual interdependence. Concentrations of solutes are lowest where Rustler halite is less abundant, consistent with the hypothesis that solutes in Rustler groundwaters are derived locally by dissolution of minerals (e.g., halite, gypsum, and dolomite) in adjacent strata.

The Total Dissolved Solids (TDS) in the Magenta groundwater ranges in concentration from 5,460 to 270,000 milligrams per liter. This water is considered saline to briny. The transmissivity in areas of lower TDS concentrations is very low, thus greatly decreasing its usability, and the Magenta is not considered as a water supply. In general, the chemistry of Magenta water is variable. Groundwater types range from a predominantly sodium chloride type to a calcium-magnesium-sodium-sulfate type chemistry. The water chemistry may indicate a general overall increase in TDS concentrations to the south and southwest, away from the WIPP site, and a potential change to a predominantly sodium chloride water in that area.

In the WIPP area, the water quality of the Magenta is better than that of the Culebra. However, water from the Magenta is not used anywhere in the vicinity of the WIPP.

2.4.2.2 Surface-Water Quality

The Pecos River is the nearest permanent water source to the WIPP site. Natural brine springs, representing outfalls of the brine aquifers in the Rustler, feed the Pecos at Malaga Bend, 12 miles (19 kilometers) southwest of the site. This natural saline inflow adds approximately 70 tons of chloride per day to the Pecos. Return flow from irrigated areas above Malaga Bend further contributes to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend but tend to decrease downstream. The metals presumably are rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos below Malaga Bend exceed the water quality standards of the World Health Organization, the U.S. Environmental Protection Agency (EPA), and the State of New Mexico. For example, the maximum water quality standard for lead is 50 parts per billion. Levels of up to 400 parts per billion have been measured.

As it flows into Texas south of Carlsbad, the Pecos River is a major source of dissolved salt in the west Texas portion of the Rio Grande Basin. Natural discharge of highly saline groundwater into the Pecos River in New Mexico keeps TDS levels in the water in and above the Red Bluff Reservoir very high. The TDS levels in this interval exceed 7,500 milligrams per liter 50 percent of the time and, during low flows, can exceed 15,000 milligrams per liter. Additional inflow from saline water-bearing aquifers below the Red Bluff Reservoir, irrigation return flows, and runoff from oil fields continues to degrade water quality between the reservoir and northern Pecos County in Texas. Annual discharge-weighted average TDS concentrations exceed 15,000 milligrams per liter. Water use is varied in the southwest Texas portion of the Pecos River drainage basin. For the most part, water use is restricted to irrigation, mineral production and refining, and livestock. In many instances, surface-water supplies are supplemented by groundwaters that are being depleted and are increasing in salinity.[3]

2.4.3 Air Quality

Measurement of selected air pollutants at the WIPP site begin in 1976 and were reported by DOE in the FEIS.[3] Since the preparation of that document, a more extensive air quality monitoring program has been established. Seven classes of atmospheric gases regulated by the EPA have been monitored at the WIPP site between August 27, 1986 and October 30, 1994. These gases are carbon monoxide (CO), hydrogen sulfide (H_2S), ozone (O_3), nitrogen oxides (NO, NO_2, NO_x), and sulfur dioxide (SO_2). The total suspended particulates (TSPs) are monitored in conjunction with the air-monitoring programs of the WIPP. The results of the monitoring program are detailed in the annual reports for the WIPP Environmental Monitoring Program; this program is discussed in more detail in WIPP-CAO-95-1014.[10]

2.4.4 Environmental Radioactivity

The background radiation conditions in the vicinity of the WIPP site are influenced by natural sources of radiation, fallout from nuclear tests, and one local research project (Project Gnome). Prior to the WIPP project, long-term radiological monitoring programs were established in southeastern New Mexico to determine the widespread impacts of nuclear tests at the Nevada Test Site and to evaluate the effects of Project Gnome. Project Gnome resulted in the underground detonation of a nuclear device on December 10, 1961, at a site approximately 8 miles (13 kilometers) southwest of the WIPP site.

The WIPP Radiological Baseline Program (RBP), which included the Radiological Environmental Surveillance Program, was initiated in July 1985 to describe background levels of radiation and radionuclides in the WIPP environment prior to the underground emplacement of radioactive waste. The RBP consisted of five subprograms: (1) atmospheric baseline; (2) ambient radiation (measuring gamma radiation); (3) terrestrial baseline (sampling soils); (4) hydrologic baseline (sampling surface water and bottom sediments and groundwater); and (5) biotic baseline (analyzing radiological parameters in key organisms along potential radionuclide migration pathways).

2.4.4.1 Atmospheric Radiation Baseline

Historically, most gross alpha activity in airborne particulates has shown little variation and is within the range of 1 to 3 x 10^{-15} microcuries per milliliter, which is equivalent to 3.7 to 11 x 10^{-11} becquerels per milliliter. Mean gross beta activity in airborne particulates fluctuates but is typically within the range of 1 to 4 x 10^{-14} microcuries per milliliter (3.7 to 15 x 10^{-10} becquerels per milliliter). A peak of 3.5 x 10^{-13} microcuries per milliliter (1.2 x 10^{-8} becquerels per milliliter) in mean gross beta activity occurred in May 1986 and has been attributed to atmospheric fallout from the Chernobyl incident in the former Soviet Union. The average level of gamma radiation in the environment is approximately 7.5 microroentgens per hour, or approximately 66 millirems per year.

2.4.4.2 Ambient Radiation Baseline

Using the average rate of 7.5 microroentgens per hour, the estimated annual dose is approximately 66 millirems. The fluctuations noted are primarily due to calibration of the system and meteorological events such as the high-intensity thunderstorms that frequent this area in late summer. A seasonal rise in ambient radiation has been observed in the first and fourth quarters each year. It is speculated that this fluctuation may be due to variations in the emission and dispersion of radon-222 from the soil around the WIPP site. These variations can be caused by meteorological conditions, such as inversions, which would slow the dispersion of the radon and its progeny.

2.4.4.3 Terrestrial Baseline

Data were collected as part of the RBP at the WIPP in December 1985 and July 1987. Soil samples were collected and analyzed from a total of 37 locations within an 50-mile (80-kilometer) radius of the WIPP (see Table 2.4-1). The soil samples were analyzed for 19 radionuclides: ^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, two isotopes of radium, three isotopes of thorium, four isotopes of uranium, ^{237}Np, four isotopes of plutonium (^{239}Pu and ^{240}Pu were measured together), ^{241}Am, and ^{244}Cm. Four isotopes (^{40}K, ^{234}U, ^{235}U, and ^{238}U) exhibited significant differences among the three geographic groups, with samples from the outer sites having significantly higher levels of radioactivity than those from the 5-mile (8 kilometer) ring sites (i.e., 16 sampling sites in a ring around the WIPP with a 5-mile [8-kilometer] radius). For ^{234}U, ^{235}U, and ^{238}U, the 5-mile ring sites also showed higher levels than the WIPP sites. The isotopes ^{137}Cs, ^{226}Ra, ^{228}Th, and ^{230}Th exhibited differences between the outer sites and the other two groups, which were indistinguishable. Again, the outer sites had significantly higher levels of radioactivity than the other two groups. Measured mean values for ^{40}K, ^{137}Cs, ^{226}Ra, the three thorium isotopes, and the three uranium isotopes were above detection limits as shown in Table 2.4-1. The mean values for ^{60}Co, ^{90}Sr, ^{228}Ra, ^{233}U, ^{237}Np, the plutonium isotopes, ^{241}Am, and ^{244}Cm fell below detection limits.

2.4.4.4 Hydrologic Radioactivity

The hydrologic radioactivity monitoring program is designed to establish characteristic radioactivity levels in surface-water bodies, bottom sediments, and groundwater.

2.4.4.4.1 Surface-Water and Sediment Background Radiation Levels

Samples of both surface-water and groundwater were collected for the RBP. These samples were analyzed for 19 radionuclides (^{3}H, ^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, two isotopes of radium, three isotopes of thorium, four isotopes of uranium, ^{237}Np, and four isotopes of plutonium [^{239}Pu and ^{240}Pu were measured together]). The resulting data from the sampling of surface-water and groundwater were analyzed independently.

Surface Water

Samples of surface water were collected from 12 locations over the course of the RBP. Sampling locations were divided into three groups for an initial analysis of geographic variability. Stock tanks represented the largest group, with five locations; they are located closest to WIPP. Stock tanks in this area are typically man-made earthen catchment basins with no surface outflow. The Pecos River represents the next major surface-water group. Four sampling locations were used along the Pecos, from a northern (up-river) point near the town of Artesia to a southern (down-river) point near the town of Malaga, New Mexico. The third group, called Laguna Grande de la Sal, represents water from a series of playa lakes at the lower end of Nash Draw.

The sample mean radioactivity levels for most radionuclides were below their respective detection limits. Peak levels of ^{40}K from Laguna Grande de la Sal were 2.7 x 10^{-5} microcuries per gram (1.0 Becquerels per gram), whereas the mean level at all other sampling locations was less than 2.7 x 10^{-7} microcuries per gram (0.01 Becquerels per gram). All four isotopes of uranium exhibited significant differences among the three geographic groups. For all four isotopes, radionuclide levels in the tanks were at least one order of magnitude lower than levels found in the Pecos River and Laguna Grande de la Sal. Similar to ^{40}K, levels of uranium were highest in Laguna Grande de la Sal. Only ^{60}Co, ^{137}Cs, ^{228}Ra, ^{234}U, and ^{238}U were found to be above detection limits.

Sediments

Sediments were collected for the RBP from six locations: Hill Tank, Indian Tank, Noye Tank, Laguna Grande de la Sal, and two sites along the Pecos River. These samples were analyzed for 18 radionuclides (tritium, ^{3}H, was not analyzed in the sediments.).

In all five cases where differences were found among location groups, the stock tanks had higher concentrations of radionuclides, possibly indicating an accumulation effect from the closed nature of the tanks. Laguna Grande de la Sal sediments contained significantly higher concentrations of ^{234}U than did the stock tanks and the Pecos River, which were indistinguishable.

2.4.4.4.2 Groundwater Radiological Characterization

Groundwater samples were collected from 37 wells: 23 completed in the Culebra, 4 completed in the Magenta, and 10 privately owned. The samples were analyzed for the same 19 radionuclides as the surface-water samples. Elevated levels of ^{40}K were found in the Magenta/private and Culebra (2.0 to 5.4 x 10^{-7} microcuries per gram, or 7.3 to 20 x 10^{-3} Becquerels per gram, respectively) groundwater. The increased levels of ^{40}K can be attributed to the generally high levels of dissolved solids in groundwater in these formations. Only ^{60}Co, ^{137}Cs, radium, ^{234}U, and ^{238}U were found above detection limits and ^{226}Ra which was found to have a distinct geographic pattern in the Culebra. Means from individual wells, as shown in Table 2.4-2, show that levels of this radionuclide increase in concentration from west to east.

Groundwater samples were collected in accordance with the written procedures. The primary objective of the Water Quality Sampling Program (WQSP) is to obtain representative and repeatable groundwater-quality data from selected wells under rigorous field and laboratory procedures and protocols. At each well site, the well is pumped and the groundwater serially analyzed for specific field parameters. Once the field parameters have stabilized, denoting a chemical steady state with respect to these parameters, a final groundwater sample is collected to be analyzed for radionuclides.

2.4.4.5 Biotic Baseline

This subprogram characterizes background radioactivity levels in key organisms along possible food-chain pathways to man. Vegetation, rabbits, quail, beef, and fish are sampled, and palatable tissues are analyzed for concentrations of transuranics and common naturally occurring radionuclides. Because the small sample sizes in this program, no attempt has been made to interpret these data. The results are presented in total in the Annual Site Environmental Report for Calendar Year 1991, (DOE/WIPP 92-007).[11]

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Table 2.4-1, Ranges of Mean Values Measured for Radioactive Isotopes at Soil Collection Sites at WIPP, 5 Miles from WIPP, and beyond 5 Miles from WIPP

Isotope	Range of Mean Values[1]	
	μCi/gm	Bq/gm
^{40}K	4.9 to 9.3×10^{-6}	1.8 to 3.4×10^{-1}
^{60}Co	–	–[2]
^{90}Sr	–	–[2]
^{137}Cs	1.3 to 2.2×10^{-7}	4.7 to 8.1×10^{-3}
^{226}Ra	2.6 to 5.4×10^{-7}	9.6 to 20×10^{-3}
^{228}Ra	–	–[2]
^{228}Th	2.1 to 4.9×10^{-7}	7.8 to 18×10^{-3}
^{230}Th	2.5 to 52×10^{-7}	9.1 to 19×10^{-3}
^{232}Th	3.0×10^{-7}	1.1×10^{-2}
^{233}U	–	–[2]
^{234}U	1.5 to 3.3×10^{-7}	5.4 to 12×10^{-3}
^{235}U	4.4 to 17×10^{-9}	1.6 to 6.3×10^{-4}
^{238}U	1.6 to 3.0×10^{-7}	5.7 to 11×10^{-3}
^{237}Np	–	–[2]
^{238}Pu	–	–[2]
$^{239/240}Pu$	–	–[2]
^{241}Pu	–	–[2]
^{241}Am	–	–[2]
^{244}Cm	–	–[2]

[1]The ranges of mean values are expressed in terms of microcuries per gram of soil (μCi/gm) and bequerels per gram of soil (Bq/gm).

[2]Below minimum detection limit of 3.7×10^{-3} Bq/gm.

Table 2.4-2, Mean Values Measured for Radionuclides in Water Wells around the WIPP Site

Isotope	Mean Value (10^{-4} Bq/g)
^{3}H	Below <MDL (56)
^{40}K	73 to 200
^{60}Co	12
^{90}Sr	<MDL (7.4)
^{137}Cs	7.2
^{226}Ra	6.9 to 52
^{228}Ra	9.6
^{228}Th	<MDL (3.7)
^{230}Th	<MDL (0.37)
^{232}Th	<MDL (0.37)
^{233}U	<MDL (0.37)
^{234}U	2.6
^{235}U	<MDL (N/S)
^{238}U	0.72
^{237}Np	<MDL (0.37)
^{238}Pu	<MDL (0.11)
$^{239/240}Pu$	<MDL (0.74)
^{241}Pu	<MDL (37)

Key:

<MDL=Less than the minimum detection level (MDL is shown in parentheses)
N/S=MDL not specified

2.5 Meteorology

2.5.1 Recent Climatic Conditions

Current climatic conditions are provided to allow for the assessment of impacts of these factors on the disposal unit and the site. The WIPP facility does not rely on climatic conditions to control waste migration; however, meteorological information is used in the evaluation of the air pathway during operation of the facility.

2.5.1.1 General Climatic Conditions

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are mostly from the southeast and moderate. In late winter and spring, there are strong west winds and dust storms. During the winter, the weather is often dominated by a high-pressure system situated in the central portion of the western United States and a low-pressure system located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona.[1]

2.5.1.2 Regional Meteorological Conditions for Design and Operating Bases

2.5.1.2.1 Heavy Precipitation

The maximum 24-hour rainfall at Roswell was 5.65 inches in November 1901.[2] The maximum 24-hour snowfall in Roswell was 15.3 inches in December 1960. The greatest snowfall during a 1-month period was 23.3 inches in February 1905.[3]

2.5.1.2.2 Thunderstorms and Hail

The region has about 40 thunderstorm days annually. About 87.5% of these occur from May to September.[2] A thunderstorm day is recorded if thunder is heard; but, the thunderstorm record is not related to observations of rain or lightning and does not indicate the severity of storms in the region.

Hail usually occurs in April through June and is not likely to develop more than three times a year. During a 39-year period at Roswell, hail was observed 97 times (about 2.5 times a year), occurring nearly two thirds of the time between April and June.[4] For the 1° square (32° to 33° N by 103° to 104°W) surrounding the WIPP facility, hailstones 0.75 in and larger were reported eight times from 1955 to 1967 (slightly less than once a year).

2.5.1.2.3 Tornadoes

For the period 1916-1958, 75 tornadoes were reported in New Mexico on 58 tornado days.[5] Data for 1953 through 1976 indicate a state wide total of 205 tornadoes on 152 tornado days,[6] or an average of 9 tornadoes a year on 6 tornado days. The greatest number of tornadoes in 1 year was 18 in 1972; the least was 0 in 1953. The average tornado density in New Mexico during this period was 0.7 per 1,000 mi^2. Most tornadoes occur in May and June.[7] From 1955 through 1967, 15 tornadoes were reported within the 1° square containing the WIPP surface facility.[8]

H.C.S. Thom has developed a procedure for estimating the probability of a tornado striking a given point.[9] The method uses a mean tornado path length and width and a site specific frequency. Applying Thom's method to the WIPP facility yields a point probability of 0.00081 on an annual basis, or a recurrence interval of 1,235 years. An analysis by Fujita yields a point tornado recurrence interval of 2,832 years in the Pecos River Valley.[10]

According to Fujita, the WIPP design basis tornado with a million year return period has a maximum wind speed of 183 mi/h, translational velocity of 41 mi/h, a maximum rotational velocity radius of 325 ft, a pressure drop of 0.5 lb/in^2, and a pressure drop rate of 0.09 lb/in^2/s.

2.5.1.2.4 Freezing Precipitation

The region of the WIPP facility has about 1 day of freezing rain or drizzle a year.[4] An ice accumulation of more than 0.25 in has not been observed. Any ice accumulation that does occur is thin because of the scarcity of precipitation during the winter months and because daytime temperatures rise well above freezing.

2.5.1.2.5 Strong Winds

The maximum 1-min wind speeds recorded at Roswell are shown in Table 2.5-1. The fastest 1-min wind ever recorded at Roswell was 75 mi/h from the west in April 1953.[11] Windstorms with speeds of 50 knots or more occurred ten times (during the period between 1955 and 1967) about one a year.[7] The mean recurrence interval for annual high winds at 30 ft above the ground in south eastern New Mexico is shown in Table 2.5-2.[9,12] The 100-year recurrence 30-foot level wind speed in southeastern New Mexico is 82 mi/h. Based on a gust factor of 1.3,[13] the highest instantaneous gust expected once in 100 years at 30 ft above grade is 107 mi/h. The vertical wind profile for two 100-year recurrence intervals has been estimated from the 30-foot values using the 1/7 power law[16] and is presented in Table 2.5-2.

2.5.1.2.6 Restrictive Dispersion Conditions

Hosler[14] and Holzworth[15] analyze records from several National Weather Service stations with the objectives of characterizing atmospheric dispersion potential. Seasonal and annual frequencies of inversions based at or below 500 ft for the WIPP facility region are shown in Table 2.5-3. Most of these inversions are diurnal (radiation-induced) and occur because the radiation cooling at the earth's surface is increased by conditions that frequently exist at the WIPP facility. The conditions are lack of moisture, clear skies and low air density. When these conditions exist in the early morning, radiation lost from the surface is not adequately absorbed and reradiated by upper level air to heat the air at the surface sufficiently. Consequently, the air at the surface quickly becomes cooler than the upper level air and the colder surface air becomes trapped.

Holzworth gives estimates of the average depth of vertical mixing, which indicates the thickness of the atmospheric layer available for the mixing and dispersion of effluents.[15] The seasonal afternoon mixing heights for the region (Table 2.5-4) range from 1,320 meters in winter to 3,050 meters in summer. Seasonal morning mixing heights in the region range from 300 meters in winter to 680 meters in summer.

2.5.1.2.7 Sandstorms

Blowing dust or sand may occur occasionally in the region due to the combination of strong winds, sparse vegetation and the semiarid climate. High winds associated with thunderstorms are frequently a source of localized blowing dust. Dust storms covering an extensive area are rare, and those that reduce visibility to less than 1 mi occur only with the strongest pressure gradients such as those associated with intense extratropical cyclones which occasionally form in the region during winter and early spring. Winds of 50 to 60 mi/h and higher may persist for several days if these pressure systems become stationary.[3] Ten windstorms of 58 mi/h and greater were reported during 1955-1967 within the 1° square in which the WIPP facility is located.[7] Blowing dust or sand may reduce visibility to less than 5 mi over an area of thousands of square miles. However, restrictions of less than 1 mi are quite localized and depend on soil type, conditions, cultivation practices and vegetation in the immediate area.[3]

2.5.1.2.8 Snow

The 100-year recurrence maximum snowpack for the WIPP facility region is 10 lb/ft^2.[12] The probable maximum winter precipitation (PMWP) in the WIPP facility region is taken to be the probable maximum 48-hour precipitation during the winter months of December through February. The PMWP for the WIPP facility is estimated to be 12.8 inches of rain (i.e., 66 lb/ft^2).[16,17] The snowload for the WIPP facility is calculated (ground level equivalent) to be 27 lb/ft^2. Specific roof loads are estimated based on ANSI's methodology.[12]

2.5.2 Local Meteorology

2.5.2.1 Data Sources

On site meteorological data (hourly) are used to characterize the local meteorology of the WIPP facility.

2.5.2.2 Temperature Summary

Temperatures are moderate throughout the year, although seasonal changes are distinct. The mean annual temperature in southeastern New Mexico is 63°F (17.2°C). In the winter (December through February), night-time lows average near 23°F (-5°C), and average maxima are in the 50s. The lowest recorded temperature at the nearest Class-A weather station in Roswell was -29°F (-33.8°C) in February 1905. In the summer (June through August), the day-time temperature exceeds 90°F (32.2°C) approximately 75 percent of the time.[1] The National Weather Service recently documented a measurement of 122°F (50°C) at the WIPP site as the record high temperature for New Mexico. This measurement occurred on June 27, 1994. Table 2.5-5 shows the annual average, maximum, and minimum temperatures from 1990 through 1994.

2.5.2.3 Precipitation Summary

Precipitation is light and unevenly distributed throughout the year, averaging 13 inches (33 centimeters) for the past five years. Winter is the season of least precipitation, averaging less than 0.6 inches (1.5 centimeters) of rainfall per month. Snow averages about 5 inches (13 centimeters) per year at the site and seldom remains on the ground for more than a day at a time because of the typically above-freezing temperatures in the afternoon. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region.[1] Monthly average, maximum, and minimum precipitations recorded at the WIPP site from 1990 through 1994 are summarized in Figure 2.5-1.

2.5.2.4 Wind Speed and Wind Direction Summary

The frequencies of wind speeds and directions are depicted by windroses in Figures 2.5-2 through 2.5-6 for the WIPP site, and Figures 2.5-7 through 2.5-11 for Carlsbad, New Mexico. In general, the predominant wind direction at the WIPP site is from the southeast, and the predominant wind directions in Carlsbad are from the south, southeast, and west.

2.5.2.5 Topography

The land surface in the vicinity of the WIPP facility is a semiarid, wind blown plain sloping gently to the west and southwest. Its surface is made somewhat hummocky by an abundance of sand ridges and dunes. The average slope within a 3-mile radius is about 50 ft/mi from the east to west.

A plot of terrain profiles from the center of the WIPP facility out to 5 miles is presented in Figure 2.5-12 for each of the 16 direction sectors.

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4. Technical Report EP-83, Hail Size and Distribution, U.S. Army, Quartermaster Research and Engineering Center, 1958.

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7. Technical Memorandum WBTM FCST 12, Severe Local Storm Occurrence, 1955-1957, Environmental Sciences and Services Administration (ESSA), U.S. Department of Commerce, Silver Spring, 1969.

8. WASH 1300, Technical Basis for Interim Regional Tornado Criteria, U.S. Atomic Energy Commission, Washington, DC.

9. Monthly Weather Review, Tornado Probabilities, November-December, 1963.

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11. Environmental Data Service, June 1968, Weather Atlas of the United States, (originally titled Climatic Atlas of the United States), reprinted in 1975 by Gale Research Co.

12. ANSI A58.1-1972, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, Revision of A58.1-1955, American National Standards Institute, Inc., July 1972.

13. DGAF 140, Relations Between Gusts and Average Wind Speeds for Housing Load Determination, Daniel Guggenheim, Airship Institute, Cleveland, Ohio, 1946.

14. Monthly Weather Review, 89 (9), Low-Level Inversion Frequency in the Contiguous United States, 1961.

15. U.S. Environmental Protection Agency (EPA), Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States, Research Triangle Park, North Carolina, 1972.

16. Hydrometeorological Report No. 33, Seasonal Variations of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours, Weather Bureau, 1956.

17. Housing and House Finance Agency, Snow Load Studies, Office of the Administrative Division of Housing Research, 1956.

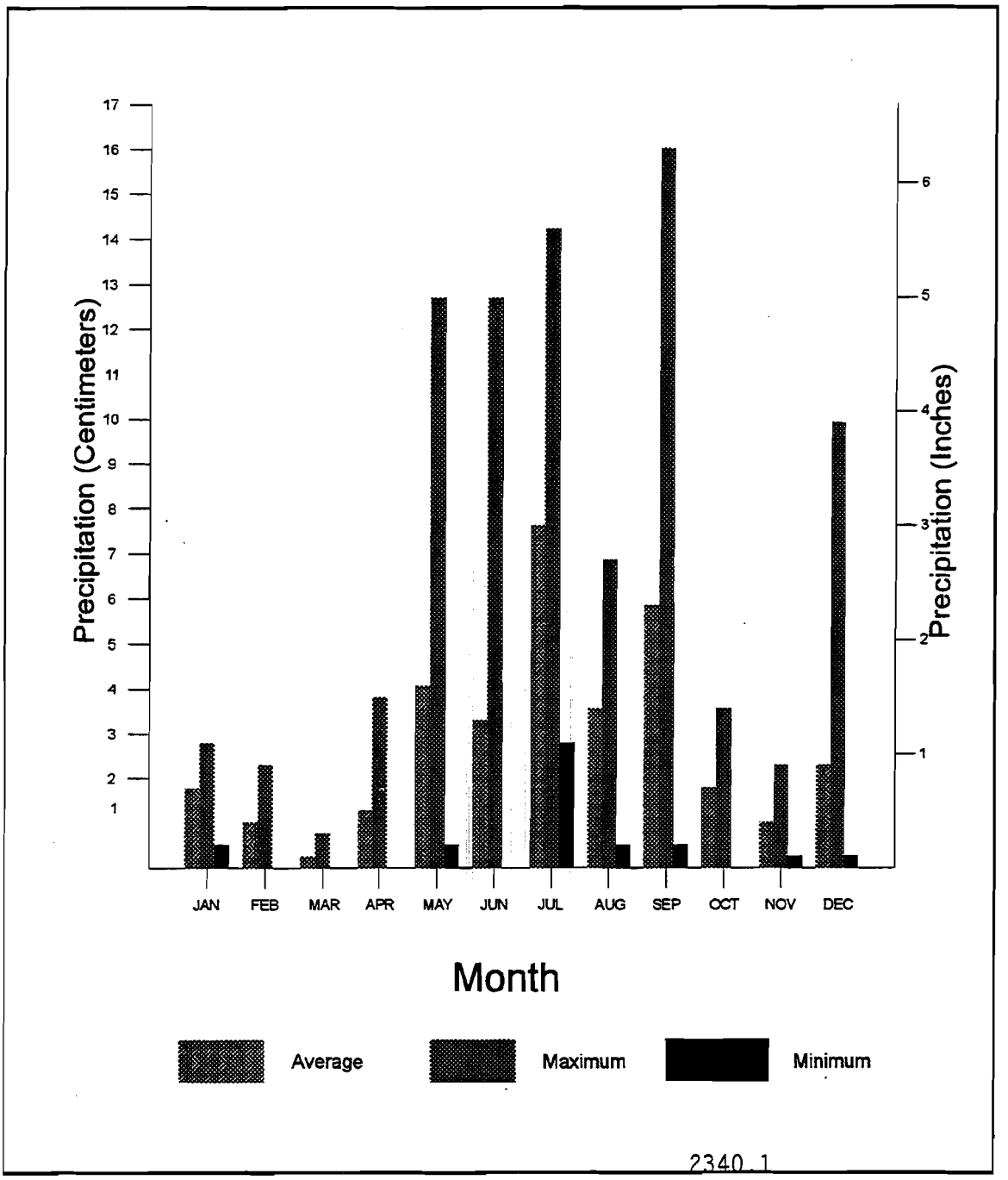


Figure 2.5-1, Monthly Precipitation for the WIPP Site from 1990 through 1994

Figure 2.5-2, 1990 Annual Windrose - WIPP Site (figure unavailable)

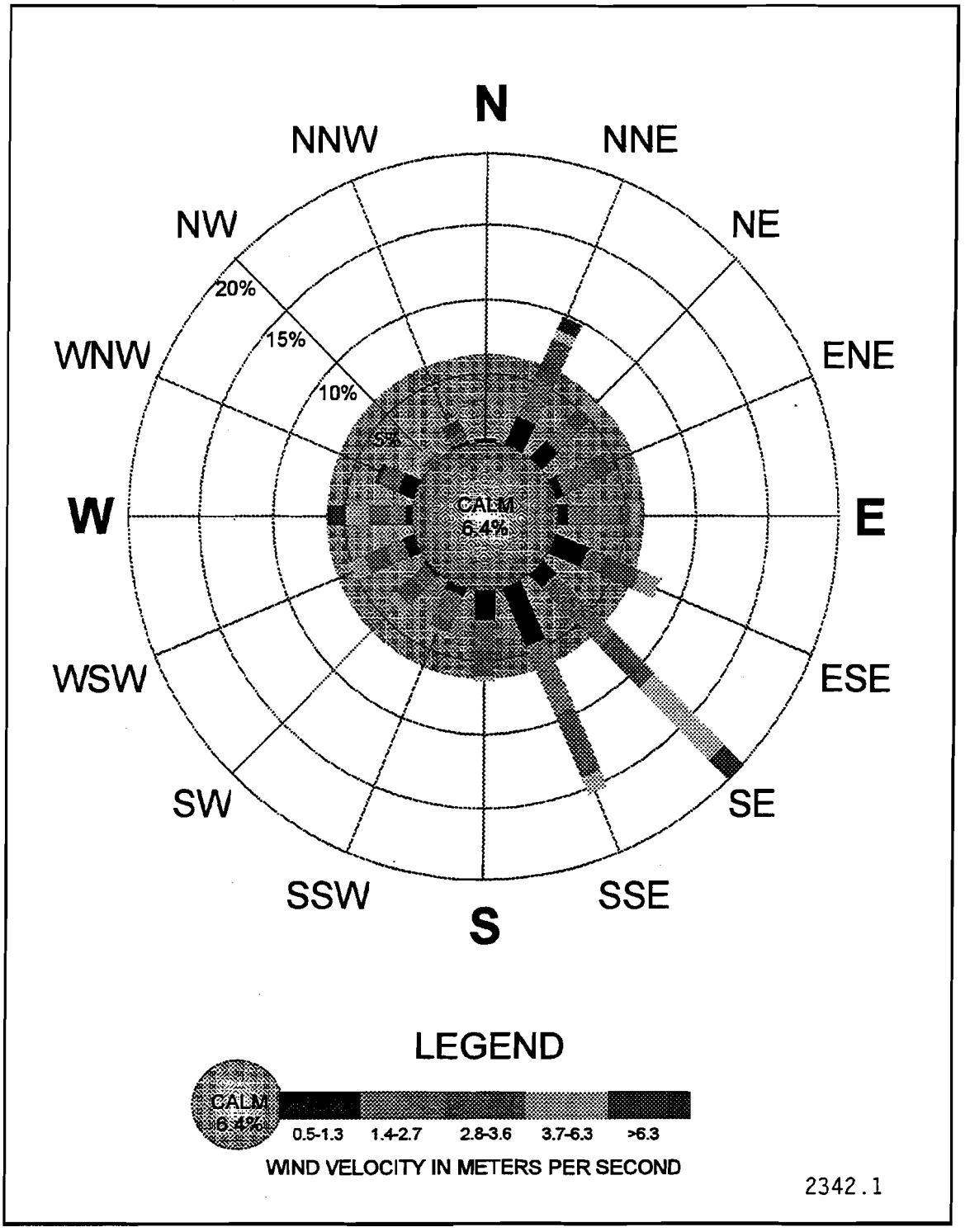


Figure 2.5-3, 1991 Annual Windrose - WIPP Site

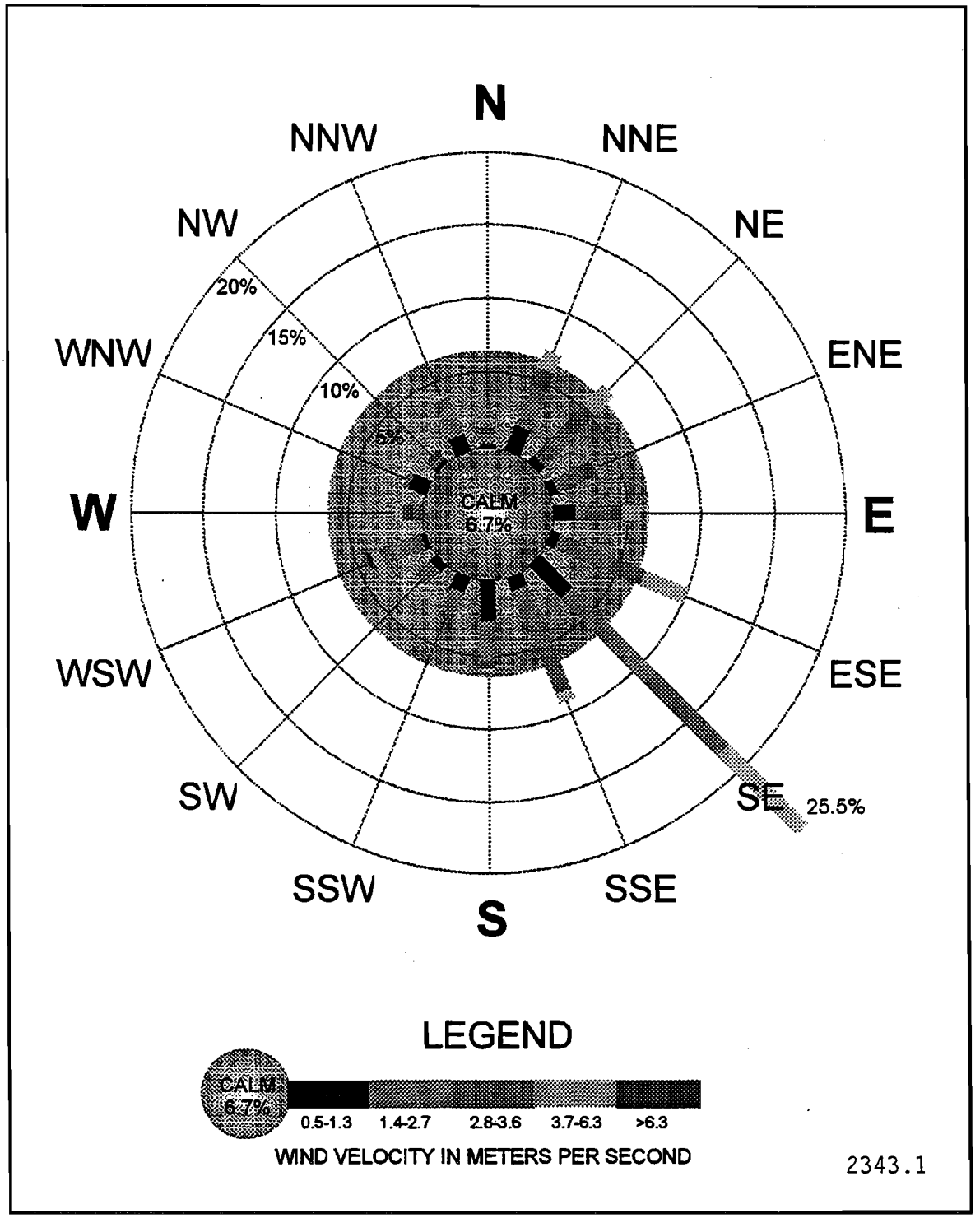


Figure 2.5-4, 1992 Annual Windrose - WIPP Site

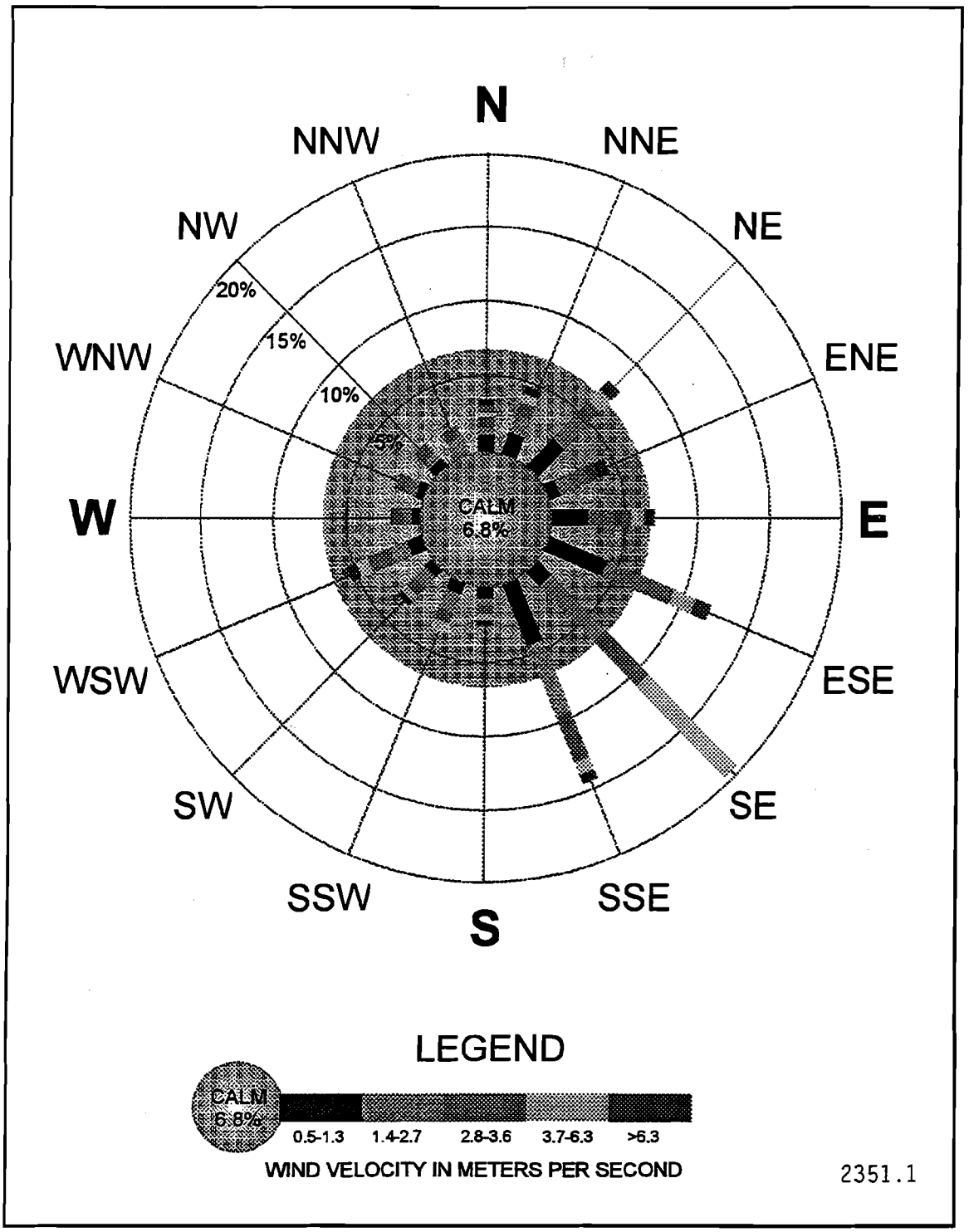


Figure 2.5-5, 1993 Annual Windrose - WIPP Site

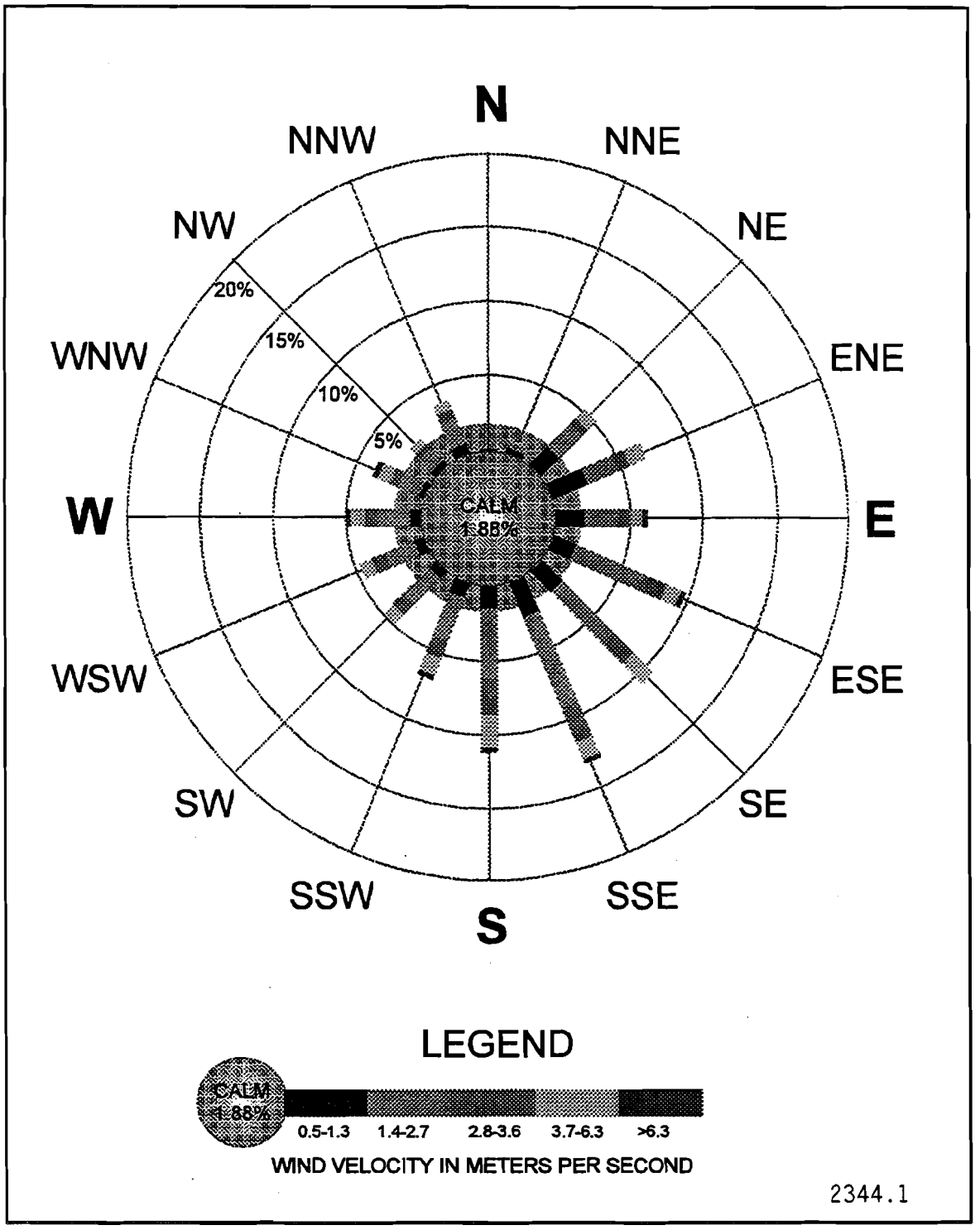


Figure 2.5-6, 1994 Annual Windrose - WIPP Site

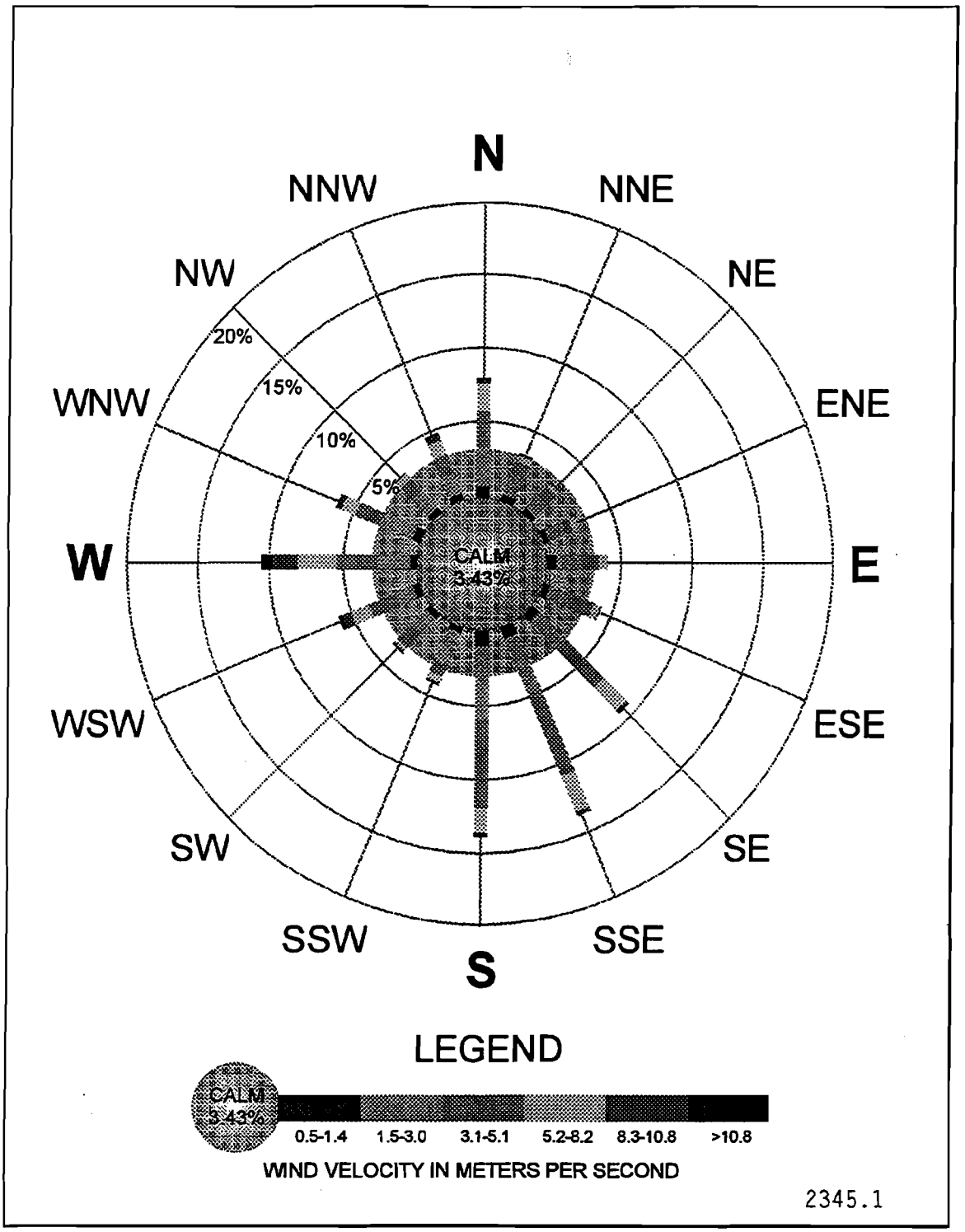


Figure 2.5-7, 1990 Annual Windrose - Carlsbad

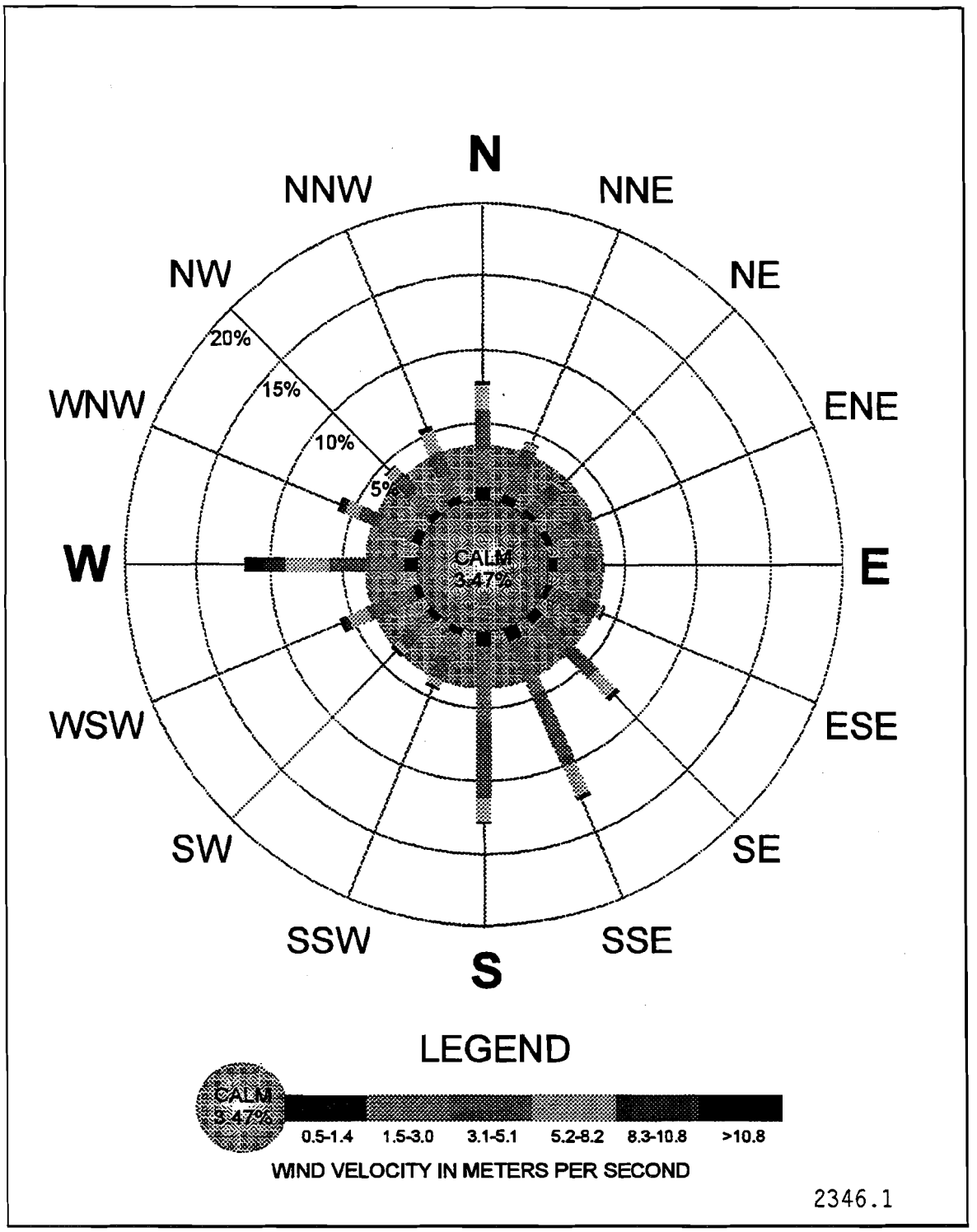


Figure 2.5-8, 1991 Annual Windrose - Carlsbad

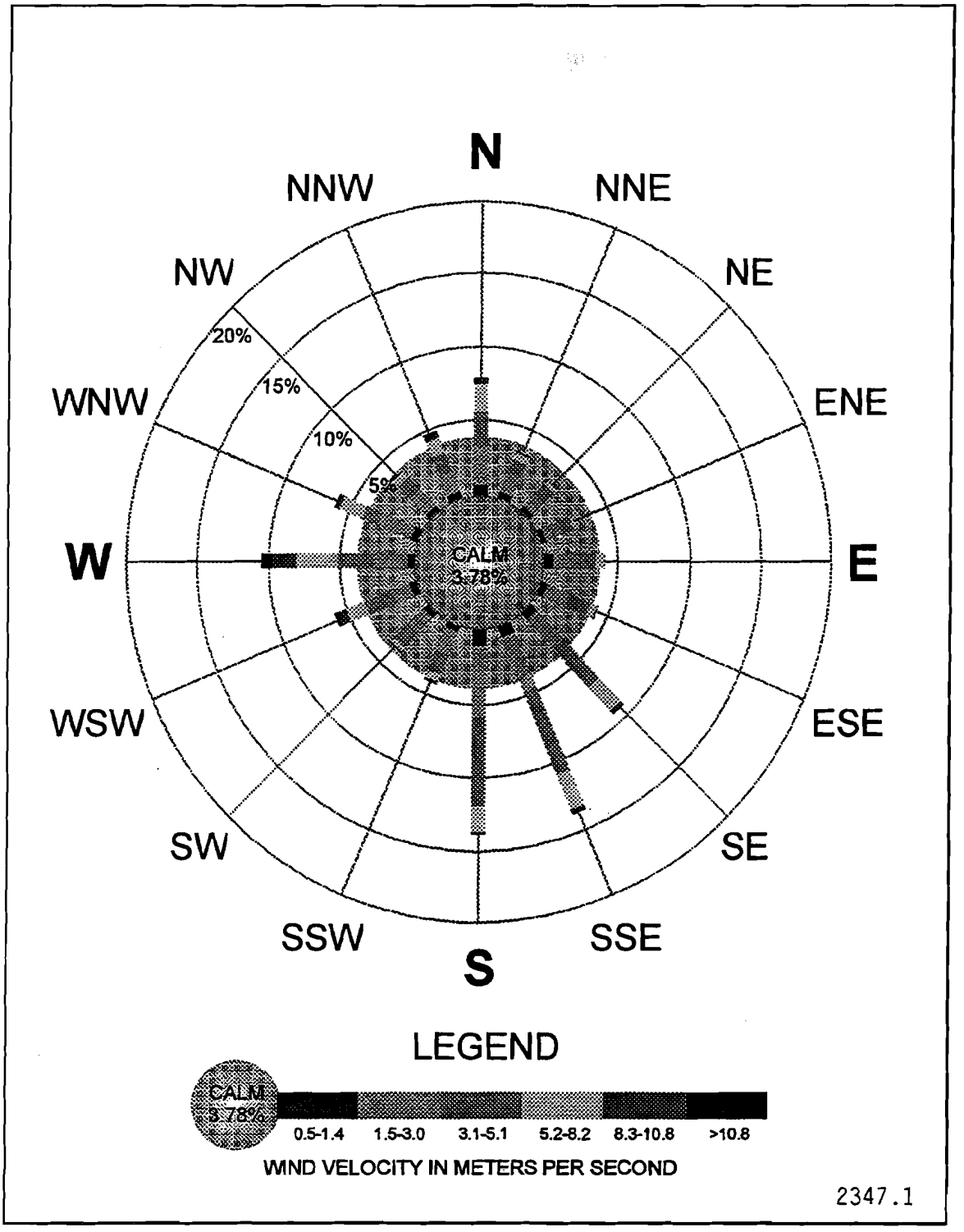


Figure 2.5-9, 1992 Annual Windrose - Carlsbad

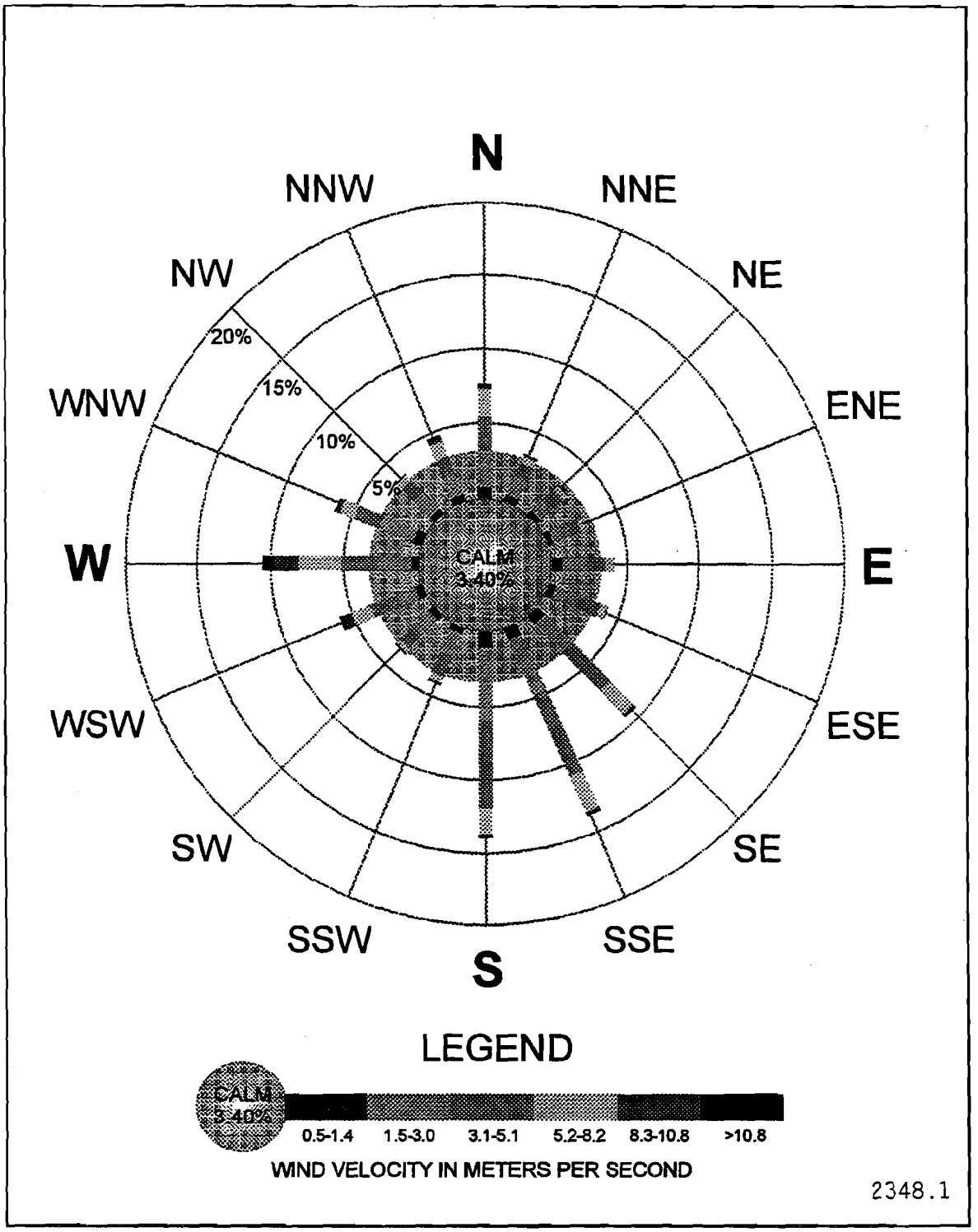


Figure 2.5-10, 1993 Annual Windrose - Carlsbad

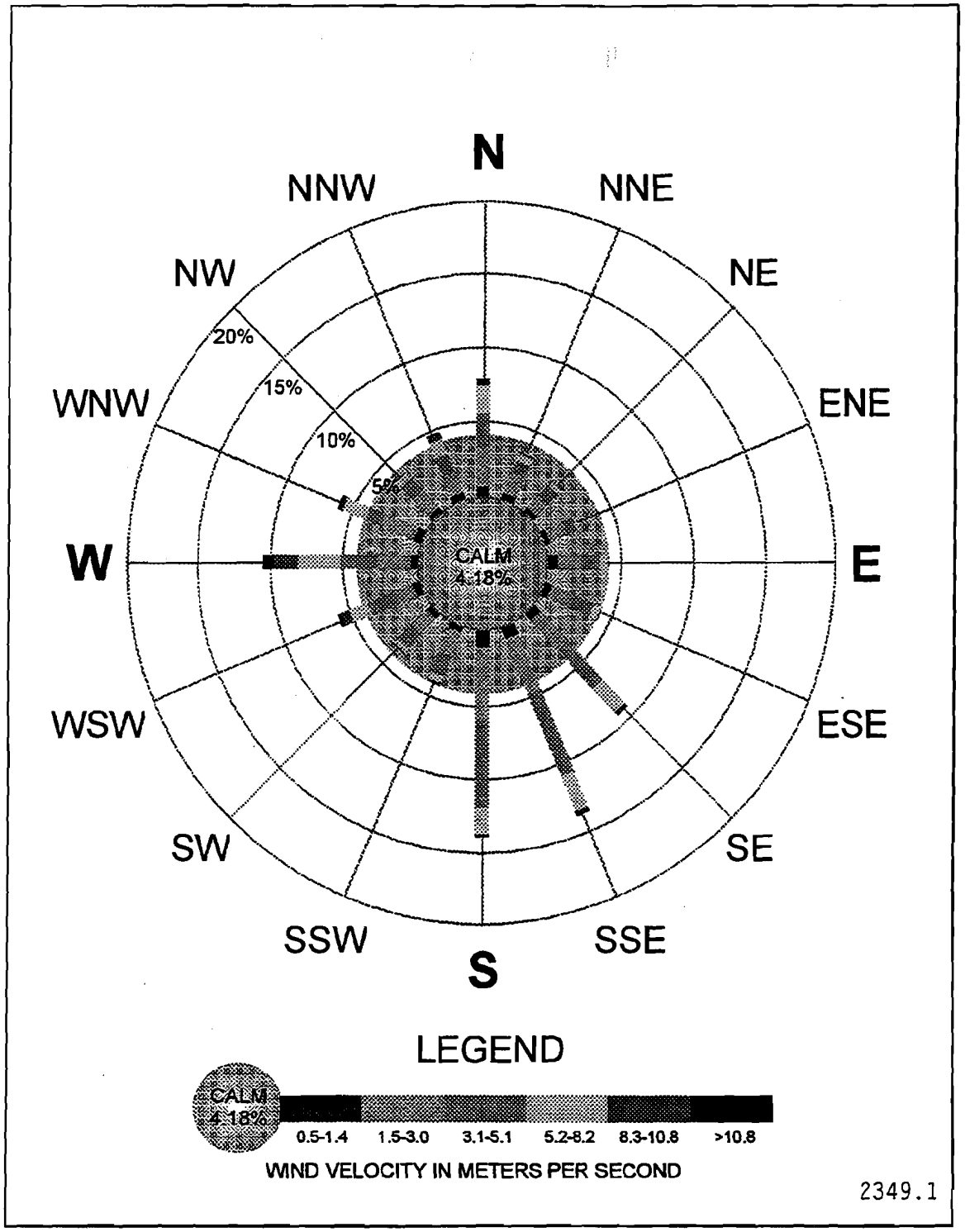


Figure 2.5-11, 1994 Annual Windrose - Carlsbad

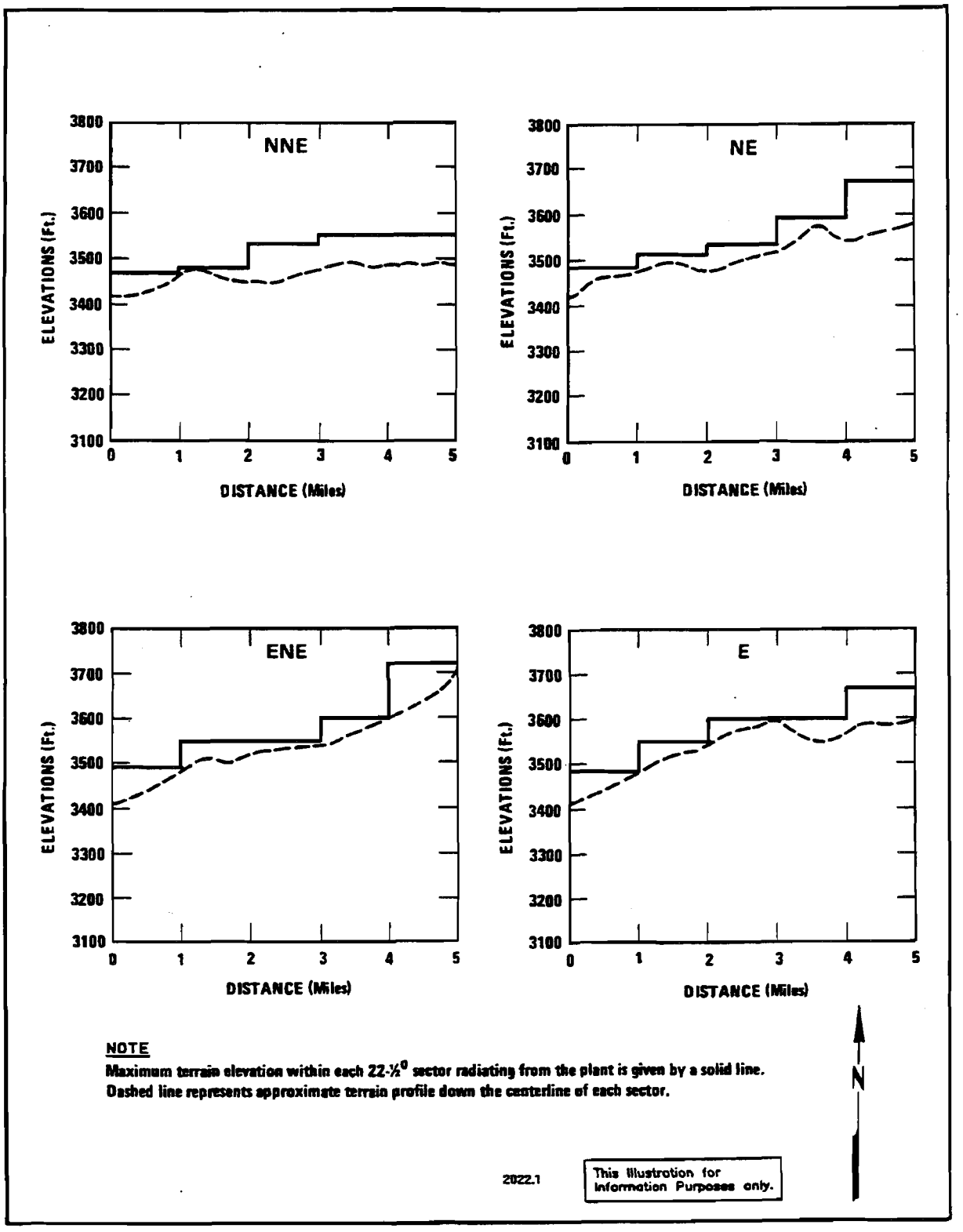
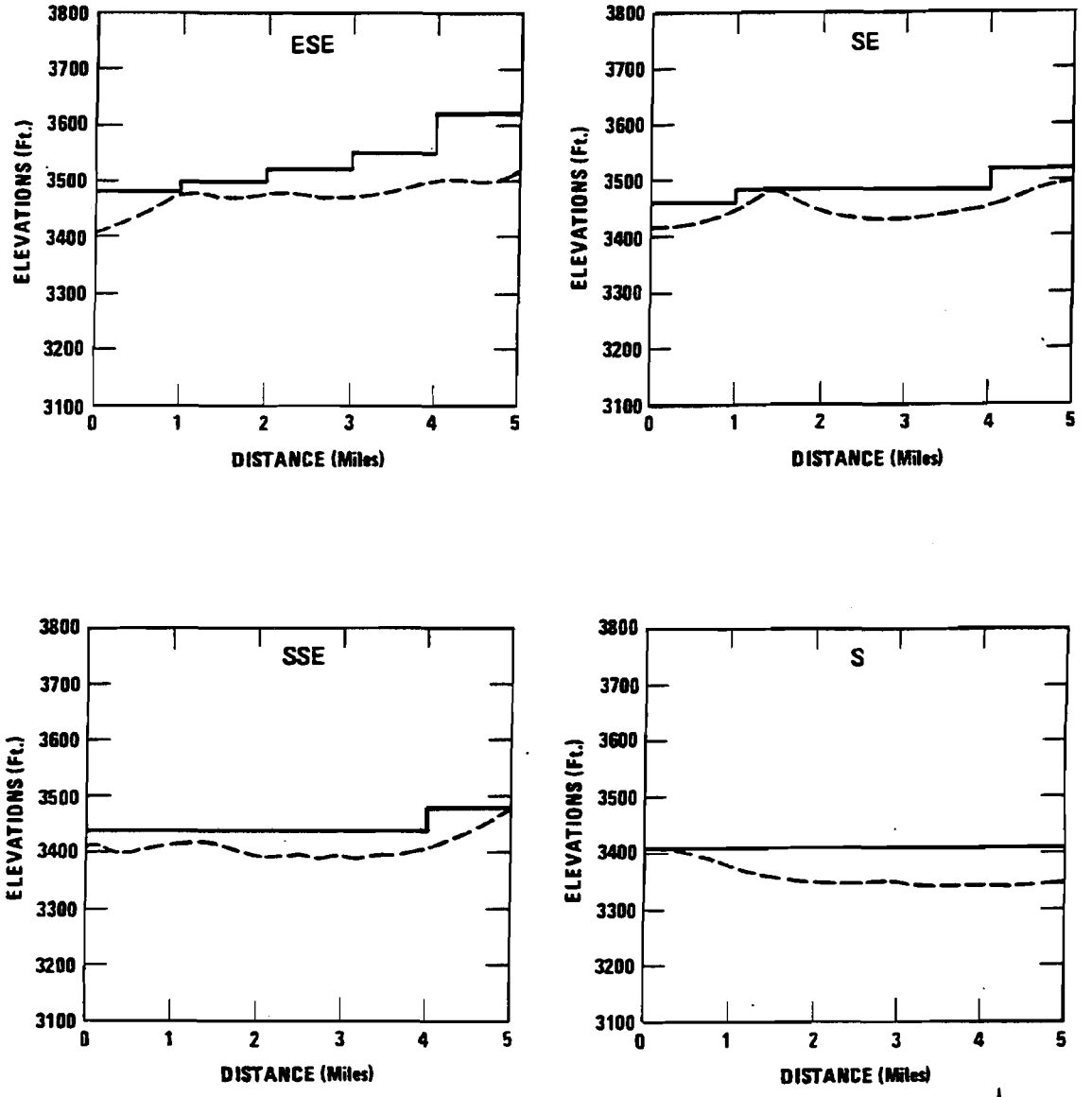


Figure 2.5-12A, Terrain Elevations Out to 5 Miles from Center of the WIPP Facility Sheet 1 of 4



NOTE
Maximum terrain elevation within each 22-½° sector radiating from the plant is given by a solid line.
Dashed line represents approximate terrain profile down the centerline of each sector.

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This Illustration for Information Purposes only.

Figure 2.5-12B, Terrain Elevations Out to 5 Miles from Center of the WIPP Facility
Sheet 2 of 4

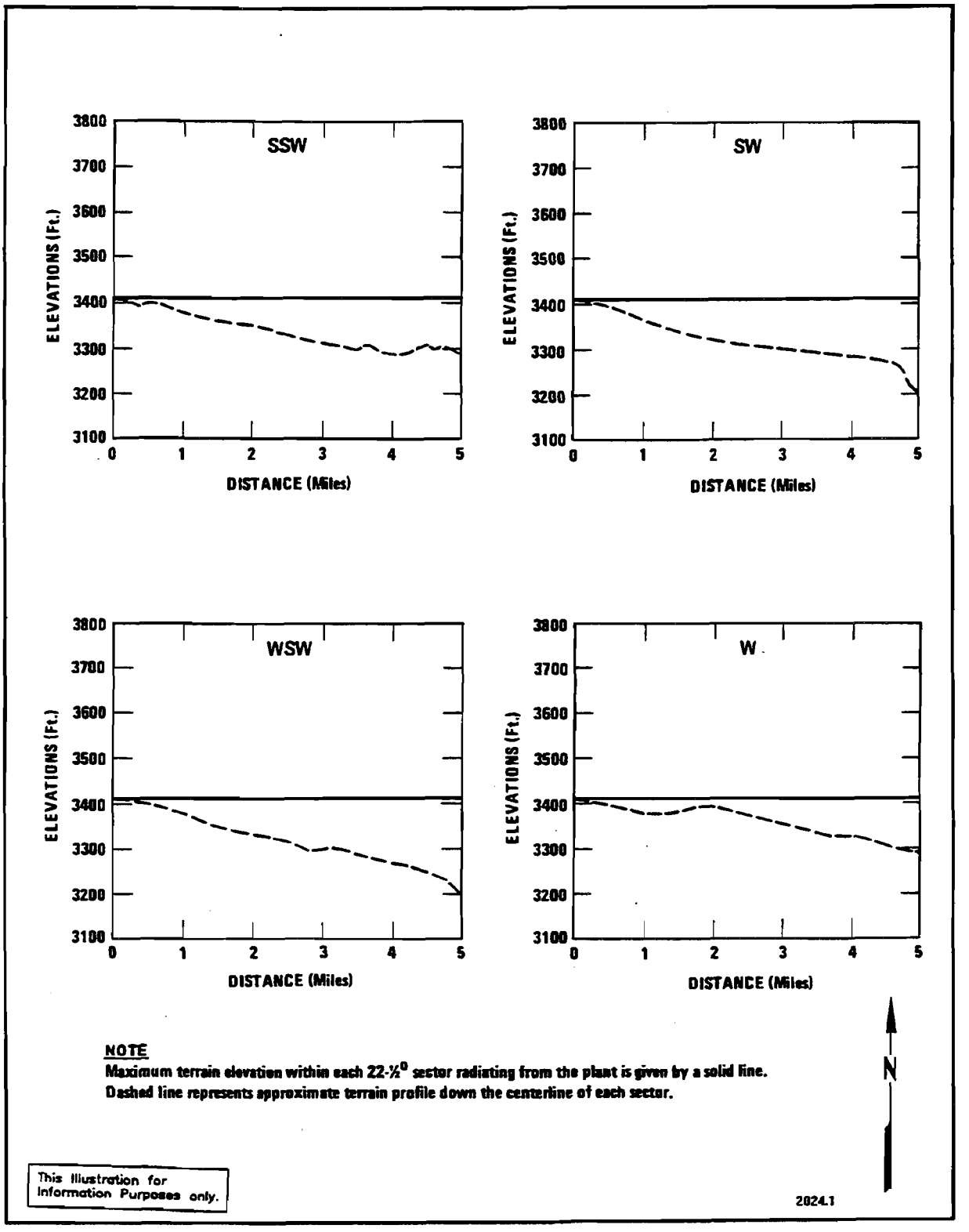

Figure 2.5-12C, Terrain Elevations Out to 5 Miles from Center of the WIPP Facility Sheet 3 of 4

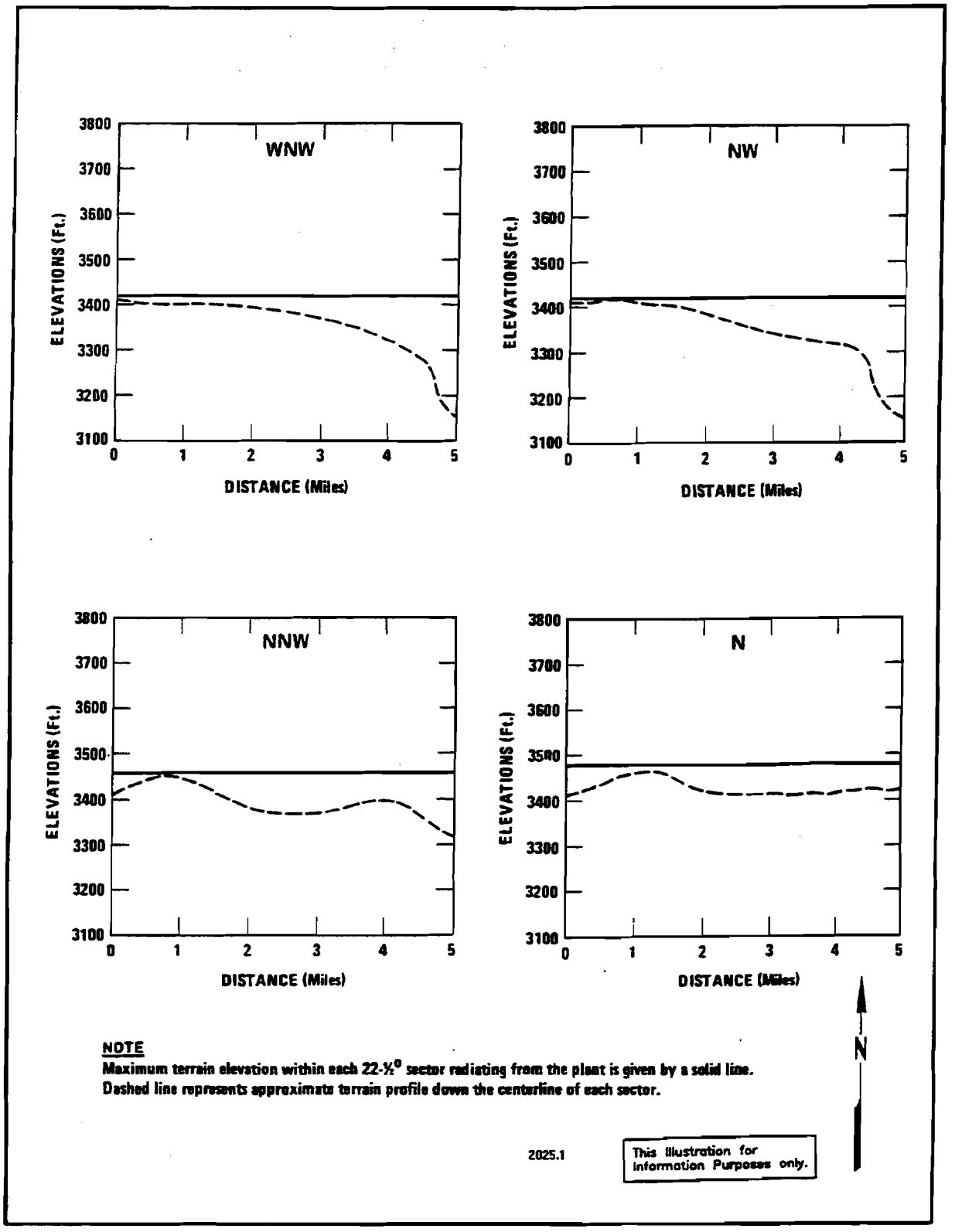

Figure 2.5-12D, Terrain Elevations Out to 5 Miles from Center of the WIPP Facility Sheet 4 of 4

Table 2.5-1, Maximum Wind Speeds for Roswell, New Mexico*

Month	Max wind speed, mph	Month	Max wind speed, mph
January	67	July	66
February	70	August	72
March	66	September	54
April	75	October	66
May	72	November	65**
June	73	December	72

*Climates of the States, Vol. 2 - Western States, Roswell, NM, U.S. National Oceanic and Atmospheric Administration (NOAA), Water Information Center, Inc., Asheville, NC, 1974, p. 804. Local Climatological Data, Annual Summary 1985, Roswell, NM, NOAA-ED.

**Occurred more than once.

Table 2.5-2, Recurrence Intervals for High Winds in Southeastern New Mexico*

	Speed, mph			
Recurrence, years	30'	50'	100'	150'
2	58	62	65	73
10	68	73	81	86
25	72	77	86	91
50	80	86	95	101
100	82	88	97	103

*O. G. Sutton, Micrometeorology (McGraw-Hill Book Co., Inc., New York, 1953), p. 238.

Table 2.5-3, Seasonal Frequencies of Inversions*

Season	Inversion frequency (% of total hours)	Maximum %**
Spring	32	65
Summer	25	68
Fall	35	72
Winter	46	78
Annual	35	70

*C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, 89 (9) (1961).

**Frequency of 24-hour periods with at least 1 hour of inversion based at or below 500 feet.

Table 2.5-4, Seasonal Values of Mean Mixing Heights*

Season	Mean afternoon mixing height, m	Mean morning mixing height, in.
Spring	2800	480
Summer	3050	680
Fall	2000	440
Winter	1320	300
Annual	2400	470

*G. C. Holzworth, Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States, U.S. Environmental Protection Agency (EPA), Research Triangle Park, NC (1972).

Table 2.5-5, Annual Average, Maximum, and Minimum Temperatures

Year	Annual Average Temperature (°C)	Annual Average Temperature (°F)	Maximum Temperature (°C)	Maximum Temperature (°F)	Minimum Temperature (°C)	Minimum Temperature (°F)
1990	17.8	64.0	46.1	115.0	-13.9	7.0
1991	17.2	63.0	42.8	109.0	-7.8	18.0
1992	17.2	63.0	42.8	109.0	-10.0	14.0
1993	17.8	64.0	42.8	109.0	-18.9	-2.0
1994	17.8	64.0	50.0	122.0	-14.4	6.0
Average	17.6	63.6	44.9	112.8	-13.0	8.6

Source: WIPP Annual Site Environmental Report for Calendar Years 1990 through 1994 (Draft)

2.6 Surface-Water and Groundwater Hydrology

The hydrological characteristics of the disposal system are important because contaminant transport via fluid flow has the potential of having the greatest impact on the disposal system. At the WIPP site, one of the DOE's selection criterion was to choose a location that would minimize these impacts. This was accomplished when the DOE selected (1) a disposal medium that is essentially devoid of groundwater; (2) a location where the effects of groundwater circulation are minimal and predictable; (3) an area where groundwater use is virtually non-existent; (4) an area where there are no surface-waters; (5) an area where future groundwater use is unlikely; and (6) a repository host rock that will not likely be affected by anticipated long-term climate changes possible within 10,000 years.

The following discussion summarizes the characteristics of the groundwater and surface-water at and around the WIPP site. This summary is based on data collection programs that were initiated at the inception of the WIPP program and which continue to some extent today. These programs have several purposes:

- To provide sufficient information to develop predictive models of the groundwater movement within the vicinity of the WIPP site
- To collect data to evaluate the predictive models and to adapt them to the specific conditions of the WIPP site
- To develop an understanding of the surface-water characteristics and the interaction between surface-waters and groundwater
- To develop predictive models of the interaction between surface-water and groundwater during reasonably expected climate changes.

In order to provide a comprehensive understanding of the impact of groundwater and surface-water on the disposal system, the following are the relevant factors which have been evaluated:

Groundwater

- General flow direction
- Flow type
- Horizontal and vertical flow velocities
- Hydraulic interconnectivity between rock units
- General groundwater use
- Chemistry (including, but not limited to, salinity, mineralization, age, oxidation potential (Eh, and pH).

Surface-Water

- Regional precipitation and evapotranspiration rates
- Location and size of surface-water bodies
- Water volume, flow rate, and direction
- Drainage network
- Hydraulic connection with groundwater
- Soil hydraulic properties (infiltration)
- General water chemistry and use.

The hydrological system is divided into three segments for the purposes of modeling and discussion. These are (1) the Salado, which for the most part concerns the performance of the disposal system; (2) the non-Salado rock units, which are of interest to the extent they can affect the Salado and the performance of the disposal system; and (3) the surface-waters, which are impacted by the natural variability of the climate.

The WIPP site lies within the Pecos River drainage area (Figure 2.6-1). The climate is semiarid, with an average annual precipitation of about 13 inches (0.33 meters), a mean annual runoff of from 0.1 to 0.2 inches (2.5 to 5 millimeters), and a mean annual pan evaporation of more than 100 inches (2.5 meters). Brackish water with total dissolved solids (TDS) concentrations of more than 3,000 parts per million is common in the shallow wells near the WIPP site. Surface-waters (Section 2.4.2.2) typically have high TDS concentrations, particularly of chloride, sulfate, sodium, magnesium, and calcium.

At the WIPP site, the DOE obtains hydrologic data from conventional and special-purpose test configurations in multiple surface boreholes. (Figure 2.6-2 is a map of borehole locations.) Geophysical logging of the boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through the use of standard and modified drill-stem tests.

Slug injection or withdrawal tests have provided additional data to aid in the estimation of transmissivity and storage. Also, the hydraulic head of groundwaters within many water-bearing zones in the region has been mapped from measured depths to water in the boreholes (DOE/WIPP 94-2033).[1]

2.6.1 Groundwater Hydrology

Rock units that are important to WIPP hydrology are the Delaware Mountain Group, the Castile, the Salado, the Rustler, the Dewey Lake, the Santa Rosa, and the Gatuña (Figures 2.6-3 and 2.6-4). The Bell Canyon is of interest because it is the first regionally continuous water-bearing unit beneath the WIPP. The Castile provides a hydrologic barrier underlying the Salado, though it may contain pressurized brine (DOE/EIS-0026-FS).[2]

The Culebra of the Rustler is the first laterally continuous unit located above the WIPP underground facility to contain circulating groundwater and to display hydraulic conductivity sufficient to warrant concern over lateral contaminant transport. Barring a direct breach to the surface, the Culebra provides the most direct pathway between the WIPP underground and the accessible environment.[2] The hydrology and fluid geochemistry of the Culebra are very complex and, as a result, have received a great deal of study in WIPP site characterization such as that reported in SAND88-7002,[3] SAND86-7167,[4] and SAND88-0196.[5]

At the site, the Dewey Lake is 60 feet (18 meters) below the surface and about 490 feet (149 meters) thick. This formation appears to be mostly unsaturated hydrologically in the vicinity of the WIPP shafts and over the waste emplacement panels.

At the WIPP site, the Culebra and the Magenta are considered to be the most significant water-bearing units. Sampling and analysis of non-Salado groundwater has focused on these two rock units, and the hydrologic background presented here is more detailed than for other non-Salado rock units. The hydrologic properties of the interface between the Rustler and the Salado will also be discussed. Table 2.6-1 provides an overview of the hydrologic characteristics of the rock units of interest at the WIPP site and the Rustler-Salado contact zone (Section 2.6.1.4 also describes the hydrology of the Rustler-Salado contact zone).

2.6.1.1 Hydrology of the Capitan Limestone

The Capitan, cropping out in the southern end of the Guadalupe Mountains, is a massive limestone unit that grades basinward into recemented, partly dolomitized reef breccia and shelfward into bedded carbonates and evaporites (DOE/EIS-0026).[6] Its hydraulic conductivity ranges from 1 to 25 feet (0.3 to 7.6 meters) per day in southern Lea County and is 5 feet (1.5 meters) per day east of the Pecos River at Carlsbad. Average transmissivities around the northern and eastern margins of the Delaware Basin are 10,000 square feet (929 square meters) per day in thick sections and 500 square feet (46.5 square meters) per day in incised submarine canyons.[7] In the aquifer, water table conditions are found southwest of the Pecos River at Carlsbad; however, artesian conditions exist to the north and east. A deeply incised submarine canyon near the Eddy-Lea county line has been identified. This canyon is filled with sediments of lower permeability than the Capitan and restricts fluid flow.[7] The hydraulic gradient to the southeast of this restriction has been affected by large oil field withdrawals. The Capitan limestone is recharged by percolation through the northern shelf aquifers, by flow from underlying basin aquifers to the south and west, and by direct infiltration at its outcrop in the Guadalupe Mountains.[6]

2.6.1.2 Hydrology of the Delaware Mountain Group

Formations of the Delaware Mountain Group underlie the Capitan Reef and form the floor of the Delaware Basin evaporite sequence. Three separate formations, each about 1,000 feet (305 meters) thick, are assumed to form a single aquifer system, with an average hydraulic conductivity of 0.02 foot (0.065 meters) per day and a calculated transmissivity of about 50 square feet (4.6 square meters) per day (SAND78-1596).[8] Figure 2.6-5 presents a potentiometric map representing a composite surface for the Delaware Mountain Group and the Capitan aquifer (Hiss, 1976).[45] These data were adjusted for saline density and expressed as freshwater equivalents. The brines in the Delaware Mountain Group flow northeasterly under a hydraulic gradient of from 25 to 40 feet per mile (4.7 to 7.6 meters per kilometer) and discharge into the Capitan aquifer. Velocities range from 0.2 to 0.3 feet (0.06 to 0.09 meters) per year, and groundwater yields from wells in the Delaware Mountain Group are from 0.6 to 1.5 gallons (2.3 to 5.8 liters) per minute.[6]

2.6.1.3 Hydrology of the Salado and Castile Formations

As described below the Salado and the Castile consist mainly of halite and anhydrite. A considerable amount of information about the hydraulic properties of these rocks has been collected through field and laboratory experiments.

2.6.1.3.1 Salado Hydrology

Hydraulic testing in the Salado halite-rich sections provided quantitative estimates of the hydraulic properties that control brine flow through the Salado. The tests are interpreted in SAND90-0083[10] and SAND92-0533[11] using models based on potentiometric flow. The tests influence rock as far as 33 feet (10 meters) distant from the test zone. There does not appear to be any evidence that the tests themselves significantly alter the pre-test conditions of the rock. The stratigraphic intervals tested include both pure and impure halite. Because tests close to the repository are within the disturbed rock zone (DRZ), it is reasonable to use the results of the tests farthest from the repository as most representative of undisturbed conditions.

Twenty-two hydraulic tests have been performed in impure halite, and two in pure halite. Interpreted permeabilities using a Darcy-flow model range from 1×10^{-23} to 4×10^{-18} square meters for impure halite intervals. Interpreted formation pore pressures range from 0.3 to 9.7 megapascals for impure halite. Tests in pure halite show no observable response, indicating either extremely low permeability ($< 10^{-23}$ square meters), or no flow whatsoever, even though appreciable pressures are applied to the test interval.

Fourteen hydraulic tests have been performed in anhydrite. Interpreted permeabilities using a Darcy-flow model range from 2×10^{-20} to 7×10^{-18} square meters for anhydrite intervals. Interpreted formation pore pressures range from atmospheric to 12.5 megapascals for anhydrite intervals. Lower values are caused by depressurization near the excavation.

The properties of anhydrite interbeds have also been investigated in the laboratory. Tests were performed on three groups of core samples from MB 139 as part of the Salado Two-Phase Flow Laboratory Program. The laboratory experiments provided porosity, intrinsic permeability, and capillary pressure data. Preliminary analysis of capillary pressure test results indicate a threshold pressure of less than 1 megapascal.

Fluid pressures that are much higher than hydrostatic is a hydrologic characteristic of the Castile and the Salado that the DOE believes plays a potentially important role in the repository behavior. It is difficult to accurately measure natural pressures in these formations because the boreholes or repository excavations required to access the rocks decrease the stress in the region measured. Stress release instantaneously decreases fluid pressure in the pores of the rock, so measured pressures must be considered as a lower bound of the actual natural pressures. Stress effects related to test location, and the difficulty of long-duration testing in lower permeability rocks, results in higher pore pressures being observed in anhydrites. The highest observed pore pressure in halite-rich units, near Room Q, is on the order of 9 megapascals, whereas the highest pore pressures observed in anhydrite are 12.5 megapascals. The farfield pore pressures in halite-rich and anhydrite beds in the Salado at the repository level are expected to be similar. For comparison, the hydrostatic pressure at the depth of the repository is about 7 megapascals and the lithostatic pressure calculated from density measurements in U.S. Energy and Research Administration (ERDA-9) borehole is about 15 megapascals.

Fluid pressures in sedimentary basins that are much higher or much lower than hydrostatic are referred to as "abnormal pressures" in the literature of the petroleum industry, where they have received considerable attention. The explanations of how these pressures can be maintained over very long periods of time, perhaps millions of years, generally fall into two categories. The first is based on the concept that the maintenance of abnormal pressures indicates the rock volumes containing the high pressures must be "hydraulically isolated" from normally pressured sediments. The second maintains that all rocks have finite permeability and that abnormal pressures must be viewed as a transient phenomenon. In the absence of a generating method, according to the second category, these pressures would decay away over geologic time even in rocks with extremely low permeability. Except for pure halite, it has been demonstrated that the rocks of the Castile and the Salado have a small but finite permeability.

The high pressures are almost certainly maintained because of the large compressibility and plastic nature of the halite, and to a lesser extent, the anhydrite. The lithostatic pressure at a particular horizon must be supported by a combination of the stress felt by the rock matrix and the pore fluid. In highly deformable rocks, the portion of the stress that must be borne by the fluid exceeds hydrostatic pressure but cannot exceed lithostatic pressure.

Brine content within the Salado is estimated at 1 to 2 percent by weight although the thin clay seams have been observed by the Brine Sampling and Evaluation Program (BSEP), DOE/WIPP 91-036[12] to contain up to 25 percent brine by weight. This brine may move to areas of less pressure, such as a borehole or mined section of the Salado. Ten years of BSEP data have been collected and interpreted to indicate that clay seams are the most likely source of the Salado brines flowing into the excavations. This mechanism predicts that observed brine flow will cease when structural creep in the formation ceases.

Observation of the response of pore fluids in the Salado to potential gradients (to walls in the repository, to boreholes without packers, or to packer-sealed boreholes) is complicated by low permeability and low porosity. Flow has been observed to move to walls in the repository, to boreholes without packers, and to packer-sealed boreholes. In certain cases, evidence for flow is no longer observed where it once was; in others, flow has begun where it once was not observed. In many cases, observations and experiments must last for months or years to obtain useful results. In part because of design requirements such as duration (experimental period is short relative to the time required for the geological materials to fully respond), few quantitative data have been obtained for certain lithologic units within the Salado. There is much direct, qualitative experience regarding the behavior of flow crossing the walls of the repository.

2.6.1.3.2 Castile Hydrology

The hydrology of the Castile differs from that of the Salado in that fracturing in the upper anhydrite has generated regions with much greater permeability than the surrounding intact anhydrite. These regions are located in areas of structural deformation. The higher permeability regions of the Castile contain brine at pressures greater than hydrostatic and have been referred to as "brine reservoirs." The fluid pressure measured in the WIPP-12 drillhole (12.7 megapascals) is greater than the nominal hydrostatic pressure for a column of equivalent brine at that depth (11.1 megapascals). Therefore, under open-hole conditions, brine could flow upward through an intrusion borehole.

Hydraulic tests performed in the ERDA-6 and WIPP-12 boreholes and reported in SAND78-1596[13] suggest that the highly permeable portions of the Castile are limited in extent. The vast majority of brine is thought to be stored in low-permeability microfractures; about 5 percent of the overall brine volume is stored in large open fractures. The volumes of the ERDA-6 and WIPP-12 brine reservoirs are estimated to be 3.5×10^6 cubic feet (100,000 cubic meters) and 9.5×10^6 cubic feet (2,700,000 cubic meters), respectively.[13]

The origin of brine in the Castile has been investigated geochemically. SAND78-1596[13] concluded that the ratios of major and minor element concentrations in the brines indicate that these fluids originated from ancient seawater and that there is no evidence for fluid contribution from present meteoric waters. The gas and brine chemistries of Castile waters from the ERDA-6 and WIPP-12 reservoirs are distinctly different from each other and from local groundwaters. The brines are saturated, or nearly so, with respect to halite and, consequently, have little or no halite dissolution potential.

2.6.1.4 Hydrology of the Rustler-Salado Contact Zone

In the vicinity of the Nash Draw, the contact between the Rustler and the Salado is an unstructured residuum of gypsum, clay, and sandstone created by the dissolution of halite. The residuum is absent under the WIPP site. It is clear that dissolution in Nash Draw occurred after deposition of the Rustler.

Brine in the Rustler-Salado contact residuum, immediately above the top of the salt in the vicinity of Nash Draw, was first described and referred to as the "brine aquifer," by Robinson and Lang.[14] This reference suggested that the structural conditions that caused the development of Nash Draw might control the occurrence of the brine; thus, the brine aquifer boundary may coincide with the topographic surface expression of Nash Draw. Studies show the brine to be concentrated along a strip from 2 to 8 miles (3.2 to 13 kilometers) wide and about 26 miles (43 kilometers) long. Data from the test holes Robinson and Lang drilled indicate that the residuum (containing the brine) ranges in thickness from 10 to 60 feet (3 to 19 meters) and averages about 24 feet (17 meters). Hydraulic properties were computed primarily for the area between Malaga Bend on the Pecos River and Laguna Grande de la Sal.[15] Robinson and Lang calculated a value of transmissivity of 8,000 square feet (8.6×10^{-3} square meters per second) per day and estimated the potentiometric gradient to be 1.4 feet per mile (0.27 meters per kilometer). In this area, the "Rustler-Salado residuum" apparently is part of a continuous hydrologic system as evidenced by the coincident fluctuation of water levels in the test holes (as far away as Laguna Grande de la Sal) with pumping rates in irrigation wells along the Pecos River.[15]

In the northern one-half of Nash Draw, the approximate outline of the brine aquifer (Rustler-Salado contact residuum) has been supported by drilling associated with the WIPP hydrogeologic studies.[14] These studies also indicate that the main differences in areal extent occur along the eastern side where the boundary is very irregular and, in places (test holes P-14 and H-07), extends farther east than previously indicated by Robinson and Lang.

Other differences from the earlier studies include the variability in thickness of residuum present in test holes WIPP-25 through WIPP-29. These holes indicate thicknesses ranging from 11 feet (3.3 meters) in WIPP-25 to 108 in WIPP-29 in Nash Draw compared to 8 feet (2.4 meters) in test hole P-14 east of Nash Draw. The specific geohydrologic mechanism that has caused dissolution to be greater in one area than in another is not apparent, although a general increase in chloride concentration in water from the north to the south may indicate the effects of movement down the natural hydraulic gradient in Nash Draw.

The average hydraulic gradient within the residuum in Nash Draw is about 10 feet per mile (1.9 meters per kilometer); in contrast, at the WIPP site the average gradient is 39 feet per mile (7.4 meters per kilometers). This difference reflects the changes in transmissivity, which are as much as five orders of magnitude greater in Nash Draw. The transmissivity determined from aquifer tests in test holes completed in the Rustler-Salado contact residuum of Nash Draw ranges from 2×10^{-4} square feet per day at WIPP-27 to 8 square feet per day (8.6×10^{-6} square meters per second) at WIPP-29. This is in contrast to the WIPP site proper, where transmissivities range from 3×10^{-5} square feet (3.2×10^{-11} square meters per second) per day at test holes P-18 and H-05c to 5×10^{-2} square feet per day (5.4×10^{-8} square meters per second) at test hole P-14. Locations and estimated hydraulic heads of these wells are illustrated in Figure 2.6-6.

Hale et al. (1954)[15] believed the Rustler-Salado contact residuum discharges to the alluvium near Malaga Bend on the Pecos River. Because the confining beds in this area probably are fractured due to dissolution and collapse of the evaporites, the brine (under artesian head) moves up through these fractures into the overlying alluvium and then discharges into the Pecos River.

Evidence for very slow groundwater movement is found in the water quality, especially in the magnesium concentrations. Large magnesium concentrations appear to be indicative of an environment in which groundwater flow is extremely slow and there has been extensive interaction between the water and its host rock. Large concentrations of magnesium, ranging from 21,000 milligrams per liter in water from test hole H-06 to 82,000 milligrams per liter in water from test hole H-05, were present in most of the test wells in the eastern part of the WIPP site. Aquifer tests at these test holes were characterized by very low transmissivities. To the west, approaching the more developed part of the flow system of the Rustler-Salado contact residuum in Nash Draw, the magnesium concentrations decreased by one to two orders of magnitude. Magnesium concentrations of 1,200 milligrams per liter in water from test hole P-14 and 350 milligrams per liter in water from test hole P-15 may indicate the eastern boundary of the more developed Rustler-Salado flow system. Magnesium concentrations are as small as 430 milligrams per liter in water from test hole H-08; other values range from 910 milligrams per liter in water from test hole H-07 to 3,200 milligrams per liter in water from test hole WIPP-25.

According to the Water Resources Investigation Report 83-4016,[9] water in the Rustler-Salado contact residuum contains the largest concentrations of dissolved solids in the WIPP area, ranging from 79,800 milligrams per liter in test hole H-07 to 480,000 milligrams per liter in test hole H-01. These waters are classified as brines. The dissolved mineral constituents in the brine largely consist of sulfates and cholorides of calcium, magnesium, sodium, and potassium; the major constituents are sodium and chloride. Concentrations of the other major ions vary according to the spatial location of the sample and probably are directly related to the interaction of the brine and the host rocks and reflect residence time within the rocks. Residence time of the brine depends upon the transmissivity of the rock. For example, the presence of large concentrations of potassium and magnesium in water is correlated with minimal permeability and a relatively undeveloped flow system.

2.6.1.5 Hydrology of the Rustler Formation

The Rustler is of particular importance for WIPP because it contains the most transmissive units above the repository. The Rustler is divided into four formally named members and an unnamed lower member. These five units[16,9] are, in ascending order, the unnamed lower member (the oldest), the Culebra, the Tamarisk, the Magenta, and the Forty-niner Member (the youngest).

2.6.1.5.1 Unnamed Lower Member of the Rustler Formation

The basal interval of the unnamed lower member is composed of siltstone, mudstone, and claystone and can be considered the water-producing zones of the lowermost Rustler.[2] Transmissivities of 2.9×10^{-10} square meters per second (2.7×10^{-4} square feet per day) and 2.4×10^{-10} square meters per second (2.2×10^{-4} square feet per day) were calculated by Beauheim (1987a, b)[46,47] from tests at well H-16 that included this interval. These transmissivity values correspond to hydraulic conductivities of 1.5×10^{-11} meters per second (4.2×10^{-6} feet per day) and 1.2×10^{-11} meters per second (3.4×10^{-6} feet per day). Hydraulic conductivity in the lower portion of the unnamed lower member is believed to increase to the west in and near Nash Draw, where dissolution in the underlying Rustler-Salado contact zone has caused subsidence and fracturing of the sandstone and siltstone.[17]

The remainder of the unnamed lower member contains mudstones, anhydrite, and variable amounts of halite. The hydraulic conductivity of these lithologies is extremely low: tests of mudstones and claystones in the Waste Shaft gave hydraulic conductivity values ranging from $6x10^{-15}$ meters per second ($2x10^{-9}$ feet per day) to $1x10^{-13}$ meters per second ($3x10^{-8}$ feet per day).[18]

2.6.1.5.2 The Culebra Member of the Rustler Formation

The Culebra is modeled in the performance assessment as the most likely pathway for the release of radionuclides to the accessible environment because of its relatively high transmissivity near the WIPP site, and hydrologic research activity has concentrated on the unit for over a decade.[19,20,9,21,22,23,3,24,25]

According to Water Resources Investigation Report 83-4016,[9] the transmissivity of the Culebra varies over six orders of magnitude from east to west in the vicinity of the WIPP (Figure 2.6-7). The transmissivity ranges from $1x10^{-9}$ ($1x10^{-3}$ square feet per day) square meters per second at well P-18 east of the WIPP site to ($1x10^{3}$ square feet per day) $1x10^{-3}$ square meters per second at well H-7 in Nash Draw (see Figure 2.6-2 for the locations of these wells).

Measured matrix porosities of the Culebra range from 0.03 to 0.30.[26,27] Fracture porosity values have not been measured directly, but interpreted values from tracer tests at the H-3, H-6, and H-11 hydropads[28] range from $5x10^{-4}$ to $3x10^{-3}$.[29] Data are insufficient to map the spatial variability of the porosity.

Variations in transmissivity in the Culebra are believed by many experts to be controlled by the relative abundance of open fractures rather than by primary (i.e., depositional) features of the unit.[30] Lateral variations in depositional environments were small within the mapped region, and primary features of the Culebra show little map-scale spatial variability according to DOE/WIPP88-004.[31] Direct measurements of the density of open fractures are not available from core samples because of incomplete recovery and fracturing during drilling, but comparisons with the relatively unfractured exposures in the WIPP shafts suggest that the density of open fractures in the Culebra decreases to the east. Qualitative correlations have been noted between transmissivity and several geologic features possibly related to open-fracture density, including (1) the distribution of overburden above the Culebra;[31] (2) the distribution of halite in other members of the Rustler;[30] (3) the dissolution of halite in the upper portion of the Salado; and (4) the distribution of gypsum fillings in fractures in the Culebra.

The distribution of groundwater hydrogeochemical facies is not consistent with the southward flow direction calculated in SAND8970681[32] from potentiometric data (see Figure 2.6-8), if one assumes that the ionic strength of a groundwater increases along a flow path. One possible explanation for the apparent inconsistency has been proposed in EEG 35[33] and 39,[34] who coupled an extensive compilation of stable and radiogenic isotope ratios of Rustler Formation groundwaters with isotopic data from regional groundwaters and surficial waters. Chapman[33,34] cited evidence for short residence times of Culebra groundwaters and postulated that recharge from the surface could account for the less concentrated groundwaters south of the WIPP Site. That explanation, however, is not supported by the isotopic and solute data described in later work by Lambert, Siegel, and others. Specifically, radiogenic isotopic signatures suggest that the age of the groundwater in the Culebra is on the order of tens of thousands of years.[35,36,37] An alternative explanation for the apparent inconsistency was put forth in SAND88-0196.[5] Those authors contend that there has been a change in the location and amount of recharge since the last glacial maximum and that the present distribution of solutes and isotopes in the Culebra is a relict of a flow regime of a wetter climate, in which the recharge area was in the vicinity of Nash Draw resulting in an eastward paleo-flow direction. The current distribution of hydrogeochemical facies, therefore, represents a rock-water system that is still slowly reaching a new chemical and physical equilibrium.

Currently, the issue of the relationship between water chemistry and groundwater flow in the Culebra remains unresolved. It is possible that lack of resolution reflects the way the problem has been posed and the relatively simple conceptual models that have been used to represent the hydrology of the system. Previous discussions, for example, have focused on flow directions but not flow rates. Computer models of flow in the Culebra suggest that flow rates are orders of magnitude slower in the region of the halite facies than in the region of the anhydrite facies. It is possible that the geochemical signature of flow from the halite facies to the anhydrite facies is not observed because only minute amounts of water flow along this path. In addition, some of the previous studies have not considered, or have not ruled out, transport of solutes from units above and below the Culebra. For example, the region of the halite facies correlates well with the extent of halite in strata above and below the Culebra. The possibility that the halite facies results from vertical advective or diffusive transport into a region of extremely slow flow in the Culebra has not been investigated. Preliminary results of calculations using the groundwater basin approach suggest that addressing these issues as a three-imensional transport system will facilitate resolution.

2.6.1.5.3 Tamarisk Member of the Rustler Formation

Attempts were made in two wells, H-14 and H-16, to test a 2.4-meter (7.9-foot) sequence of the Tamarisk member that consists of claystone, mudstone, and siltstone overlain and underlain by anhydrite. Permeability was too low to measure in either well within the time allowed for testing; consequently the transmissivity of the claystone sequence was estimated to be one or more orders of magnitude less than that of the tested interval in the unnamed lower member.[22] Transmissivity in the Tamarisk was estimated to be less than approximately 2.5×10^{-5} square feet per day (2.7×10^{-11} square meters per second), corresponding to a hydraulic conductivity of less than approximately 1.3×10^{-6} square feet per day (1.4×10^{-12} meters per second).

2.6.1.5.4 Magenta Member of the Rustler Formation

The Magenta member of the Rustler is a fine-grained dolomite that ranges in thickness from 13 to 26 feet (4 to 8 meters) and is about 19 feet (6 meters) thick at the WIPP (Holt and Powers, 1988).[31] The Magenta is saturated except near outcrops along Nash Draw, and hydraulic data are available from 15 wells. According to Water Resources Investigation Report 83-4016,[9] transmissivity ranges over five orders of magnitude from $1\text{x}10^{-3}$ to $4\text{x}10^{2}$ square feet per day ($1\text{x}10^{-9}$ to $4\text{x}10^{-4}$ square meters per second).

The hydraulic transmissivities of the Magenta, based on sparse data, shows a decrease in conductivity from west to east, with slight indentations of the contours north and south of the WIPP that correspond to the topographic expression of Nash Draw.[38] In most locations, the hydraulic conductivity of the Magenta is one to two orders of magnitude less than that of the Culebra.

No porosity measurements have been made on the Magenta. A representative dolomite porosity of 0.20 for the interpretations of well tests was assumed according to SAND87-0039.[22] The hydrologic gradient across the site varies from 16 to 20 feet per mile on the eastern side, steepening to about 32 feet per mile along the western side near Nash Draw (Figure 2.6-8).

2.6.1.5.5 Forty-niner Member of the Rustler Formation

The uppermost member of the Rustler Formation, the Forty-niner Member, is about 66 feet (20 meters) thick throughout the WIPP area and consists of low-permeability anhydrite and siltstone. Tests in H-14 and H-16 yielded transmissivities of about $3\text{x}10^{-2}$ to $7\text{x}10^{-2}$ square feet per day ($3\text{x}10^{-8}$ to $8\text{x}10^{-6}$ square meters per second) and $5\text{x}10^{-3}$ to $6\text{x}10^{-3}$ square feet per day ($3\text{x}10^{-9}$ to $6\text{x}10^{-9}$ square meters per second), respectively.[22]

2.6.1.6 Hydrology of the Supra-Rustler Rocks (Dewey Lake, Santa Rosa Sandstone, and Gatuña)

The Supra-Rustler rocks consist of (in ascending order) the Dewey Lake, Santa Rosa Sandstone, and Gatuña and are comprised of a confining siltstone bed, water-bearing sandstone, and a confining mudstone bed (respectively). The Dewey Lake and Gatuña may act as barriers to downward percolation of surface waters while the Santa Rosa Sandstone provides water for irrigation and livestock.[2,6]

2.6.1.6.1 Dewey Lake

No hydraulic-conductivity data are available for the Dewey Lake Red Beds, which overlie the Rustler. Drilling during areal geohydrologic evaluation did not identify a continuous zone of saturation within the Dewey Lake Red Beds; however, localized zones of permeability were detected. In these geologic test holes, the presence of these zones was indicated by minor losses of circulation during drilling.[9] As indicated in the Water Resources Investigation Report 83-4016,[9] these fine-grained sandstones and siltstones have relatively low hydraulic conductivity. Therefore, a hydraulic conductivity of $3x10^{-3}$ feet per day (10^{-8} meters per second), which falls at the low end of the range of typical values for fine-rained sandstones, was used in the standard simulation models.[24]

In the latter part of calendar year 1994, DOE drilled six monitoring wells on the WIPP site. Water in the Dewey Lake Formation was encountered in only one well, located in the southern portion of the site (WQSP-6). In order to further study this zone of saturation, WQSP-6a was drilled in the upper part of the Dewey Lake.

Based on studies of wells completed in the Dewey Lake Formation at the James Ranch, Mercer[9] speculated in his 1983 report that water in the Dewey Lake Formation is found in discontinuous perched or semi-perched saturated lenses, believed to be recharged through nearby active dune areas. WQSP-6a is located on the edge of an active dune area, which supports Mercer's theory of local recharge.

Site investigations by Bechtel, prior to sinking the shafts, showed that the Dewey Lake Formation does not contain enough water to sample in the vicinity of the shafts. Studies of wells H-1, H-2, and H-3, coupled with the studies made in each of the shafts at the WIPP,[39,40,41] confirm that water in the Dewey Lake Formation over and surrounding the repository is non-existent and does not pose a viable transport mechanism for a release scenario.

2.6.1.6.2 Santa Rosa Sandstone

The Santa Rosa Sandstone is about 140 to 300 feet (43 to 91 meters) thick and is present over the eastern half of the WIPP site. It dips gently westward, except in local areas of collapse, and crops out northeast of Nash Draw. As a water-bearing unit, the Santa Rosa near the WIPP site has a saturated thickness of only 1 to 2 feet (.3 to .61 meters) and occurs in lenses that are very limited in extent. It has a porosity of about 13 percent and a specific capacity of 0.14-0.20 gallon per minute per foot of drawdown. Lows in the potentiometric surface near the Eddy-Lea county line and the San Simon Swale suggest recharge into underlying rocks, possibly through collapse zones, and a possibility of a groundwater divide (at a surface ridge) between the site and San Simon Swale. In general, groundwater flows south and is of better quality than that found in the Rustler.[6]

It is not known at this time what quantities of water, if any, from the Santa Rosa recharge the shallow aquifers along the Pecos River. The groundwater gradient in adjacent Texas along the Pecos River is influenced by a large-scale withdrawal of groundwater, resulting in a net loss of groundwater storage. The water-level declines have created sizable cones of depression along the river and gradients toward the river. The Santa Rosa aquifer in southwest Texas adjacent to the New Mexico border is not downgradient from the WIPP site. Several reasons exist for believing that Santa Rosa waters at the WIPP site flow into the Pecos River rather than to the south into Texas. Those are the configuration of the potentiometric head map (Figure 2.6-5), the influence of extensive pumping, and a topographic groundwater divide east of the WIPP site. Groundwaters pumped from the Santa Rosa and alluvium deposits are used extensively for irrigation and livestock.[6]

2.6.1.6.3 Gatuña

The Gatuña is a mudstone deposit above the Santa Rosa to the east of the site. It ranges in thickness from near zero near the Eddy-Lea county line to as much as 800 feet (244 meters) north of San Simon Swale. Because of the low hydraulic conductivity of mudstone, the Gatuña is hydrologically a confining bed.[6]

2.6.1.6.4 Groundwater Elevation Measurements in 1991

Groundwater levels have been measured continuously in the vicinity of the WIPP site for several decades. These levels can be used to determine the longer term trends in water level changes, either natural or in response to human activities in the region. The groundwater-level data indicate that there is a gradual trend of rising water-level elevations within the Culebra. Of the surveillance locations, 39 of the 46 showed some increase in water-level elevations within the Culebra. Two anomalous occurrences were noted in the data. The first was a net loss of 8.64 feet (2.63 meters) of groundwater-evel elevation at the Cabin Baby (CB-1) well site from January through December 1991, and the second was a gain of 24.77 feet (7.55 meters) of groundwater-level elevation at well P-18 (Figure 2.6-6). The two wells are located within 5 miles (8 kilometers) of each other. The suspected cause of the loss of water-level elevation at Cabin Baby is the failure of a bridge plug located between the Culebra and the portion of the hole open to the Salado and Castile. The anomalous water-level elevation increase at P-18 is gradually decreasing from year to year. In 1988, the water level in well P-18 increased approximately 45 feet (14 meters), whereas the increase was approximately 33 and 25 feet (10 and 7.6 meters), respectively, in 1990 and 1991. The smaller increase from year to year indicates that P-18 is trending toward an equilibrium state; however, the magnitude of elevation gains indicates that years may pass before equilibrium is achieved.

Freshwater head distribution in the Culebra indicate that the generalized directional flow of groundwater is north to south. However, caution should be used when making assumptions based on groundwater-level data alone. Recent studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction. One should also be aware that the fractured media of the Culebra, coupled with variable fluid densities, can cause localized flow patterns to have little or no relationship to general flow patterns.

Measurements at 11 surveillance locations in the Magenta also indicated an upward trend in water-level elevations. No anomalous losses or gains were noted within the Magenta. Seven of eleven Magenta surveillance locations show a gain in the elevation of groundwater levels from January to December 1991. Four wells showed lower groundwater-level elevations in December than in January 1991. All of the four surveillance locations that indicated a loss of head elevation from January to December were wells that are pumped routinely as part of the Water Quality Sampling Program (WQSP). These locations are H-03b1, H-04c, H-05c, and H-06c (Figure 2.6-6). Recovery from these pumping events may have influenced the water-level data collected at these locations.

When groundwater elevations taken in 1991 are compared to potentiometric elevation maps produced in Water Resources Investigation Report 83-4016,[9] groundwater elevations appear to be below 1983 levels. The 1983 Mercer study was performed prior to the onset of the large-scale hydrologic activities that took place in the vicinity of the WIPP site to support site characterization and other hydrologically oriented activities during the mid to late 1980s. Since the end of the 1980s, only modest amounts of groundwater have been removed from these formations. The possibility exists that the increasing groundwater elevations observed in 1991 represent a natural trend for the recovery of the formations to groundwater elevations near those of the 1983 potentiometric elevations.

2.6.2 Surface-Water Hydrology

The WIPP site is in the Pecos River basin, which contains about 50 percent of the drainage area of the Rio Grande Water Resources Region. The Pecos River headwaters are northeast of Santa Fe, and the river flows to the south through eastern New Mexico and western Texas to the Rio Grande. The Pecos River has an overall length of about 500 miles (805 kilometers), a maximum basin width of about 130 miles (209 kilometers), and a total drainage area of about 44,535 square miles (115,301 square kilometers). About 20,500 square miles (53,075 square kilometers) contained within the basin have no external drainage and do not contribute to Pecos River flows. Figure 2.6-1 shows the Pecos River drainage area.[6]

The Pecos River is generally perennial, except in the reach below Anton Chico and between Fort Sumner and Roswell, where the low flows percolate into the stream bed. The main stem of the Pecos River and its major tributaries have low flows, and the streams are frequently dry. About 75 percent of the total annual precipitation and 60 percent of the annual flow result from intense local thunderstorms between April and September. The principal tributaries of the Pecos River, in downstream order, are the Gallinas River, Salt Creek, Rio Hondo, Rio Felix, Eagle Creek, Rio Penasco, Black River, and Delaware River.[6]

There are no perennial streams at the WIPP site. At its nearest point, the Pecos River is about 12 miles (19 kilometers) southwest of the WIPP site boundary. The drainage area of the Pecos River at this location is 19,000 square miles. A few small creeks and draws are the only westward flowing tributaries of the Pecos River within 20 miles (32 kilometers) north or south of the site. A low-flow investigation has been initiated by the USGS within the Hill Tank Draw drainage area, the most prominent drainage feature near the WIPP site. The drainage area is about 4 square miles (10.3 kilometers), with an average channel slope of 1 to 100, and the drainage is westward into Nash Draw. Two years of observations showed only four flow events. The USGS estimates that the flow rate for these events was under 2 cubic feet per second. The Black River (drainage area: 400 square miles [1,035 square kilometers]) joins the Pecos from the west about 16 miles (25 kilometers) southwest of the site. The Delaware River (drainage area: 700 square miles [1,812 square kilometers]) and a number of small creeks and draws also join the Pecos along this reach. The flow in the Pecos River below Fort Sumner is regulated by storage in Sumner Lake, Brantley Reservoir, Lake Avalon, and several other smaller irrigation dams.[6]

Four major reservoirs are located in the Pecos River basin: Sumner Lake, Brantley Reservoir, Lake Avalon, and the Red Bluff Reservoir, the last located just over the border in Texas (Figure 2.6-9). The storage capacities of these reservoirs and other Pecos River reservoirs adjacent to the Pecos River basin are shown in Table 2.6-2.

With regards to surface drainage onto and off of the WIPP site, there are no major lakes or ponds within 10 miles (16 kilometers) of the center of the site. Laguna Gatuña, Laguna Tonto, Laguna Plata, and Laguna Toston are playas more than 10 miles (16 kilometers) north of the site and are at elevations of 3,450 feet (1,052 meters) or higher. Thus, surface runoff from the site (elevation 3,310 feet [1,009 meters] above sea level) would not flow toward any of them. To the north, west and northwest, Red Lake, Lindsey Lake, Laguna Grande de la Sal, and a few unnamed stock tanks are more than 10 miles (16 kilometers) from the site, at elevations of 3,000 to 3,300 feet (914 to 1,006 meters).[6]

The average precipitation in the region is about 13 inches (0.33 meters), and the mean annual runoff is 0.1-0.2 inch (2.5 to 5 millimeters). The maximum recorded 24-hour precipitation at Carlsbad was 5.12 inches (130 millimeters) in August 1916. The 6-hour, 100-year precipitation event for the site is 3.6 inches (91 millimeters) and is most likely to occur during the summer. The maximum daily snowfall at Carlsbad was 10 inches (254 millimeters) in December 1923.

The maximum recorded flood on the Pecos River occurred near Malaga on August 23, 1966, with a discharge of 120,000 cubic feet per second (3,396 cubic meters per second) and a stage elevation of about 2,938 feet (895 meters) above mean sea level. The minimum surface elevation of the WIPP site is over 500 feet (152 meters) above the river bed and over 400 feet (122 meters) above the elevation of this maximum historical flood elevation.[6]

More than 90 percent of the mean annual precipitation at the site is lost by evapotranspiration. On a mean monthly basis, evapotranspiration at the site greatly exceeds the available rainfall; however, intense local thunderstorms may produce runoff and percolation.

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows (see Section 2.4.2.2 for surface-water quality). At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1,650 tons per day. Large amounts of chlorides from Salt Creek and Bitter Creek enter the river near Roswell. River inflow in the Hagerman area contributes increased amounts of calcium, magnesium, and sulfate; and waters entering the river near Lake Arthur are high in chloride. Below Brantley Reservoir, springs flowing into the river are usually submerged and difficult to sample; springs that could be sampled had TDS concentrations of 3,350 to 4,000 milligrams per liter. Concentrated brine entering at Malaga Bend adds an estimated 70 tons per day of chloride to the Pecos River.

2.6.3 Groundwater Discharge and Recharge

The only documented points of naturally occurring groundwater discharge in the vicinity of the WIPP are the saline lakes in Nash Draw and the Pecos River, primarily near Malaga Bend.[42] Although this is local flow associated with Nash Draw and unrelated to groundwater flow at the WIPP site, it is presented here for completeness. Discharge into one of the lakes from Surprise Spring was measured at a rate of less than 0.35 cubic feet per second (0.01 cubic meters per second).[42] It was also estimated total groundwater discharge into the lakes is 24 cubic feet per second (0.67 cubic meters per second).[42] Discharge from the spring comes from fractured and more transmissive portions of the Tamarisk Member of the Rustler, and the lakes are hydraulically isolated from the Culebra Dolomite and lower units.[9]

Groundwater discharge into the Pecos River is greater than discharge into the saline lakes. Groundwater discharge into the Pecos River between Avalon dam north of Carlsbad and a point south of Malaga Bend was no more than approximately 32.5 cubic feet per second (0.92 cubic meters per second). Most of this gain in stream flow occurs near Malaga Bend (see Figure 2.1-1) and is the result of groundwater discharge from the residuum at the Rustler-Salado contact zone.[15,43,42]

The only documented point of groundwater recharge is also near Malaga Bend, where an almost immediate water-level rise has been reported in a Rustler-Salado well following a heavy rainstorm.[15] This location is hydraulically downgradient from the repository, and recharge here has little relevance to flow near the WIPP. Examination of the potentiometric surface map for the Rustler-Salado contact zone (Figure 2.6-5) indicates that some inflow may occur north of the WIPP, where fresh-water equivalent heads are highest. Additional inflow to the contact zone may occur as leakage from overlying units, particularly where the units are close to the surface and under water table conditions.

No direct evidence exists for the location of either recharge to or discharge from the Culebra. The freshwater-head contour map (Figure 2.6-10) implies inflow from the north and outflow to the south.[9] Recharge from the surface probably occurs 9-19 miles (15-30 kilometers) northwest of the WIPP in and north of Clayton Basin (Figure 2.6-5) where the Rustler Formation crops out. An undetermined amount of inflow may also occur as leakage from overlying units throughout the region.

The freshwater-head contour map (Figure 2.6-10) indicates that flow in the Culebra is toward the south. Some of this southerly flow may enter the Rustler-Salado contact zone under water table conditions near Malaga Bend and ultimately discharge into the Pecos River. Additional flow may discharge directly into the Pecos River or into alluvium in the Balmorhea Loving Trough to the south.

Recharge to the Magenta may also occur north of the WIPP in Bear Grass Draw and Clayton Basin. The freshwater-head contour map indicates that discharge is toward the west in the vicinity of the WIPP, probably into the Tamarisk and the Culebra near Nash Draw. Some discharge from the Magenta may ultimately reach the saline lakes in Nash Draw. Additional discharge probably reaches the Pecos River at Malaga Bend or alluvium in the Balmorhea Loving Trough according to SAND89-147.[38]

Isotopic data from groundwater samples suggest that groundwater travel time from the surface to the Dewey Lake and the Rustler is long and rates of flow are extremely slow. Based on observations cited in SAND87-0138,[37] low tritium levels in all WIPP-area samples indicate minimal contributions from the atmosphere since 1950. SAND86-1054[35] indicates four modeled radiocarbon ages from Rustler and Dewey Lake groundwater are between 12,000 and 16,000 years.[44] The uranium isotope activity ratios observed require a conservative minimum residence time in the Culebra of several thousands of years and more probably reflect minimum ages of 10,000 to 30,000 years.[36]

Potentiometric data from four wells support the conclusion that little infiltration from the surface reaches the transmissive units of the Rustler. Hydraulic head data are available for a claystone in the Forty-niner member from wells DOE-2, H-3, H-4, H-5, and H-6 (Figure 2.6-2). According to SAND87-0039, comparison of these heads to heads in the surrounding Magenta wells shows that flow between the units at all four wells may be upward.[22] This observation offers no insight into the possibility of infiltration reaching the Forty-niner, but it rules out the possibility of infiltration reaching the Magenta or any deeper units at these locations.

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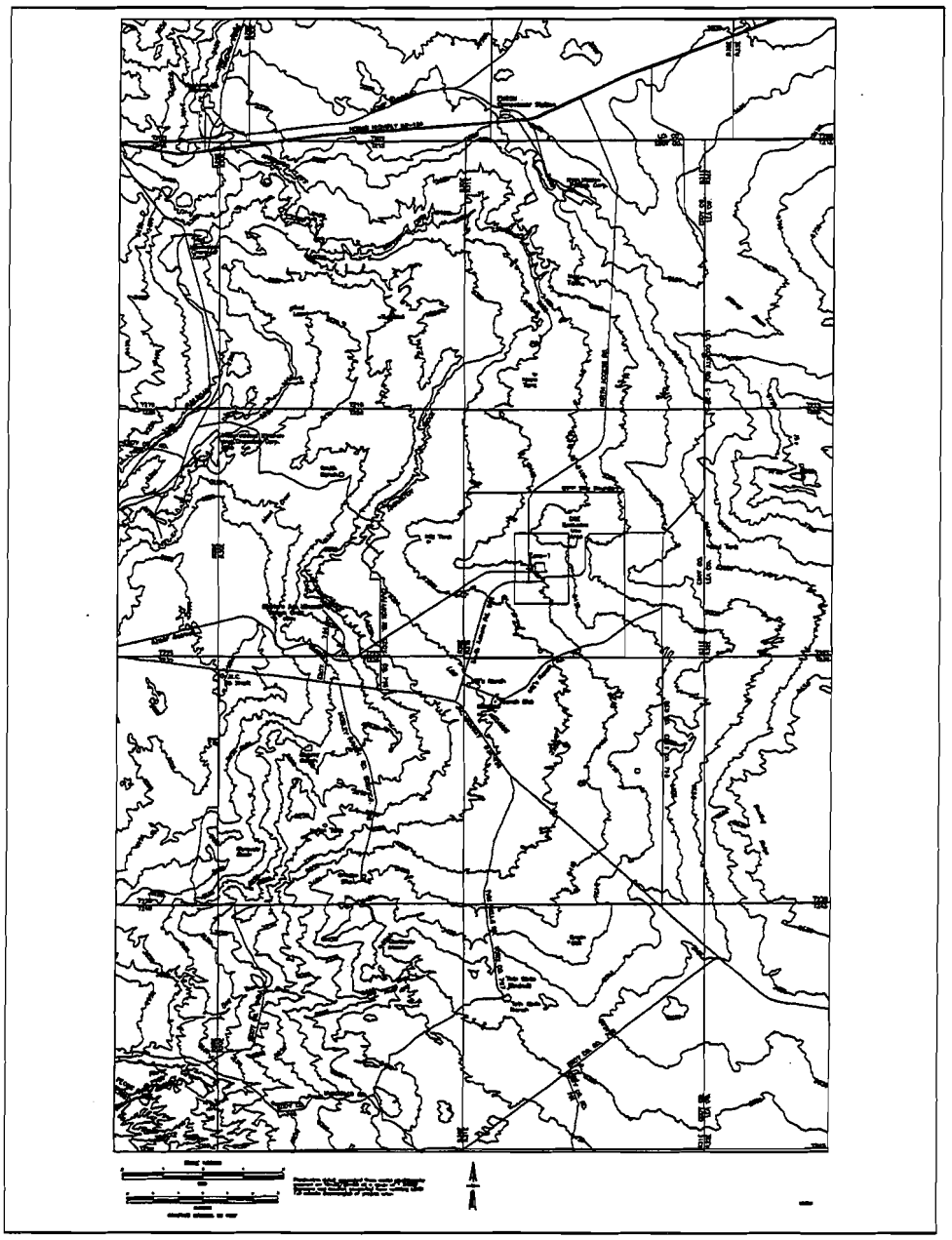


Figure 2.6-1, Drainage Pattern and Gaging Stations, Pecos River Basin

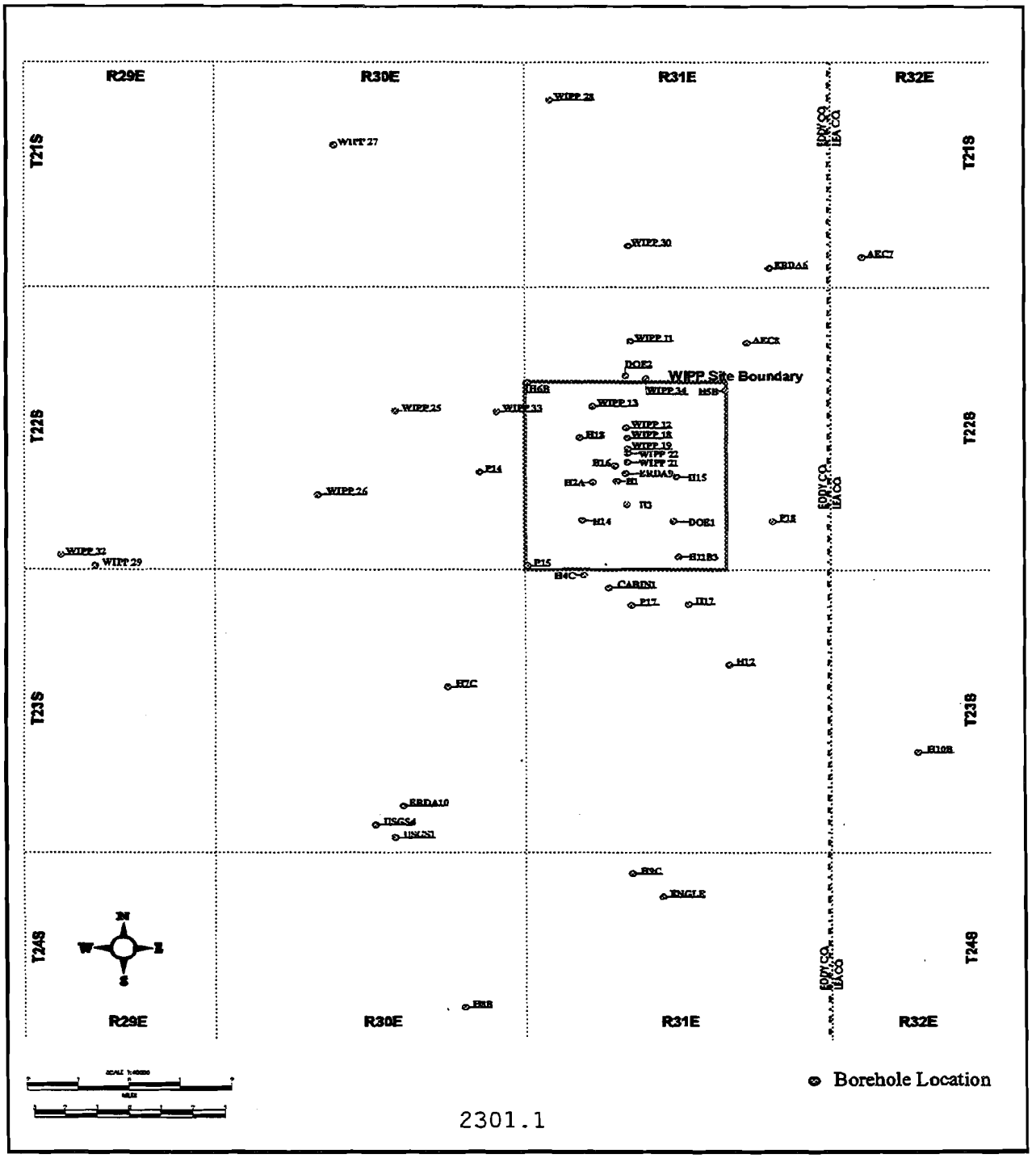
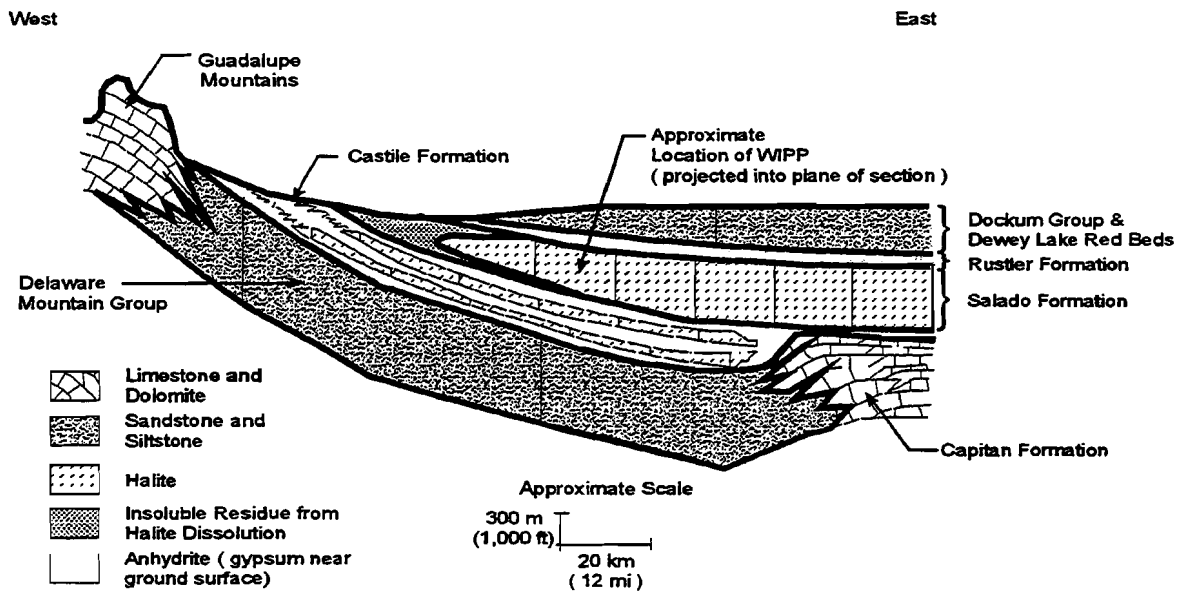
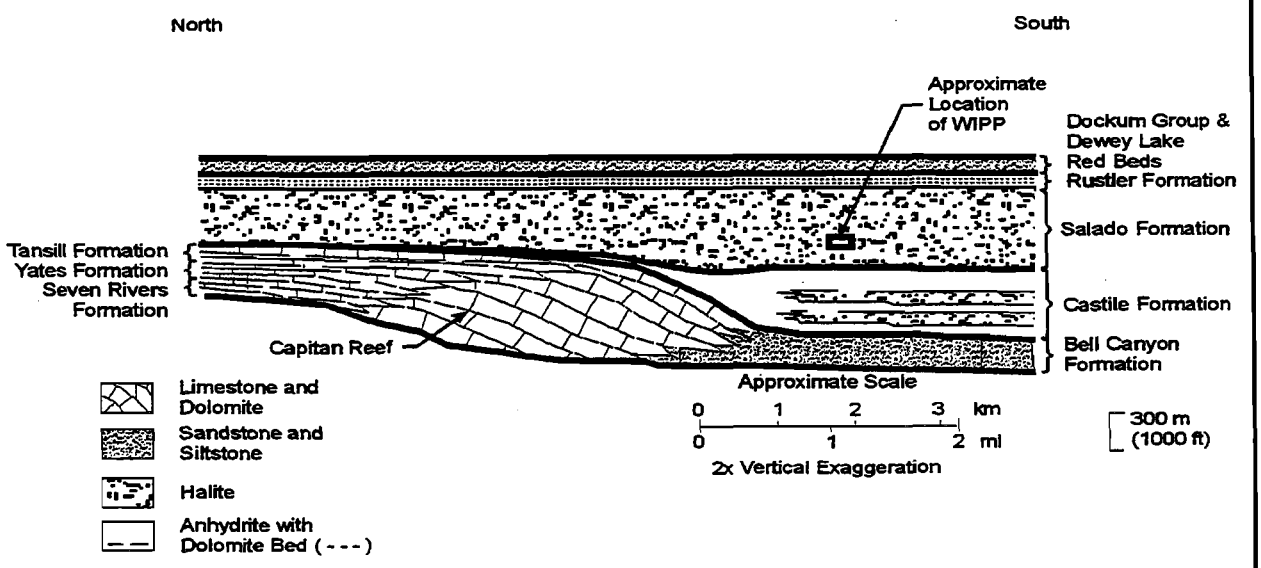


Figure 2.6-2, Borehole Location Map



Source: Sandia, 1992, 2, 2-7. 2324.1

Figure 2.6-3, Schematic East-West Cross Section Through the North Delaware Basin



Source: Sandia, 1992, 2, 2-8.

2325.1

Figure 2.6-4, Schematic North-South Cross Section Through the North Delaware Basin

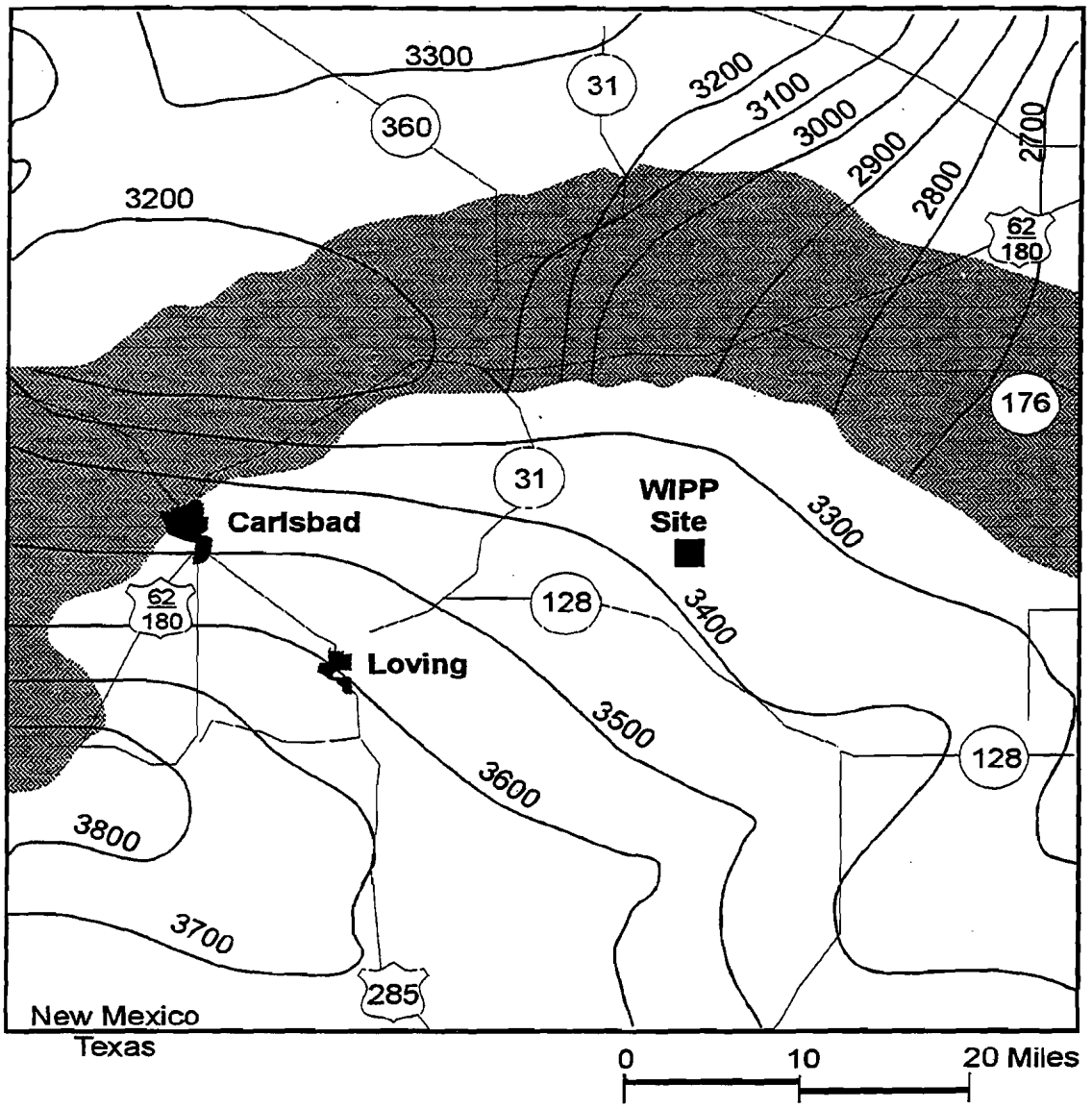


Figure 2.6-5, Potentiometric Surface Map (composite) of the Delaware Mountain Group and Capitan Aquifer

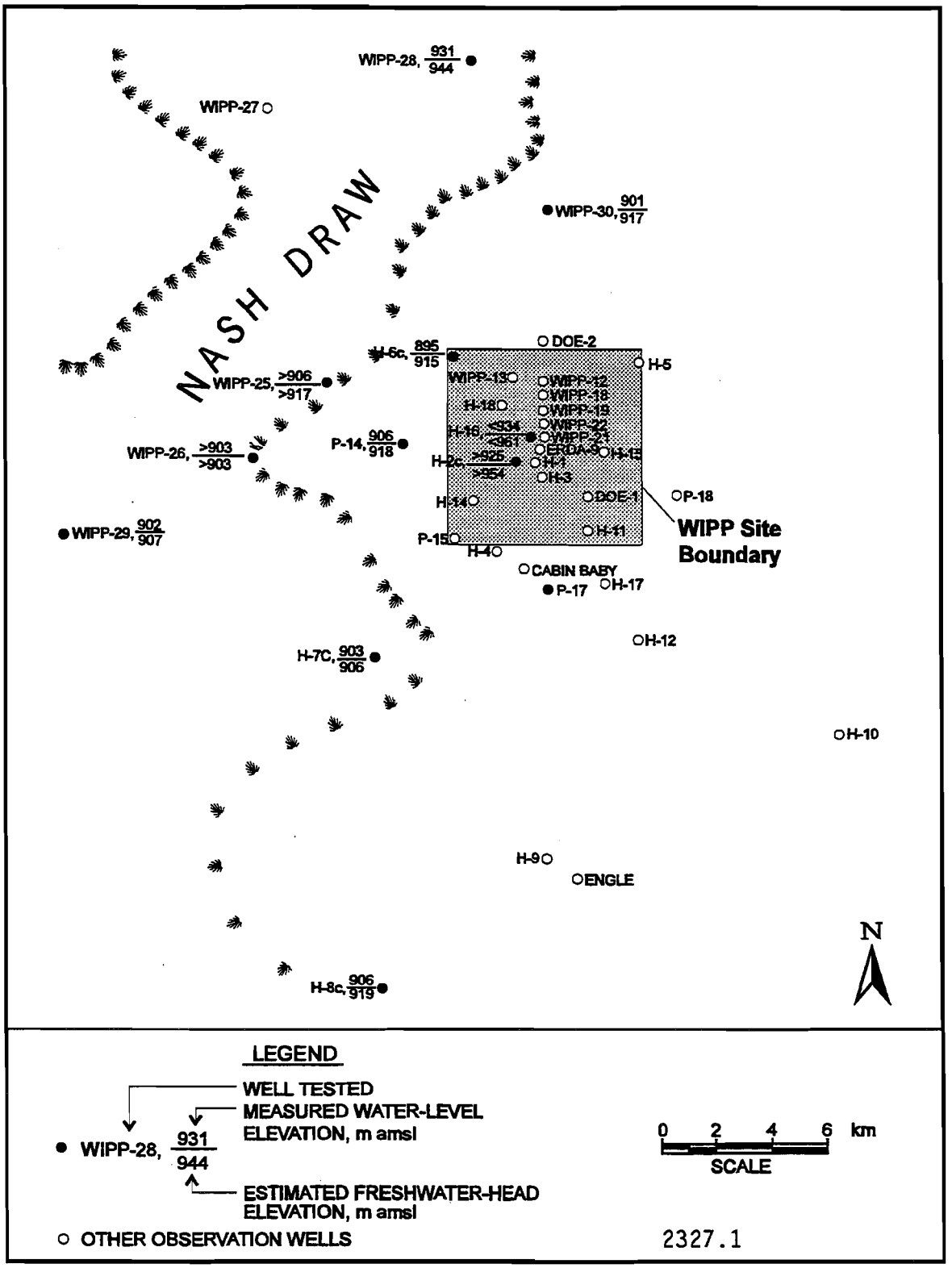


Figure 2.6-6, Measured Water Levels and Estimated Freshwater Heads of the Unnamed Lower Member and Rustler Salado Contact Zone

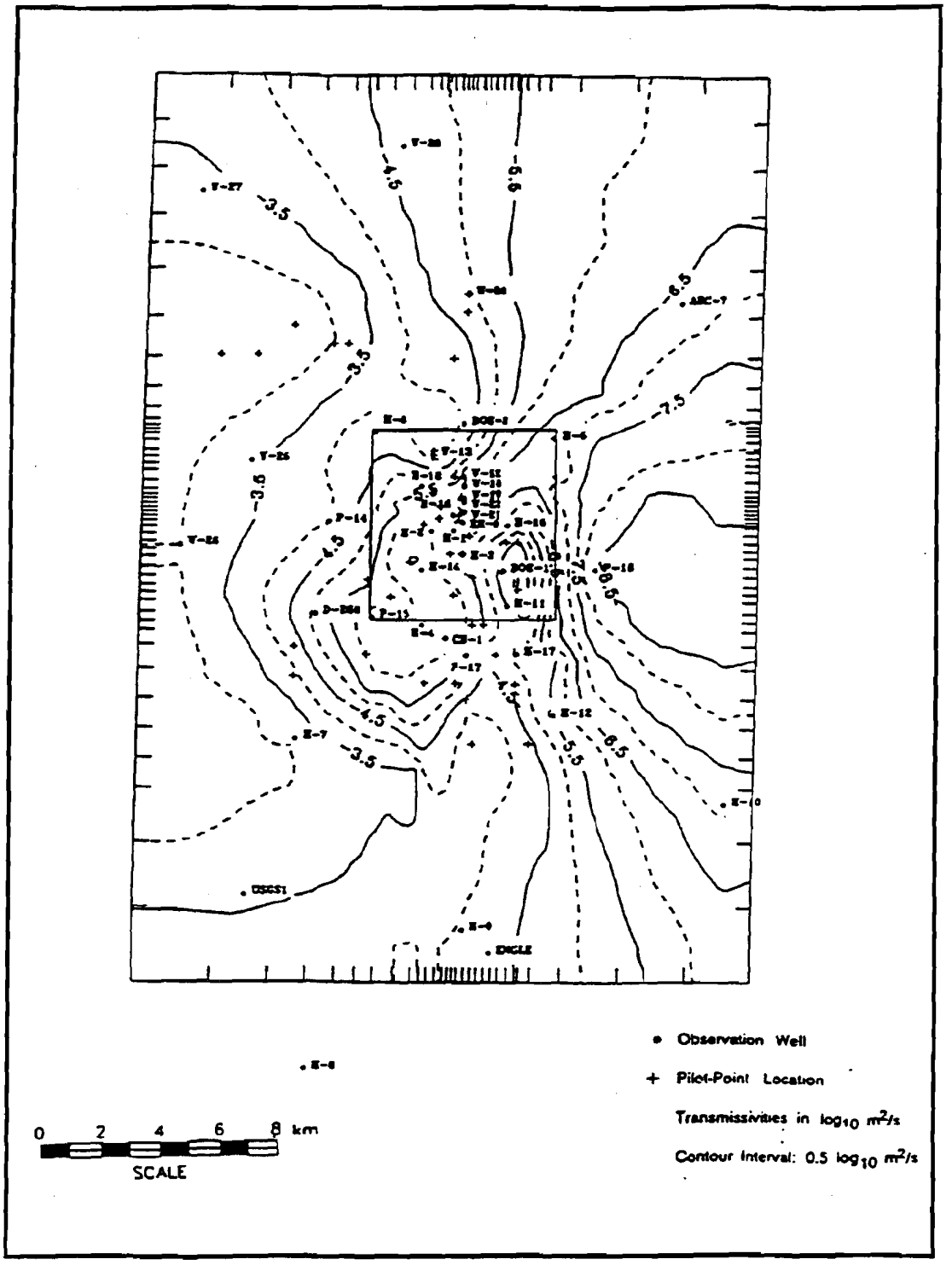


Figure 2.6-7, The Transient Calibrated Log_{10} Transmissivities

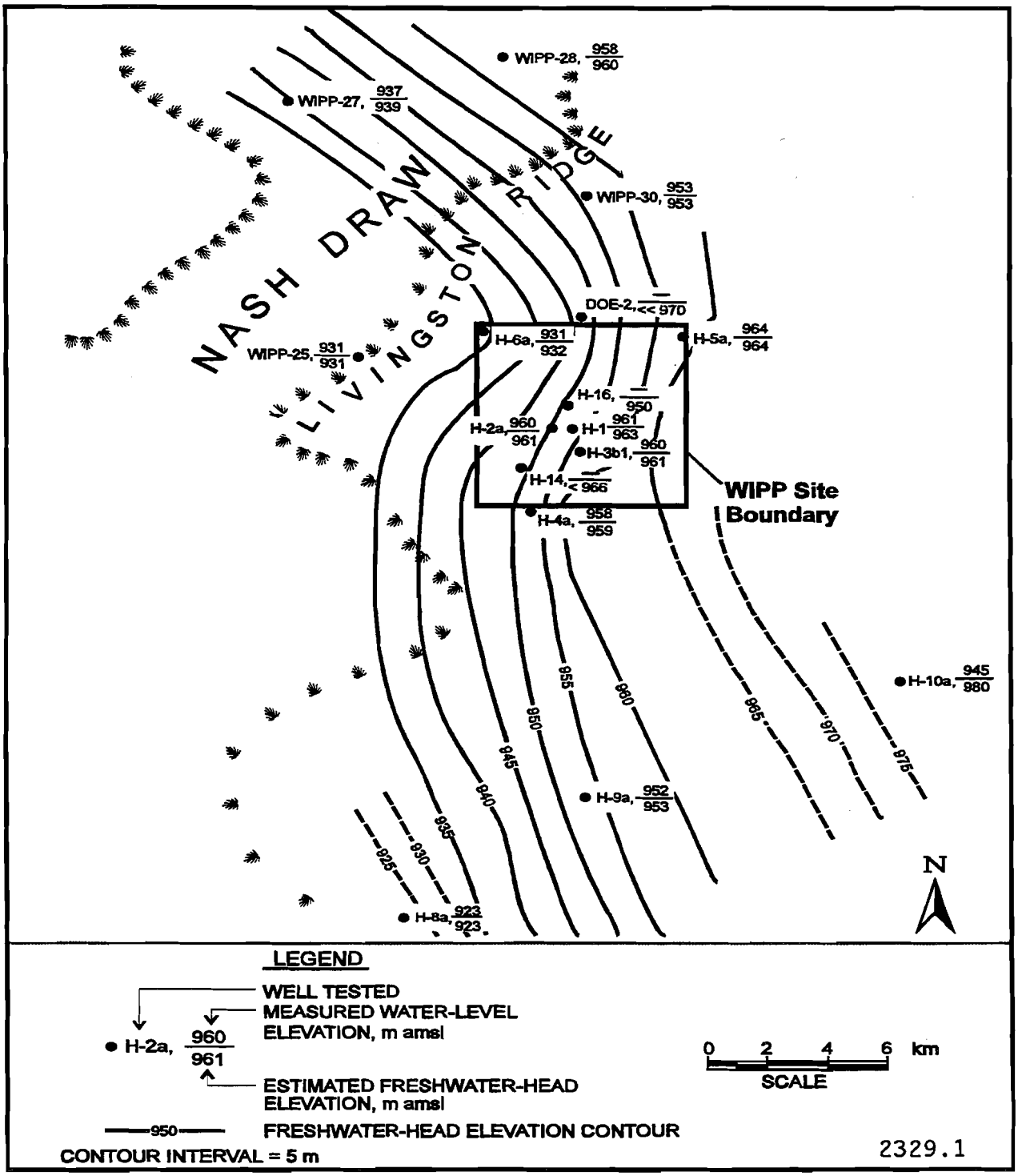
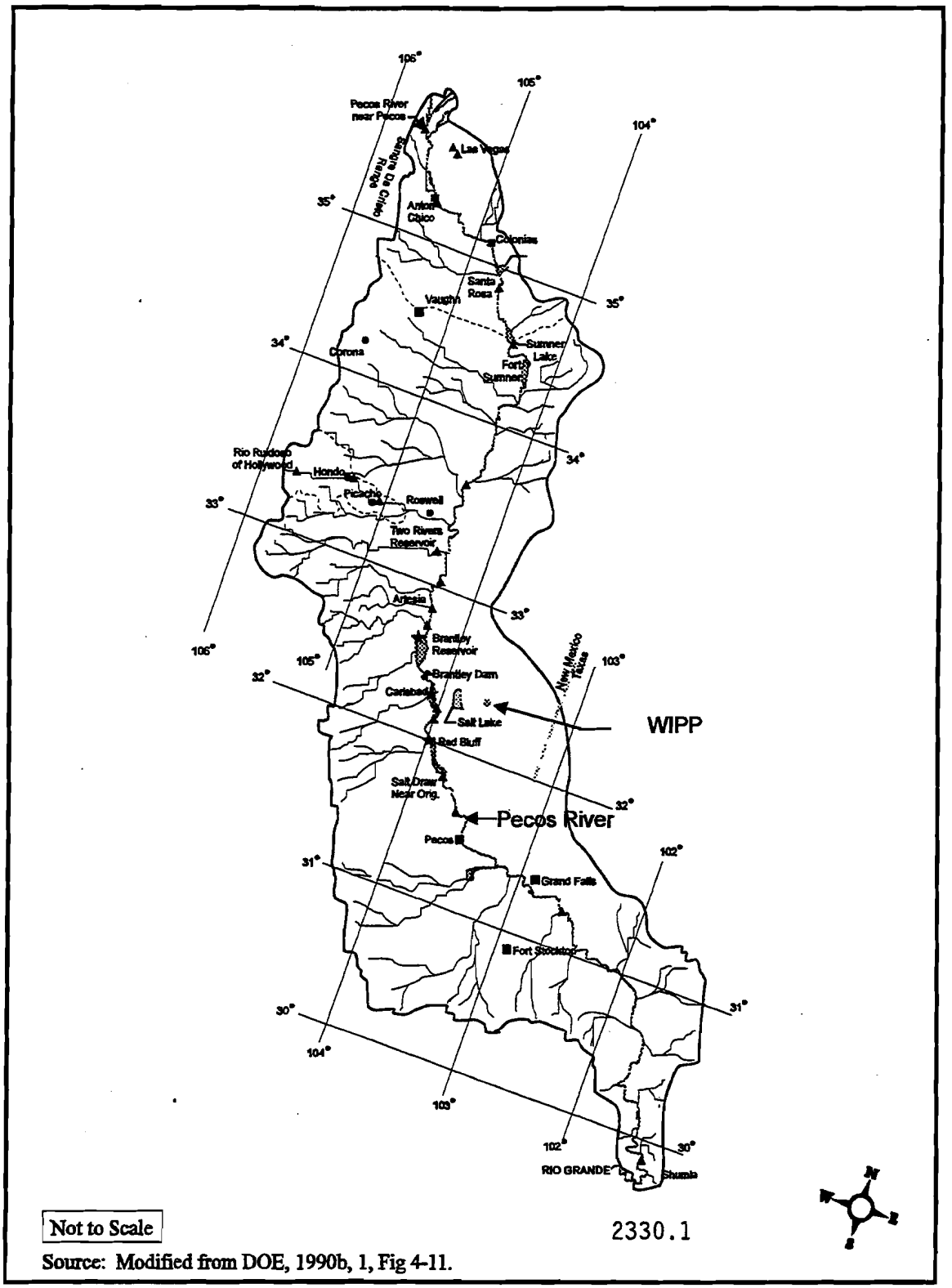


Figure 2.6-8, Water Levels and Estimated Freshwater Heads in the Magenta Dolomite Member[7]



Source: Modified from DOE, 1990b, 1, Fig 4-11.

Figure 2.6-9, Location of Reservoirs in Pecos River Basin

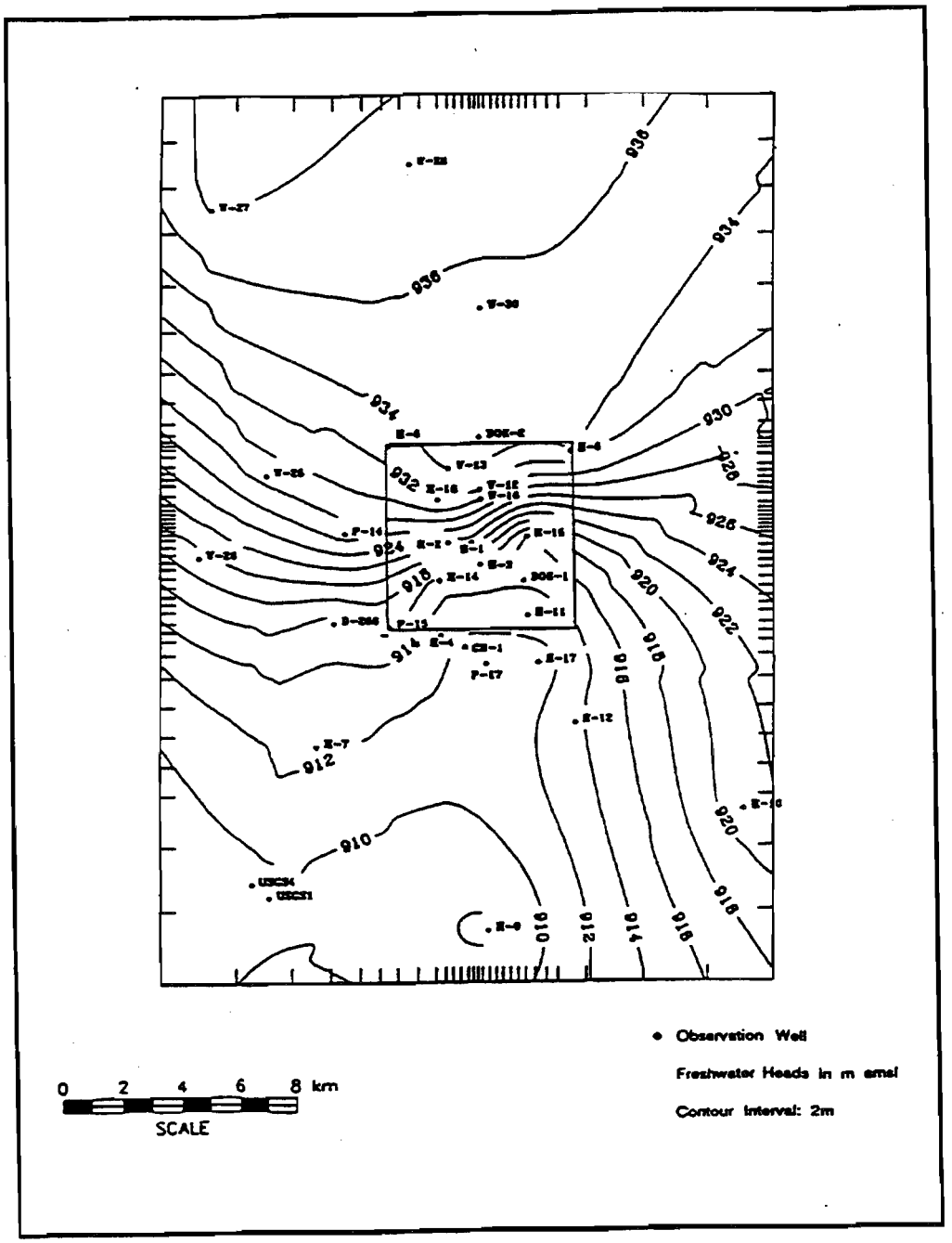


Figure 2.6-10, Culebra Freshwater-Head Contour Surface

Table 2.6-1, Hydrologic Characteristics of Rock Units at the WIPP Site

Member Name	Thickness (meters)		Hydraulic Conductivity (meters/second)		Porosity	
	max	min	max	min	max	min
Forty-niner	20		5.0×10^{-9}	5.0×10^{-10}		
Magenta	8	4	5.0×10^{-5}	5.0×10^{-10}		
Tamarisk	84	8				
Culebra	11.6	4	1×10^{-4}	2×10^{-10}	0.30	0.03
Unnamed	36		1×10^{-11}	6×10^{-15}		
Rustler-Salado Contact Zone	33	2.4	1×10^{-6}	1×10^{-12}	0.33	0.15

Table 2.6-2, Capacities of Reservoirs in the Pecos River Drainage

Reservoir	River	Total Storage Capacity[a] (acre-feet)	Use[b]
Los Esteros	Pecos	282,000	FC
Sumner Lake	Pecos	122,100	IR, R
Brantley	Pecos	42,000	IR, R, FC
Avalon	Pecos	5,000	IR
Red Bluff	Pecos	310,000	IR, P
Two Rivers	Rio Hondo	167,900	FC

[a]Capacity below the lowest uncontrolled outlet or spillway.

[b]Key:
FC flood control
IR irrigation
R recreation
P hydroelectric

2.7 Geology

A thorough description of the WIPP facility's natural environmental setting is considered crucial by the DOE to a demonstration of compliance to both the operational and disposal standards. Environmental factors and long-term environmental changes that may impact the waste isolation potential of the disposal system are addressed. Detail is sufficient to assess the degree of waste isolation achievable.

Geological data have been collected from the WIPP site and surrounding area for use in evaluating the site's suitability as a radioactive waste repository. These data have been collected principally by the DOE and its predecessor agencies, the United States Geological Survey (USGS), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private organizations engaged in natural resource exploration and extraction. The analysis of data provided in the following discussion generally supports the position that the WIPP site is suitable for the long-term isolation of radioactive waste. Numerous questions have been raised and subsequently discussed, investigated, and resolved in order for the DOE to reach the conclusion that the site is suitable. These questions are discussed in the following sections with emphasis on the resolution of the issues. The majority of the data collected have been reported or summarized in two reports.[1,2]

2.7.1 Data Sources and Quality

The geology of southeastern New Mexico has been of great interest for more than a century. The Guadalupe Mountains have become a common visiting and research point for geologists because of the spectacular exposures of Permian-age reef rocks and related facies.[3,4,5,6] Because of intense interest in both hydrocarbon and potash resources in the region, a large volume of data exists as potential background for the WIPP site, though some data are proprietary. Finally, there is the geological information developed directly and indirectly by studies sponsored by WIPP; it ranges from raw data to interpretive reports.

Elements of the geology of southeastern New Mexico have been discussed or described in professional journals or technical documents from many different sources. These types of articles are an important source of information and, where there is no contrary evidence, the information in these articles is included through reference where subject material is relevant. Implicit rules of professional conduct of research and reporting are assumed to have been applied, and journal/editorial review has normally been applied. Certain elements of the geology presented in such sources may be important to the WIPP, and these have normally been the subject of specific WIPP studies to add to the database.

The geological data developed explicitly for the WIPP project have been produced by different organizations and contractors over a project history with changing requirements. Early project data, especially, do not have all the same elements of quality assurance (QA) that more recent data may have; for at least some studies there is a sufficient record to clearly follow the field programs, objectives, and results. Data from project records will be incorporated here through specific reference or appendices.

Geological data have been developed through a variety of WIPP-sponsored studies using drilling, mapping or other direct observation, geophysical techniques, and laboratory work. Most of the techniques and statistics of data acquisition will be incorporated by specific reference. However, drill holes are a major source of geological data for the WIPP and surrounding area. From drill holes come raw data (e.g., depth measurements, amount of core, geophysical logs) that provide the basis for point data and interpreted data sets. Because of that, a special interpreted data set from boreholes is being developed by several sources and will be checked extensively to ensure that information about location and the stratigraphic data are highly accurate.[7] These data will be the base for computing other useful elements, such as structure maps for selected stratigraphic horizons, or isopachs (thickness) of selected stratigraphic intervals.

2.7.2 Geologic History

This section summarizes the more important points of the geologic history within about 200 miles (320 kilometers) of the WIPP site, with emphasis on more recent or nearby events. Major elements of the geological history from the end of the Precambrian in the vicinity of the WIPP site are compiled in graphic form in Figure 2.7-1. The geologic time scale is based on the compilation by Palmer[8] for The Decade of North American Geology (DNAG). There are several compiled sources of chronologic data related to different reference sections or methods.[9,10] Although most of these sources show generally similar ages for chronostratigraphic boundaries, there is no consensus on either reference boundaries or most-representative ages. The DNAG scale is accepted here as a standard that is useful and sufficient for WIPP purposes, as no known critical parameters require more accurate or precise dates.

The determinable geologic history in this region can conveniently be subdivided into three general phases:[1]

- A Precambrian period, represented by metamorphic and igneous rocks, ranging in age from about 1.5 to 1.0 billion years old
- A period principally of erosion from about 1.0 to 0.5 billion years, as there is not known to be any rock record from this time
- An interval from 0.5 billion years to the present represented by a more complex set of mainly sedimentary rocks and shorter periods of erosion and dissolution.

This youngest phase is the main subject of detailed discussion of this text.

Precambrian crystalline rocks have been penetrated in only a few deep boreholes in the vicinity of the WIPP; therefore, relatively little petrological information is available.[11] Foster extrapolated the elevation of the Precambrian surface under the area of WIPP as being between 14,500 feet (4,420 meters) and 15,000 feet (4,572 meters) below sea level; the site surface at WIPP is about 3,400 feet (1,036 meters) above sea level.[11] Keesey projected a depth to the top of Precambrian rocks of 18,191 feet (5,545 meters) based on the geology of the nearby drill hole in Section 15, Township 22 South, Range 31 East (Section 15, T22S, R31E).[12]

Precambrian rocks of a variety of types crop out in the following locations: (1) the Sacramento Mountains northwest of WIPP; around the Sierra Diablo and Baylor Mountains near Van Horn, Texas (note the Van Horn Sandstone could also be as young as Ordovician);[13] west of the Guadalupe Mountains at Pump Station Hills; and in the Franklin Mountains near El Paso, Texas. East of the WIPP, a relatively large number of boreholes on the Central Basin Platform have penetrated the top of the Precambrian.[11] As summarized by Foster, Precambrian rocks in the area considered similar to those in the vicinity of the WIPP site range in age from about 1.14 to 1.35 billion years.[11]

For a period of about 500 million years (1.1 to 0.6 billion years ago), there is no certain rock record in the region around the WIPP. The most likely rock record for this period may be the Van Horn sandstone, but there is no conclusive evidence that it represents part of this time period. The region is generally interpreted to have been subject to erosion for much of the period, until the Bliss sandstone began to accumulate during the Cambrian.

2.7.3 Stratigraphy and Lithology in the Vicinity of the WIPP Site

This section presents the stratigraphy and lithology of the Paleozoic and younger rocks underlying the WIPP site and vicinity (Figure 2.7-2), emphasizing the units nearer the surface. Details begin with the Permian (Guadalupian) Bell Canyon Formation (hereafter referred to as the Bell Canyon)—the upper unit of the Delaware Mountain Group—because this is the uppermost water-bearing formation below the evaporites. The principal stratigraphic data are the chronologic sequence, age, and extent of rock units, including some of the nearby relevant facies changes.

2.7.3.1 General Stratigraphy and Lithology below the Bell Canyon

As stated previously, the Precambrian basement near the site is projected to be about 18,200 feet (5,545 meters) below the surface,[12] consistent with information presented by Foster (1974).[11] Ages of similar rock suites in the region range from about 1.14 to 1.35 billion years.

The basal units overlying Precambrian rocks are clastic rocks commonly attributed either to the Bliss sandstone or the Ellenberger Group,[11] considered most likely to be Ordovician in age in this area. The Ordovician system comprises the Ellenberger, Simpson, and Montoya groups in the northern Delaware Basin. Carbonates are predominant in these groups, with sandstones and shales common in the Simpson Group. Foster reported 975 feet (297 meters) of Ordovician north of the site area and extrapolated a thicker section of about 1,300 feet (396 meters) at the present site.[11] Keesey projected a thickness of 1,200 feet (366 meters) within the site boundaries.[12]

Silurian-Devonian rocks in the Delaware Basin are not stratigraphically well defined, and there are various notions for extending nomenclature into the basin. Common drilling practice is not to differentiate, though the Upper Devonian Woodford shale at the top of the sequence is frequently distinguished from the underlying dolomite and limestone.[11] Foster showed a reference thickness of 1,260 and 160 feet (384 and 49 meters) for the carbonates and the Woodford shale, respectively; he estimated thickness contours for the present WIPP site of about 1,150 feet (351 meters) and 170 feet (52 meters), respectively.[11] Keesey projected 1,250 feet (381 meters) of carbonate and showed 82 feet (25 meters) of the Woodford shale.[12]

The Mississippian system in the northern Delaware Basin is commonly attributed to "Mississippian limestone" and the overlying Barnett shale, but the nomenclature is not well settled.[11] At the reference well used by Foster, the limestone is 540 feet (165 meters) thick and the shale is 80 feet (24 meters); isopachs at the WIPP are 480 feet (146 meters) and less than 200 feet (61 meters).[11] Keesey, indicates 511 feet (156 meters) and 164 feet (50 meters), respectively, within the site boundaries.[12]

The nomenclature of the Pennsylvanian system applied within the Delaware Basin is both varied and commonly inconsistent with accepted stratigraphic rules. Chronostratigraphic or time-stratigraphic names are applied to these lithologic units: the Morrow, Atoka, and Strawn, from base to top.[11] Foster extrapolated thicknesses of about 2,200 feet (671 meters) for the Pennsylvanian at the WIPP site.[11] Keesey reports 2,088 feet (636 meters) for these units.[12] The Pennsylvanian rocks in this area are mixed clastics and carbonates, with carbonates more abundant in the upper half of the sequence.

The Permian system is the thickest system in the northern Delaware Basin, and it is divided into four series from the base to top: Wolfcampian, Leonardian, Guadalupian, and Ochoan. According to Keesey, the total thickness of the three lower series is 8,684 feet (2,647 meters) near the site,[12] while Foster indicates a total thickness of 7,665 feet (2,336 meters) for a reference well north of WIPP.[11] Foster's isopach maps of these series indicate a thickness of about 8,500 feet (2,591 meters) for the WIPP site area. The Ochoan series at the top of the Permian is considered in more detail later because the formations host and surround the WIPP repository horizon. The Ochoan is 3,938 feet (1,200 meters) thick at DOE-2 (Figure 2.6-2), which is about 2 miles (3.2 kilometers) north of the site center.[14]

The Wolfcampian series is also referred to as the Wolfcamp Formation (hereafter referred to as the Wolfcamp) in the Delaware Basin. In the site area, the lower part of the Wolfcamp is dominantly shale with carbonate and some sandstone;[11] carbonate increases to the north. Clastics increase to the east toward the margin of the Central Basin Platform. Keesey reports the Wolfcamp to be 1,493 feet (455 meters) thick at a well near the WIPP site.[12]

The Leonardian series is represented by the Bone Spring Limestone or Formation (hereafter referred to as the Bone Spring) (erroneously called the Bone Springs Limestone in many publications). According to Foster the lower part of the formation is commonly interbedded carbonate, sandstone, and some shale, while the upper part is dominantly carbonate.[11] Near the site, the Bone Spring is 3,247 feet (990 meters) thick according to Keesey.[12]

The Guadalupian series is represented in the general area of the site by a number of formations exhibiting complex facies relationships (Figures 2.7-3 and 2.7-4). The Guadalupian series is known in considerable detail west of the site from outcrops in the Guadalupe Mountains, where numerous outcrops and subsurface studies have been undertaken.[15,5,6] Similar facies relationships are expected from the site to the north.[16]

Within the Delaware Basin, the Guadalupian series comprises three formations: Brushy Canyon, Cherry Canyon, and Bell Canyon, from base to top. These formations are dominated by submarine channel sandstones with interbedded limestone and some shale. A limestone (Lamar) generally tops the series, immediately underneath the Castile Formation (hereafter referred to as the Castile). Around the margin of the Delaware Basin, reefs developed during the same time the Cherry Canyon and Bell Canyon formations were being deposited. These massive reef limestones, the Goat Seep and Capitan limestones, are equivalent in time to these basin sandstone formations, but were developed much higher topographically around the basin margin. A complex set of limestone to sandstone and evaporite beds was deposited further away from the basin behind the reef limestones. The Capitan reef limestones are well known because the Carlsbad Caverns are partially developed in these rocks.

2.7.3.2 The Bell Canyon

The Bell Canyon is known from outcrops on the west side of the Delaware Basin and from subsurface intercepts for oil and gas drilling. Several informal lithologic units are commonly named during such drilling. SAND 86-0611 states that DOE-2 penetrated the Lamar limestone, the Ramsey sand, the Ford shale, the Olds sand, and the Hays sand.[14] This informal nomenclature is used for the Bell Canyon in some other WIPP reports.

The Clayton Williams Badger Federal drill hole near the WIPP (Section 15, T22S, R31E) intercepted 961 feet (293 meters) of Bell Canyon, including the Lamar limestone.[12] Reservoir sandstones of the Bell Canyon were deposited in channels that are straight to slightly sinuous. Density currents flowed from shelf regions, cutting channels and depositing the sands.[17]

Within the basin, the Bell Canyon (Lamar Limestone)-Castile contact is distinctive on geophysical logs because of the contrast in low natural gamma of the basal Castile anhydrite compared to the underlying limestone. Density or acoustic logs are also distinctive because of the massive and uniform lithology of the anhydrite compared to the underlying beds. In cores, the transition is sharp as described by Mercer for D[illegible]-2.[14]

2.7.3.3 The Castile

The Castile is the lowermost lithostratigraphic unit of the Late Permian Ochoan series (Figure 2.7-2). It was originally named by Richardson in 1904 for outcrops in Culberson County, Texas. The Castile crops out along a lengthy area along the western side of the Delaware Basin. The two distinctive lithologic sequences, now known as the Castile and the Salado, were separated into the upper and lower Castile Formation by Cartwright.[18] Lang clarified the nomenclature by restricting the Castile to the lower unit and naming the upper unit the Salado.[19] By defining an anhydrite resting on the marginal Capitan limestone as part of the Salado, Lang[20,21] effectively restricted the Castile to the Delaware Basin inside the ancient reef rocks.

Through detailed studies of the Castile, Anderson[22] introduced an informal system of names that are widely used and included in many WIPP reports. They named the units from the base as anhydrite 1 (A1), halite 1 (H1), anhydrite 2 (A2), etc. The informal nomenclature varies through the basin from A3 up because of complexity of the depositional system. The Castile consists almost entirely of thick beds of two lithologies: (1) interlaminated carbonate and anhydrite, and (2) high-purity halite. The interlaminated carbonate and anhydrite are well known as possible examples of annual layering or varves.

In the eastern part of the Delaware Basin, the Castile is commonly 1,400 to 1,500 feet thick (427-457 meters).[23] At DOE-2, the Castile is 989 feet (301 meters) thick. The Castile is thinner in the western part of the Delaware Basin, and it lacks halite units. Anderson correlated geophysical logs, interpreting thin zones equivalent to halite units as dissolution residues.[24] Anderson further interpreted the lack of halite in the Castile and overlying units as indicating that about 50 percent of the halite in the basin had been removed by dissolution.[25,26,27]

A primary objective of drill hole DOE-2 was to ascertain whether a series of depressions in the Salado, (2 miles [3.3 kilometers] north of the site) was due to dissolution in the Castile as proposed by Davies in his doctoral thesis (1984). Studies by Borns[28] and Chaturvedi[29] suggested that these depressions were not due to dissolution but to halokinesis in the Castile. In their analysis, Robinson and Powers analyzed one such unit as part due to synsedimentary, gravity-driven, clastic deposition, and suggested that the extent of dissolution was overestimated.[30] No Castile dissolution is known to be present in the immediate vicinity of the WIPP site. The process of dissolution and the resulting features are further discussed later in this chapter.

In Culberson County, Texas, the Castile hosts major native sulfur deposits.[31,32,33] The outcrops of Castile on the Gypsum Plain south of White's City, New Mexico, have been explored for native sulfur without success,[30] and there is no reported indicator of native sulfur anywhere in the vicinity of the WIPP.[34]

Powers reports that in part of the area around the WIPP, the Castile has been significantly deformed, and there are pressurized brines associated with the deformed areas; drill hole ERDA-6 encountered both.[1] WIPP-12, 1 mile (1.6 kilometers) north of the site center, revealed lesser Castile structure, but it also encountered a zone of pressurized brine within the Castile.

The Castile continues to be an object of research interest unrelated to the WIPP program as an example of evaporites supposedly deposited in "deep water."[35,22] Anderson[36] and Leslie[37] discuss alternatives and contradictory evidence. Although these discussions and a resolution might eventually affect some concepts of Castile deposition and dissolution, this issue is largely of academic interest and bears no impact on the suitability of the Los Medaños region for the WIPP site.

2.7.3.4 The Salado

The Salado is dominated by halite, in contrast to the underlying Castile. The Salado extends well beyond the Delaware Basin, and has been termed a "saline giant."[38] The Fletcher Anhydrite Member, which is deposited on the Capitan reef rocks, is defined as the base of the Salado,[20,21] but both Open-file Report 4339-7[39] and Circular 184[40] consider that the Fletcher Anhydrite Member may interfinger with anhydrites normally considered part of the Castile within the basin. The Castile-Salado contact is not uniform across the basin, and whether it is conformable is unresolved. Around the WIPP site, the Castile-Salado contact is commonly placed at the top of a thick anhydrite informally designated A3; the overlying halite is called the infra-Cowden salt and is included within the Salado. Bodine suggests that the clay mineralogy of the infra-Cowden in ERDA-9 cores changes at about 15 feet (4.6 meters) above the lowermost Salado and that the lowermost clays are more like Castile clays.[41] The top of the thick anhydrite remains the local contact for differentiating the Salado from the Castile, and there is no known significance to WIPP from these differences.

The Salado in the northern Delaware Basin is broadly divided into three informal members used here.[39] Figure 2.7-5 details the Salado's stratigraphy. The middle member is known locally as the McNutt Potash Zone (also called the McNutt Potash Member) and it includes 11 defined potash zones, 10 of which are of economic significance in the Carlsbad Potash District. The lower and upper members remain unnamed. The WIPP repository level is located below the McNutt Potash Zone in the lower member.

Within the Delaware Basin, Jones[42] provided a system for numbering the more significant sulfate beds within the Salado, designating these beds as marker beds (MB) from MB 100 (near the top of the formation) to MB 144 (near the base). The system is generally used within the Carlsbad Potash District as well as at and around the WIPP site. The facility horizon is located between MB 139 and MB 138.

In the central and eastern part of the Delaware Basin, the Salado is at its thickest ranging up to about 2,000 feet (about 600 meters) thick and consisting mainly of interbeds of sulfate minerals and halite, with halite dominating. The thinnest portions of the Salado consist of a brecciated residue of insoluble material a few tens-of-feet-thick and crop out in parts of the western Delaware Basin. The common sulfate minerals are anhydrite ($CaSO_4$), gypsum ($CaSO_4 \bullet 2H_2O$) near the surface, and polyhalite ($K_2SO_4 \bullet MgSO_4 \bullet 2CaSO_4 \bullet 2H_2O$). They form beds and are also found along halite grain boundaries. Sylvite (KCl) is an important economic mineral in the halitic beds of several ore zones. Langbeinite ($K_2SO_4 \bullet MgSO_4$) is a less common mineral in ore zones, but it is a fertilizer for chloride-sensitive crops, including citrus, tobacco, potatoes, and sugar beets.[43]

Early investigators of the Salado[44] recognized a repetitious vertical succession or cycle of beds in the Salado: clay - anhydrite - polyhalite - halite and minor polyhalite - halite. Later, Jones (1954)[42] described the cyclical units as clay - magnesite - anhydrite, polyhalite or glauberite - halite - argillaceous halite capped by mudstone. Lowenstein[38] defined a depositional cycle (Type I) consisting of (1) basal mixed siliciclastic and carbonate (magnesite) mudstone, (2) laminated to massive anhydrite or polyhalite, (3) halite, and (4) halite with mud. Lowenstein also recognized repetitious sequences of halite and halite with mud as incomplete Type I cycles and termed them Type II cycles. Lowenstein interpreted the Type I cycles as having formed in a shallowing upward, desiccating basin beginning with a perennial lake or lagoon of marine origin and evaporating to saline lagoon and saltpan environments.[38] Type II cycles are differentiated because they do not exhibit features of prolonged subaqueous deposition and also have more siliciclastic influx than do Type I cycles.

From detailed mapping of the Salado in the Air Intake Shaft at WIPP, a more detailed sedimentological analysis of Salado depositional cycles was constructed,[45,46] similar in broad aspects to the Type I cycle.[38] The details available from the shaft demonstrated the important role of syndepositional water level to water table changes that created solution pits and pipes within the halitic beds while they were at the surface.[47] Holt and Powers concluded that passive halite cements filled the pits and pipes, as well as less dramatic voids, as the water table rose.[45,46] Early diagenetic to synsedimentary cements filled the porosity early and rather completely, reducing the porosity to a very small volume.[48] These void-filling halites are commonly clear and coarsely crystalline and might be mistaken for recrystallization textures. Although Holt and Powers did not find it in their study, other investigators have found much evidence for halite recrystallization (or halite diagenesis) in the Salado.[49]

The effects of water-rock interactions resulting in evaporite dissolution in the Salado are observable near the surface in Nash Draw and other localities where gypsum karst is developed and where overlying units such as the Rustler Formation (hereafter referred to as the Rustler), Dewey Lake Redbeds (hereafter referred to as the Dewey Lake), and post-Permian rocks have subsided. Physical evidence of water-rock interaction (e.g., post-depositional accumulation of insoluble residues, brecciation from differential collapse, mass removal) in the Salado is less apparent, especially where it is buried at depths greater than 990 feet (300 meters). However, given the susceptibility of evaporite minerals to dissolution by circulating groundwater, geochronological investigations provide a means of determining the approximation time of latest episode of regional recrystallization of the evaporite minerals, which can be inferred as the approximate time of the latest episode of freely circulating groundwater. Radiometric dates for minerals of the Salado are available from several sources.[50,51,52,53,54] The distribution of dates shows that rubidium-strontium (Rb-Sr) isochron determinations on evaporite minerals, largely sylvite (179 to 229 million years ago), are in good agreement with potassium-argon (K-Ar) determinations on pure polyhalites (195 to 216 million years ago).

The only recrystallization event found younger than Early Jurassic (200 million years ago) was known to be a contact phenomenon associated with emplacement of an Oligocene lamprophyre dike (21 million years ago for polyhalite versus 32 to 34 million years ago for the dike.[55] Clay minerals have both Rb-Sr isochron and K-Ar ages significantly older (390$\pm$77 million years ago) than the evaporites.

It has been known that sylvite yields significantly younger K-Ar ages than Rb-Sr ages. This has been explained as loss of radiogenic argon. Radiogenic strontium, as a solid, and thus dating by the Rb-Sr isochron method is not considered as likely to give spurious results, especially if the isochron is well defined. The results of radiometric determinations argue for the absence of pervasive recrystallization of the evaporites in the Salado in the last 200 million years. This conclusion is supported by the number of replicate determinations, the wide distribution of dated minerals throughout the Delaware Basin, and the concordance of dates obtained by various radiometric methods.

Argillaceous halites and halitic mudstone at the top of many depositional cycles were interpreted in terms of modern features such as those at Devil's Golf Course at Death Valley National Monument, California.[45,46] The evaporative basin was desiccated, and varying amounts of insoluble residues collected on the surface through surficial dissolution, eolian sedimentation, and some clastic sedimentation from temporary flooding caused by runoff from surrounding areas. The surface developed local relief that could be mapped in some cycles, while the action of continuing desiccation and exposure increasingly concentrated insoluble residues. Flooding, most commonly from marine sources, reset the sedimentary cycle by depositing a sulfate bed.

Within Nash Draw, Robinson and Lang[56] recognized a zone equivalent to the upper Salado but lacking halite. Test wells in southern Nash Draw produced brine from this interval, and it has become known as the brine aquifer. Robinson and Lang[56] since considered this zone a residuum from dissolution of Salado halite (see Section 2.7.6.2.1 of this chapter). The Open-file Report of 1960[42] remarked that the residuum should be considered part of the Salado, though geophysical log signatures may resemble the lower Rustler.

At the center of the site, WTSD-TME-038[57] recognized clasts of fossil fragments and mapped channeling in siltstones and mudstones above halite; they considered these beds to be a normal part of the transition from shallow evaporative lagoons and desiccated salt pans of the Salado to the saline lagoon of the lower Rustler. Though Salado salt may have been dissolved prior to deposition of Rustler clastics, this process is far removed from the concept of subsurface removal of salt from the Salado in more recent time to develop a residuum and associated "brine aquifer."

Based on Salado isopachs, thickness begins to change significantly near Livingston Ridge, the eastern margin of Nash Draw. That should be the approximate eastward limit to the residuum and "brine aquifer," though the normal sedimentary sequence may yield limited fluids east of this margin.

The Salado is of primary importance to the containment of waste. As the principle natural barrier, many of the properties of the Salado have been characterized and a numerical code(s) developed to simulate the natural processes within the Salado that affect disposal system performance. These properties fall into two categories: physical and hydrological.

2.7.3.5 Rustler Formation

The Rustler Formation (hereafter referred to as the Rustler) is the youngest evaporite-bearing formation in the Delaware Basin. It was originally named[58] for outcrops in the Rustler Hills of Culberson County, Texas. Adams[59] first used the names "Culebra member" and "Magenta member" to describe the two carbonates in the formation, indicating that Lang favored the names, though Lang[56] did not use these names in the most recent publication. Vine[60] later described extensively the Rustler in Nash Draw and proposed the four formal names and one informal term for the stratigraphic subdivisions still used for the Rustler (from the base): unnamed lower member, Culebra Dolomite Member, Tamarisk Member, Magenta Dolomite Member, and Forty-niner Member (Figure 2.7-6). (The Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member, and the Forty-niner Member are hereafter referred to as the Culebra, the Tamarisk, the Magenta, and the Forty-niner.) Though it has been noted by some investigators[49,61] that the unnamed lower member might be named the Los Medaños Member, this nomenclature has not been formalized. An additional system of informal subdivisions was contributed by Holt and Powers,[45,49] based on more detailed lithologic units of the non-carbonate members (Figure 2.7-6). These subdivisions have partially been related to hydrostratigraphic units for the Rustler.

Two studies of the Rustler since Vine[60] contribute important information about the stratigraphy, sedimentology, and regional relationships while examining more local details as well. Eager[62] reported on relationships of the Rustler observed in the southern Delaware Basin as part of sulfur exploration in the area. Holt and Powers[49,45] reported the details of sedimentologic and stratigraphic studies of WIPP shafts and cores as well as of geophysical logs from about 600 drill holes in southeastern New Mexico.

The Rustler is regionally extensive;[59,49,45] a similar unit in the Texas panhandle is also called the Rustler.[63] Within the area around WIPP, evaporite units of the Rustler are interbedded with significant siliciclastic beds and the carbonates. Both the Magenta and the Culebra extend regionally beyond areas of direct interest to the WIPP. In the general area of the WIPP, both the Tamarisk and the Forty-niner have similar lithologies: lower and upper sulfate beds and a middle unit that varies principally from mudstone to halite from west to east (Figure 2.7-6).

In a general sense, halite in the unnamed lower member broadly persists to the west of the WIPP site, and halite is found east of the center of the WIPP in the Tamarisk and the Forty-niner (Figure 2.7-7). (Additional detail on the lithologies of these members follow.) Two different explanations have been used to account for the halite distribution. A prominent model in many documents is that halite was originally deposited relatively uniformly in the non-carbonate members across southeastern New Mexico, including the WIPP site area. The modern distribution resulted from the dissolution of Rustler halite to the west. Holt and Powers[49,45] described sedimentary features and textures within WIPP shafts and cores that led them to propose an explicit model of depositional facies for the mudstone-halite units; halite was dissolved syndepositionally from mudflat facies, especially to the west, and was redeposited in a halite pan to the east. Culebra transmissivity shows about six orders of magnitude variation across the area around the site, and the changes have commonly been attributed to post-depositional dissolution of Rustler halite.

In the region around WIPP, the Rustler reaches a maximum thickness of more than 500 feet (152 meters) (Figure 2.7-10 and Figure 2.7-8), while it is about 300-350 feet (91-107 meters) thick within most of the WIPP site. Most of the difference in the Rustler thickness can be attributed to the amount of halite contained in the formation from place to place. Variations in the Tamarisk accounts for a larger part of thickness changes than do variations in either the unnamed lower member or the Forty-niner.

Much project-specific information about the Rustler is contained in DOE/WIPP 88-004.[49] The WIPP shafts were a crucial element in the 1988 study by Holt and Powers, exposing features not previously reported. Cores were available from several WIPP boreholes, and their lithologies were matched to geophysical log signatures to extend the interpretation throughout a larger area in southeastern New Mexico.

Source data for the Rustler also include tabular information provided by Richey[64] and unpublished work (both by Powers and by Holt) in support of regional hydrogeological modeling. These data are provided as tabular information on locations and stratigraphy with accompanying review of data sources and quality.[7]

2.7.3.5.1 Unnamed Lower Member

The unnamed lower member rests on the Salado with apparent conformity at the WIPP site. It consists of significant proportions of bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains. These beds record the transition from strongly evaporative environments of the Salado to saline lagoonal environments. The upper part of the unnamed lower member includes halitic and sulfitic beds within clastics. Holt and Powers[49] interpret these as facies changes within a saline playa environment. The implied model from earlier descriptions (Jones, 1978)[65] is that the non-halitic areas of the upper unnamed lower member are dissolution residues from post-depositional dissolution.

According to Holt and Powers[49] the unnamed lower member ranges in thickness from about 96 to 126 feet (29 to 38 meters) within the site boundaries. The maximum thickness recorded during that study was 208 feet (63 meters) southeast of the WIPP site. Halite extends west of most of the site area in this unit.[66,67] (See Figure 2.7-7 for an illustration of the halite margins.) Cross-sections based on geophysical log interpretations in DOE/WIPP 88-004[49] show the relationship between the thickness of the unit and the presence of halite.

2.7.3.5.2 The Culebra Dolomite Member

The Culebra rests with apparent conformity on the unnamed lower member, though the underlying unit ranges from claystone to its lateral halitic equivalent in the site area. West of the WIPP site, in Nash Draw, the Culebra is disrupted in response to dissolution of the underlying halite. Holt and Powers[49] attribute this principally to dissolution of Salado halite, while Snyder[66] indicates that salt was dissolved postdepositionally from the unnamed lower member. These alternative models provide the basis for differing explanations of how the existing Rustler hydrologic system developed and might continue to develop. The regulatory period of concern is short enough and boundaries close enough that these differences are not important to disposal system performance.

The Culebra was described as a dolomite 35 feet (11 meters) in thickness;[56] Adams[59] noted that oölites are present in some outcrops as well. The Culebra is generally brown, finely crystalline, locally argillaceous and arenaceous dolomite with rare-to-abundant vugs with variable gypsum and anhydrite filling. DOE/WIPP 88-004[49] describes Culebra features in detail, noting that most of the Culebra is microlaminated to thinly laminated while some zones display no depositional fabric. WTSD-TME-038[57] described an upper interval of the Culebra consisting of waxy, golden-brown carbonate, dark organic claystone, and some coarser siltstone of probable algal origin. Because of the unique organic composition of this thin layer, DOE/WIPP 88-004[49] did not include it in the Culebra for thickness computations, and this will be factored into discussions of Culebra thickness. Based on core descriptions from the WIPP project, DOE/WIPP 88-004[49] concluded that there is very little variation of depositional sedimentary features throughout the Culebra.

Vugs are an important part of Culebra porosity. They are commonly zoned parallel to bedding.[45] In outcrop, vugs are commonly empty. In the subsurface, vugs may be filled with anhydrite or gypsum, or they may have some clay lining.[49] Lowenstein noted similar features.[38] DOE/WIPP 88-004[49] attributed vugs partly to syndepositional growth as nodules and partly as later replacement textures. Lowenstein[38] also described textures related to later replacement and alteration of sulfates. According to the Geologic Society of America 1990 Annual Meeting Field Trip #14 Guidebook,[68] vug or pore fillings vary across the WIPP site and contribute to the porosity structure of the Culebra. Natural fractures filled with gypsum are common east of the WIPP site center and in a smaller area west of the site center.

After dolomite, SAND97-7036[69] reports that clay is the second most abundant mineral of the Culebra. Clay minerals include corrensite, illite, serpentine, and chlorite. Clay occurs in bulk rock and in fracture surfaces.

In the WIPP site area, the Culebra varies in thickness. The choice of Culebra thickness and saturated interval are important hydrological parameters for performance assessment. Holt and Powers[49] considered the organic-rich layer at the Culebra-Tamarisk contact separately from the Culebra in interpreting geophysical logs. Comparing data sets, Holt and Powers typically interpret the Culebra as being about 3 feet (1 meter) thinner than have other sources, including Open-file Report 78-592, Open-file Report 89-32 and SAND88-7002.[65,64,70] In general, this reflects the difference between including or excluding the unit at the Culebra-Tamarisk contact. Each data set shows areal differences in thickness of the Culebra when it is examined township by township.

SAND88-7002[70] calculated a mean thickness of 25 feet (7.7 meters) for the Culebra based on 78 drill holes. Mercer[71] reported a data set similar to SAND88-7002,[70] but without statistics. The borehole database makes it possible to defend choices of Culebra thickness for the area being modeled.[7]

2.7.3.5.3 The Tamarisk Member

Vine[60] named the Tamarisk for outcrops near Tamarisk Flat in Nash Draw. Outcrops of the Tamarisk are distorted, and subsurface information was used to establish member characteristics. Vine reported two sulfate units separated by a siltstone, about 5 feet (1.5 meters) thick, interpreted by Jones[42] as a dissolution residue.

The Tamarisk is generally conformable with the underlying Culebra. The transition is marked by an organic-rich unit interpreted as being present over most of southeastern New Mexico.[49] The Tamarisk around the site area consists of lower and upper sulfate units separated by a unit that varies from mudstone (generally to the west) to mainly halite (to the east).[49] Near the center of the WIPP site, the lower anhydrite was partially eroded during deposition of the middle mudstone unit, as observed in the WIPP Waste and Exhaust Shafts.[57,72] The lower anhydrite was completely eroded at WIPP 19.[49] Before shaft exposures were available, the lack of the lower Tamarisk anhydrite at WIPP 19 was interpreted as the result of dissolution and the mudstone was considered a cave filling.[73]

Open-file Report 78-592[65] interprets halite to be present east of the center of the WIPP site based on geophysical logs and drill cuttings. Based mainly on cores and cuttings records from the WIPP potash drilling program, Snyder[66] prepared a map showing the halitic areas of each of the non-carbonate Rustler members. A very similar map was prepared independently by Powers[67] based on geophysical log characteristics (see Figure 2.7-9).

Holt and Powers[49] described the mudstones and halitic facies in the middle of the Tamarisk, and they interpreted the unit as formed in a salt pan to mudflat system. They cited sedimentary features and the lateral relationships as evidence of syndepositional dissolution of halite in the marginal mudflat areas. In contrast, Open-file Report 1960,[42] Report 78-592,[65] and SAND77-7017[137] interpreted the lateral decrease in thickness and absence of halite to the west as evidence of post-depositional dissolution. The differing concepts for halite distribution in the Rustler, and particularly the Tamarisk, have been used in explaining the large changes in hydrologic properties of the Culebra as described in later sections.

The Tamarisk thickness varies greatly in southeastern New Mexico, principally as a function of the thickness of halite in the middle unit.[49] Within T22S, R31E, Holt and Powers[49] show a range from 84 to 184 feet (26-56 meters) for the entire Tamarisk and a range from 6 to 110 feet (2 to 34 meters) for the interval of mudstone-halite between lower and upper anhydrites.[49] Expanded geophysical logs with corresponding lithology illustrate some of the lateral relationships for this interval.

2.7.3.5.4 The Magenta Dolomite Member

Adams[59] also attributes the name "Magenta member" to Lang, based on a feature north of Laguna Grande de la Sal named Magenta Point. According to DOE/WIPP 88-004,[49] the Magenta is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features.[49] It does not vary greatly in sedimentary features across the site area.[49]

Around the WIPP site, Holt and Powers[49] reported that the Magenta varies from 23 to 28 feet (7.0 to 8.5 meters); they did not contour the thickness because of limited changes.

2.7.3.5.5 The Forty-niner Member

Vine[60] named the Forty-niner for outcrops at Forty-niner Ridge in eastern Nash Draw, but the outcrops of the Forty-niner are poorly exposed. In the subsurface around the WIPP, the Forty-niner consists of basal and upper sulfates separated by a mudstone.[57] It is conformable with the underlying Magenta. As with other members of the Rustler, geophysical log characteristics can be correlated with core and shaft descriptions to extend geological inferences across a large area.[49]

The Forty-niner ranges from 43 to 77 feet (13 to 23 meters) thick within T22S, R31E, (Figure 2.7-10).[49] East and southeast of the WIPP, the Forty-niner exceeds 80 feet (24 meters), and some of the geophysical logs from this area indicate halite is present in the beds between the sulfates.[49]

Within the Waste Shaft, the Forty-niner mudstone displayed sedimentary features and bedding relationships indicating sedimentary transport.[57] The mudstone has been commonly interpreted as a residue from the dissolution of halitic beds because it is thinner where there is no halite. These beds are not known to have been described in detail prior to mapping in the Waste Shaft at WIPP, and the features found there led Holt and Powers[57,49] to re-examine the available evidence for, and interpretations of, dissolution of halite in Rustler units.

2.7.3.6 Dewey Lake (Redbeds)

The nomenclature for rocks included in the Dewey Lake (or alternatively Redbeds) was introduced during the 1960s to clarify relationships between these rocks assigned to the Upper Permian and the Cenozoic Gatuña Formation hereafter referred to as the Gatuña. (See discussions in West Texas Geological Society Bulletin[74] and Guidebook 18[61].)

There are three main sources of data about the Dewey Lake in the area around WIPP. Miller studied the petrology of the unit.[75,76] Schiel[77,74] described outcrops in the Nash Draw areas and interpreted geophysical logs of the unit in southeastern New Mexico and west Texas to infer the depositional environments and stratigraphic relationships. Holt and Powers[45] were able to describe the Dewey Lake in detail at the Air Intake Shaft for WIPP, confirming much of Schiel's information and adding data regarding the lower Dewey Lake.

The Dewey Lake overlies the Rustler conformably though local examples of the contact (e.g., the Air Intake Shaft described in DOE/WIPP 90-051[45]) show minor disruption by dissolution of some of the upper Rustler sulfate. The formation is predominantly reddish-brown fine sandstone to siltstone or silty claystone with greenish-gray reduction spots. Thin bedding, ripple cross-bedding, and larger channeling are common features in outcrops,[77] and additional soft sediment deformation features and early fracturing are described from the lower part of the formation.[45] Schiel[77] attributed the Dewey Lake to deposition on "a large, arid fluvial plain subject to ephemeral flood events".

There is little direct faunal or radiometric evidence of the age of the Dewey Lake. It is assigned to the Ochoan series of late Permian age, and it is regionally correlated with units of similar lithology and stratigraphic position. Schiel[77] reviewed the limited radiometric data from lithologically similar rocks (Quartermaster Formation) and concluded that much of the unit could be early Triassic in age.

Near the center of the WIPP site, Holt and Powers,[45] mapped 498 feet (152 meters) of the Dewey Lake (Figure 2.7-10). The formation is thicker to the east of the WIPP site, in part because western areas were eroded before the overlying Triassic rocks were deposited.[77,74]

The Dewey Lake contains fractures which are filled with minerals to varying degrees. Both cements and fracture fillings have been examined and used to infer groundwater infiltration. Holt and Powers[45] described the Dewey Lake as cemented by carbonate above 164.5 feet (50 meters) in the Air Intake Shaft; some fractures in the lower part of this interval were also filled with carbonate, and the entire interval surface was commonly moist. Below this point, the cement is harder (probably anhydrite), the shaft is dry, and fractures are filled with gypsum. Holt and Powers[45] suggested the cement change might be related to infiltration of meteoric water. They also determined that some of the gypsum-filled fractures are syndepositional. Dewey Lake fractures include horizontal to subvertical trends, some of which were mapped in detail.[72]

Lambert, 1991[134] analyzed the deuterium/hydrogen (D/H) ratios of gypsum in the Rustler and gypsum veins in the Dewey Lake. He suggests that none of the gypsum formed from evaporitic fluid such as Permian seawater, but that the D/H ratios all show influence of meteoric water. Nonetheless, Lambert, 1991[134] also infers that the gypsum D/H is not consistent with modern meteoric water; it may be consistent with earlier meteoric fluids. There is no obvious correlation with depth indicating infiltration. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) indicate no intermixing or homogenization of fluids between the Rustler and the Dewey Lake, but there may be lateral movement of water within the Dewey Lake. Dewey Lake carbonate vein material shows a broader range of strontium ratios than does surface caliche, and the ratios barely overlap.

2.7.3.7 The Santa Rosa

There have been different approaches to the nomenclature of rocks of Triassic age in southeastern New Mexico. Bachman[78] generally described the units as "Triassic, undivided" or as the Dockum Group, without dividing it. Vine[60] used "Santa Rosa Sandstone," and Santa Rosa has become common usage. Lucas and Anderson[79] import other formation names that are unlikely to be useful for WIPP.

The Santa Rosa has been called disconformable over the Dewey Lake.[60,79] These rocks have more variegated hues than the underlying uniformly-colored Dewey Lake. Coarse-grained rocks, including conglomerates, are common, and the formation includes a variety of cross-bedding and sedimentary features.[79]

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent (Figure 2.7-11). At the Air Intake Shaft, Holt and Powers[45] attributed about 2 feet (0.6 meters) of rock to the Santa Rosa. The Santa Rosa is a maximum of 255 feet (78 meters) thick in potash holes drilled for WIPP east of the site boundary. The Santa Rosa is thicker to the east.

2.7.3.8 The Gatuña Formation

Lang[56] named the Gatuña for outcrops in the vicinity of Gatuña Canyon in the Clayton Basin. Rocks now attributed to the Gatuña in Pierce Canyon were once included in the "Pierce Canyon Formation" with rocks now assigned to the Dewey Lake. The formation has been mapped from the Santa Rosa, New Mexico, area south to the vicinity of Pecos, Texas. It is unconformable with underlying units.

Vine[60] and Bachman[78] provided some limited description of the Gatuña. The most comprehensive study of the Gatuña is by Powers and Holt,[80] based on WIPP investigations and landfill studies for Carlsbad and Eddy County. Much of the formation is colored light reddish-brown. It is broadly similar to the Dewey Lake and the Santa Rosa, though the older units have more intense hues. The formation is highly variable, ranging from coarse conglomerates to claystones with some highly gypsiferous sections. Sedimentary structures are abundant. Analysis of lithofacies indicates that the formation is dominantly fluvial in origin with areas of low-energy deposits and evaporitic minerals. It was deposited in part over areas actively subsiding in response to dissolution.[80]

The thickness of the Gatuña is not very consistent regionally. Powers and Holt[80] report thicknesses up to about 300 feet (91 meters) at Pierce Canyon, with thicker areas generally subparallel to the Pecos River. To the east, the Gatuña is thin or absent. Holt and Powers[45] reported about 9 feet (2.7 meters) of undisturbed Gatuña in the Air Intake Shaft at WIPP.

The Gatuña has been considered to be Pleistocene in age based on a volcanic glass in the upper Gatuña[81] that has been identified as the Lava Creek B ash dated at 0.6 million years.[82] An additional volcanic ash from Gatuña in Texas yields consistent potassium-argon and geochemical data, indicating it is about 13 million years old.[80] Thus the Gatuña ranges in age over a period of time that may be greater than the Ogallala Formation on the High Plains east of WIPP.

2.7.3.9 Mescalero Caliche

The Mescalero caliche (hereinafter referred to as the Mescalero) is an informal stratigraphic unit apparently first explicitly used by Bachman,[78] though Bachman[83] described the "caliche on the Mescalero Plain." He differentiated the Mescalero from the older, widespread Ogallala caliche or caprock on the basis of textures, noting that breccia and pisolitic textures are much more common in the Ogallala caliche. The Mescalero has been noted over significant areas in the Pecos drainage, including the WIPP site area, and it has been formed over a variety of substrates.

Bachman described the Mescalero as a two-part unit: (1) an upper dense laminar caprock; and (2) a basal, earthy to firm, nodular calcareous deposit. Machette (1985)[135] classified the Mescalero as having Stage V morphologies of a calcic soil (the more mature Ogallala caprock reaches Stage VI).

Bachman[84] provided structure contours on the Mescalero caliche for a large area of southeastern New Mexico, including the WIPP site. From the contours and Bachman's discussion of the Mescalero as a soil, it is clear that the Mescalero is expected to be continuous over large areas. Explicit WIPP data are limited mainly to drill holes, though some drill hole reports do not mention the Mescalero. The unit may be as much as 10 feet (3 meters) thick.[85]

The Mescalero was inferred on basic stratigraphic and climatic grounds as having accumulated during the early to middle Pleistocene.[78,81] Bachman[81] reported finding a volcanic ash in the upper Gatuña along Livingston Ridge and underlying the Mescalero. His original report that this was the Pearlette "O" ash was superseded when Izett and Wilcox[82] reported the ash as Lava Creek B, about 0.6 million years.

The Mescalero must therefore be younger. Samples of the Mescalero from the vicinity of the WIPP were studied using uranium-trend methods. Based on early written communication from Rosholt, Bachman[85] reports that the basal Mescalero began to form about 510,000 years ago and the upper part began to form about 410,000 years ago; these ages are commonly cited in WIPP literature. The samples are interpreted by Rosholt and McKinney[86] in the formal report as indicating ages of 570,000 $\pm$ 110,000 years for the lower part of the Mescalero and 420,000 $\pm$ 60,000 years for the upper part.

Based on morphology of caliche along part of the southern rim of Pierce Canyon, Hawley[87] has argued that some of the caliche within the Delaware Basin may be Ogallala caliche instead of Mescalero. This question has not been further addressed.

According to Bachman,[85] the Mescalero soil is an indicator of stability or integrity of the WIPP surface. Bachman[85] considered the Mescalero as an impediment to erosion; the discussion by Bachman indicates the Mescalero is an indicator of surface stability over the last 500,000 years.

2.7.3.10 Surficial Sediments

The soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary system is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian system is represented by limestone, dolomite, and gypsum bedrock. Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. Subsoil colors normally are light brown to reddish-brown but are often mixed with lime accumulations (caliche) that result from limited, erratic rainfall and insufficient leaching. A soil association is a landscape with a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 5 miles (8.3 kilometers) of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three associations, only the Kermit-Berino soil series have been mapped across the WIPP site;[88] these are sandy soils developed on eolian material.[88] The Kermit-Berino soils include active dune areas. The Berino soil has a sandy A horizon; the B horizons include more argillaceous material and weak-to-moderate soil structures. A and B horizons are described as non-calcareous, and the underlying C horizon is commonly caliche. Bachman[81] interpreted the Berino soil as a paleosol that is a remnant B horizon of the underlying Mescalero.

Generally, the Berino series, which covers about 50 percent of the site, consists of deep, non-calcareous, yellow-red to red sandy soils that developed in wind-worked material of mixed origin. These soils are described as undulating to hummocky and gently sloping (ranging from 0 percent to 3 percent slopes). The soils are the most extensive of the deep, sandy soils in the Eddy County area. Berino soils are subject to continuing wind and water erosion. If the vegetative cover is seriously depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest.

The Kermit series consists of deep, light-colored, non-calcareous, excessively drained, loose sands, typically yellowish-red fine sand. The surface is undulating-to-billowy (from 0 to 3 percent slopes) and consists mostly of stabilized sand dunes. Kermit soils are slightly to moderately eroded. Permeability is very high, and, if vegetative cover is removed, the water-erosion potential is slight but the wind-erosion potential is very high. Rosholt and McKinney[86] applied uranium-trend methods to samples of the Berino soil from the WIPP site area. They interpreted the age of formation of the Berino soil as 330,000 ± 75,000 years.

2.7.4 Physiography and Geomorphology

2.7.4.1 Regional Physiography and Geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province (Figure 2.7-12), a broad highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 miles (8.3 to 50 kilometers) wide and as much as 1,000 feet (305 meters) deep in the north. The Pecos River system has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. The surface locally has a karst terrain containing superficial sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations range from more than 6,000 feet (1,829 meters) in the northwest to about 2,000 feet (610 meters) in the south.

The Pecos Valley section is bordered on the east by the Llano Estacado, a virtually uneroded plain formed by river action. The Llano Estacado is part of the High Plains section of the Great Plains physiographic province and is a poorly-drained, eastward-sloping surface covered by gravels, wind-blown sand, and caliche that has developed since early-to-middle Pleistocene time. Few and minor topographic features are present in the High Plains section, formed when more than 500 feet (152 meters) of Tertiary silts, gravels, and sands were laid down in alluvial fans by streams draining the Rocky Mountains. In many areas, the nearly flat surface is cemented by a hard caliche layer.

To the west of the Pecos Valley section are the Sacramento Mountains and the Guadalupe Mountains, part of the Sacramento section of the Basin and Range Province. The Capitan escarpment along the southeastern side of the Guadalupe Mountains marks the boundary between the Basin and Range and the Great Plains provinces. The Sacramento section has large basinal areas and a series of intervening mountain ranges.

2.7.4.2 Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest, and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the surface of the underlying Pleistocene Gatuña. Figure 2.7-13 is a topographic map of the area. Elevations at the site range from 3,570 feet (1,088 meters) in the east to 3,250 feet (990 meters) in the west. The average east-to-west slope is 50 feet per mile (9.4 meters per kilometer).

Livingston Ridge is the most prominent physiographic feature near the site. It is a west-facing escarpment that has about 75 feet (23 meters) of topographic relief and marks the eastern edge of Nash Draw, the drainage course nearest to the site. Nash Draw is a shallow 5-mile- (8-kilometer-) wide basin, 200 to 300 feet (61 to 91 meters) deep and open to the southwest. It was caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. Livingston Ridge is the approximate boundary between terrain that has undergone erosion and/or solution collapse and terrain that has been affected very little.

About 15 miles (24 kilometers) east of the site is the southeast-trending San Simon Swale, a depression due, at least in part, to subsurface dissolution. Between San Simon Swale and the site is a broad, low mesa named "the Divide." Lying about 6 miles (9.7 kilometers) east of the site and about 100 feet (30 meters) above the surrounding terrain, it is a boundary between southwest drainage toward Nash Draw and southeast drainage toward San Simon Swale. The Divide is capped by the Ogallala Formation (hereinafter referred to as the Ogallala) and the overlying caliche, upon which have formed small, elongated depressions similar to those in the adjacent High Plains section to the east.

Surface drainage is intermittent; the nearest perennial stream is the Pecos River, 12 miles (20 kilometers) southwest of the WIPP site boundary. The site's location near a natural divide protects it from flooding and serious erosion caused by heavy runoff. Should the climate become more humid, any perennial streams should follow the present basins, and Nash Draw and San Simon Swale would be the most eroded, leaving the area of the Divide relatively intact.

Dissolution-caused subsidence in Nash Draw and elsewhere in the Delaware Basin has caused a search for geomorphic indications of subsidence near the site. One feature that has attracted some attention is a very shallow sink about 2 miles (3 kilometers) north of the center of the site. It is very subdued, about 1,000 feet (305 meters) in diameter, and about 30 feet (9 meters) deep. Resistivity studies indicate a very shallow surficial fill within this sink and no disturbance of underlying beds, implying a surface, rather than subsurface, origin (DOE, 1980).[140] Resistivity surveys in the site area showed an anomaly in Section 17 within the WIPP Site boundary. It resembles the pattern over a known sink, a so-called breccia pipe, but drilling showed a normal subsurface structure without breccia, and the geophysical anomaly has been accounted for by low-resistivity rock in the Dewey Lake.

2.7.5 Tectonic Setting and Site Structural Features

The processes and features included in this section are those more traditionally considered part of tectonic, broad-scale processes that develop the features of the earth. Salt dissolution is a different process that can develop some features resembling those of tectonics.

Most broad-scale structural elements of the area around the WIPP developed during the late Paleozoic. There is little historical or recent geological evidence of significant tectonic activity in the vicinity. More recently, the entire region has tilted, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in a separate section.

Broad subsidence began in the area as early as the Ordovician, developing a sag called the Tabosa Basin by Galley.[89] By late Pennsylvanian to early Permian time, the Central Basin Platform developed (Figure 2.7-14), separating the Tabosa Basin into two parts: the Delaware Basin to the west and the Midland Basin to the east. The Permian Basin refers to the collective set of depositional basins in the area during the Permian period. Southwest of the Delaware Basin, the Diablo Platform began developing either late in the Pennsylvanian or early Permian. The Marathon Uplift and Ouachita tectonic belt limited the southern extent of the Delaware Basin. Most of these broader scale features surrounding the Delaware Basin formed during the late Paleozoic and have remained relatively constant in their relationships since.

2.7.5.1 Basin Tilting

According to Brokaw et al.[90] pre-Ochoan sedimentary rocks in the Delaware Basin show evidence of gentle downwarping during deposition, while Ochoan and younger rocks do not. A relatively simple eastward tilt generally from about 75 to 100 feet per mile (14 to 19 meters per kilometers) has been superimposed on the sedimentary sequence.[90,23] King[15] generally attributes the uplift of the Guadalupe and Delaware mountains along the west side of the Delaware Basin to later Cenozoic, though he also notes that some faults along the west margin of the Guadalupe Mountains have displaced Quaternary gravels.[91] King[15] also infers the uplift from the Pliocene-age deposits of the Llano Estacado. Subsequent studies of the Ogallala Formation of the Llano Estacado show that it ranges in age from Miocene (about 12 million years before present) to Pliocene. This is the most likely range for uplift of the Guadalupes and broad tilting to the east of the Delaware Basin sequence.

2.7.5.2 Faulting

Fault zones are well known along the Central Basin Platform, east of WIPP, from extensive drilling for oil and gas as reported by Hills.[92] Holt and Powers[49] performed a more recent analysis of geophysical logs to examine regional geology for the Rustler that show these faults displaced at least Rustler rocks of late Permian age. The overlying Dewey Lake shows marked thinning along the same trend as the fault line or zone according to Schiel,[77] but the structure contours of the top of the Dewey Lake are not clearly offset. Schiel[77] concluded that the fault was probably reactivated during Dewey Lake deposition, but movement ceased at least by the time the Santa Rosa was deposited. No surface displacement or fault has been reported along this trend, indicating movement has not been significant enough to rupture the overlying materials since Permian time.

Within the Delaware Basin, there are few examples of faults that may offset part of the evaporite section. At the northern end of the WIPP site, Snyder[93] drew structure contours on the top of the basal anhydrite (A1) of the Castile for drill holes WIPP-11, WIPP-12, and WIPP-13. He interpreted northeast-southwest trending faults displacing this unit both north and south of WIPP-11. Snyder inferred that the Bell Canyon–Castile contact is also faulted and displaced along the same trend. Barrows[93] interpreted seismic reflection data to indicate, with varying confidence, faults within Castile rocks but not in underlying units.

The faults interpreted by Snyder[93] around WIPP-11 depend on the correct identification of the basal Castile anhydrite (A1) in that borehole. The evaporite structure is complex, and some of the upper units of the Castile and the lower Salado differ from surrounding boreholes. The diagnostic Castile–Bell Canyon contact was not drilled in this borehole, and the faults inferred for the Castile–Bell Canyon contact also depend on correct identification of A1 and projection of A1 thickness by Snyder. Inferred connections with the underlying Bell Canyon or deeper units could signify circulation of fluids to the evaporite section within the site boundaries. This is unlikely, given the Castile geology within boreholes WIPP-13[94] and DOE-2[14] near the trend of the inferred fault. Drilling for hydrocarbon exploration has been extensive around the north and west boundaries of the site since the mid-1980s.

Quaternary fault scarps have been mapped along the Salt Basin graben west of both the Guadalupe and Delaware mountains.[91] These are the nearest known Quaternary faults of tectonic origin to the WIPP. Kelley[95] inferred that the Carlsbad and Barrera faults along the eastern escarpment of the Guadalupe Mountains are based mainly on vegetative lines. Hayes and Bachman[96] re-examined the field evidence for these faults and concluded that they were nonexistent.

On a national basis, Howard et al.[97] assessed the location and potential for activity of young faults. For the region around the WIPP site, Howard et al.[97] located faults along the western escarpment of the Delaware and Guadalupe mountains trend. These faults were judged to be late Quaternary (approximately the last 500,000 years) or older.

In summary, there are no known Quaternary or Holocene faults of tectonic origin offsetting rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains. A significant part of the tilt of basin rocks is attributed to a mid-Miocene to Pliocene uplift along the Guadalupe-Sacramento mountains trend that is inferred on the basis of High Plains sediments of the Ogallala Formation. Seismic activity is low and is commonly associated with secondary oil recovery along the Central Basin Platform.

2.7.5.3 Igneous Activity

Within the Delaware Basin, only one feature of igneous origin is known to have formed since the Precambrian. An igneous dike or series of echelon dikes occurs along a linear trace about 75 miles (120 kilometers) long from the Yeso Hills south of Whites City to the northeast.[98] At its closest, the dike trend passes about 8 miles (13 kilometers) northwest of the WIPP site center. The dike's data range from outcroppings at Yeso Hills to subsurface intercepts in drill holes and mines to airborne magnetic responses.

An early radiometric determination by Urry[99] for the dike yielded an age of 30 $\pm$ 1.5 million years. More recent work by Calzia and Hiss[55] on dike samples are consistent with early work, indicating an age of 34.8 $\pm$ 0.8 million years. Work by Brookins et al.[52] on dike samples in contact with polyhalite indicated an age of about 21.4 million years.

Volcanic ashes found in the Gatuña were airborne from distant sources such as Yellowstone and represent no volcanic activity at WIPP.[80]

2.7.5.4 Loading and Unloading

The loading and unloading history of the site and surrounding areas is considered a factor in the development of the hydrological system, including the Culebra, at the WIPP site. The depth to the base of the Culebra in the area (Figure 2.7-15) indicates the current state of loading for the unit. This depth is a function of regional dip, erosion, and dissolution subsidence.

Regional geology information has been used to construct a broader view of the loading and unloading history at the site for the Culebra. This information is currently being completed and interpreted.

2.7.6 Non-Tectonic Processes and Features

Halite in evaporite sequences is relatively plastic, which can lead to the process of deformation; it is also highly soluble, which can lead to the process of dissolution. Both processes (deformation and dissolution) can develop structural features very similar to those developed by tectonic processes. The features developed by dissolution and deformation can be distinguished from similar-looking tectonic features where the underlying units do not reflect the same feature as do the evaporites. As an example, the evaporite deformation can commonly be shown not to affect the underlying Bell Canyon. The deformation also tends to die out in overlying units, and the Rustler or the Dewey Lake may show little, if any, of the effects of the deformed evaporites. Beds underlying areas of dissolved salt are not affected, but overlying units to the surface may be affected.

2.7.6.1 Evaporite Deformation

Salient points of evaporite deformation for repository performance assessment are summarized here.

2.7.6.1.1 Basic WIPP History of Deformation Investigations

The Castile has been known for many years to be deformed in parts of the Delaware Basin, especially along the northern margin. Jones et al.[39] clearly showed thicker isopachs of part of the Castile from the northwestern to northern part of the basin margin, just inside the Capitan Formation (hereafter referred to as the Capitan). A dissertation by Snider[100] and a paper by Anderson et al.[22] also presented maps showing some evidence of thicker sections of Castile next to the Capitan.

ERDA-6 was drilled during 1975 as part of the program to characterize an initial site for WIPP. The drill hole penetrated increasingly deformed beds through the Salado into the Castile, and, at about a depth of 2,711 feet (826 meters), the drill hole began to produce pressurized brine and gas. Anderson and Powers[101] and Jones[102] interpreted beds to have been displaced structurally by several hundred feet. Some of the lower beds may have pierced overlying beds. The beds were considered to be too structurally deformed to mine reasonably along single horizons for a repository. Therefore, that site was abandoned in 1975, and the current WIPP site was located in 1976.[1] The deformed beds around ERDA-6 were considered part of a deformed zone within about 6 miles (10 kilometers) of the inner margin of the Capitan reef. As a consequence, the preliminary selection criteria restricted locating a new site within 6 miles (10 kilometers) of the Capitan reef margin.[103]

General criteria for the new (present) site for the WIPP appeared to be met based on initial data from drilling (ERDA-9) and geophysical surveys.[103] Beginning in 1977, the new site was more intensively characterized through geophysical surveys, including seismic reflection and drilling.[1] Extensive seismic reflection work revealed good reflector quality in the southern part of the site and poor quality, or "disturbed" reflectors, in a sector of the northern part of the site. The area of "disturbed" reflectors became known as the "disturbed zone" (DZ), "the area of anomalous seismic reflectors," or "zone of anomalous seismic reflection data." (The "disturbed zone" based on poor Castile seismic reflectors is completely different from the Disturbed Rock Zone [DRZ] that Borns and Stormont[104] used to describe the deformation around mined underground openings at the WIPP.)

Powers et al.[1] generally show the DZ beginning about 1 mile (1.6 kilometers) north of the WIPP site center. Borns et al.[93] included two areas south of the WIPP site as showing the same features of the DZ. Neill et al.[105] summarized the limits to the DZ based on differing interpretations and included the area less than 1 mile (1.6 kilometers) north of the site center where the Castile begins to steepen in dip. WIPP-11 was drilled early during 1978 about 3 miles (5 kilometers) north of the site center over part of the DZ where proprietary petroleum company data[106] had also indicated significant seismic anomalies. The drill hole encountered highly deformed beds within the Castile and altered thicknesses of halite units, but no pressurized brine and gas were found.[107]

Less than 1 mile (1.6 kilometers) north of the site center, seismic data indicated possible faulting of the upper Salado and the lower Rustler over the area of steepening Castile dips (e.g., basic data report for WIPP-18 in Sandia and USGS, 1980).[108] Four drill holes (WIPP-18, -19, -21, -22) were drilled into the upper Salado and demonstrated neither faulting nor significant deformation of the Rustler-Salado contact. Lateral changes in the seismic velocity of the upper sections contributed to the interpretation of a possible fault and thus complicate interpretations of deeper structure (see the seismic data in Hern et al., 1979).[109]

WIPP-12 was located about 1 mile (1.6 kilometers) north of the center of the site and drilled during 1978 to a depth of 2785 feet (850 meters) in the upper Castile to determine the significance of structure on possible repository horizons.[110] The top of the Castile was encountered at an elevation about 160 feet (49 meters) above the same contact in ERDA-9 at the site center.

WIPP-12 was deepened during late 1981 to a depth of 3925 feet (1200 meters) to test for possible brine and gas in the deformed Castile. The probability that brine and gas would be found was considered low because ERDA-6 and other known brine reservoirs in the Castile occurred in areas with greater deformation. During drilling, fractured anhydrite in the upper Castile (lower A3) began to yield pressurized brine and gas. The borehole was deepened to the basal anhydrite (A1) of the Castile. Over a million gallons of brine were allowed to flow from the well before the hole was shut in. Subsequent reservoir testing was conducted to estimate reservoir size (see section 2.6.1.3.2 on Castile brines).

As a consequence of discovering pressurized brine and gas in WIPP-12, the Environmental Evaluation Group (EEG) recommended that the design of the facility be changed and that proposed waste storage areas in the north be moved or re-oriented to the south.[111] After additional drilling of DOE-1, it was agreed by the DOE that the design change had advantages, and the disposal facilities were placed south of the site center.

A microgravity survey of the site was designed to try to further delineate the structure within the DZ based on the large density differences between halite and anhydrite. The gravity survey was unsuccessful in yielding any improved resolution of the Castile structure.

DOE-2 was the last WIPP drill hole to examine structure within the Castile. Salado structure from potash data[103] suggested a low point about 2 miles (3.3 kilometers) north of the site center. It was proposed by Davies (1984) that this Salado low point might indicate deeper dissolution of Castile halite, somewhat similar to the dissolution that causes breccia pipes. The drill hole demonstrated considerable Castile deformation, but there was no indication that halite had been removed by dissolution.[104]

2.7.6.1.2 Extent of the Disturbed Zone at the Site

Nearby surface drilling, shafts, and underground drilling during early excavations at WIPP showed that the repository horizon varies modestly from the regional structure over the central part of the site; north of the site center the beds dip to the south. Borns and Stormont[104] believe the south dip is probably related to the dip on the underlying Castile.

The upper surface of MB 139, under the repository horizon, exhibited significant relief in the exploratory Salt Handling Shaft. Jarolimek et al.[112] interpreted the relief as mainly due to syndepositional growth of gypsum at the water-sediment interface to form mounds, and to subsequent partial crushing. Jarolimek et al.[112] concluded that the MB relief was not due to deformation because the base of the MB showed no comparable relief. Based on concerns of the EEG, MB 139 was re-evaluated. Borns[23] found less relief on the upper surface of the MB in the areas they examined; they also concluded that depositional processes were responsible for the relief. In either case, the relief on MB 139 is not considered to have been caused by deformation.

A cross-section through the four drill holes from ERDA-9 to WIPP-11 and the cross-section to DOE-1 indicates the general nature of the Castile structure under the WIPP site. Only DOE-1 and DOE-2 penetrate the Castile–Bell Canyon contact.

2.7.6.1.3 Deformation Mechanisms

In analyzing Castile structure in the northern Delaware Basin, Borns et al.[93] proposed five processes as the principal hypotheses to explain the structure: gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes. Gravity foundering appears to be the most comprehensive explanation and is, in fact, the best accepted hypothesis out of the five possibilities. It is based on the fact that anhydrite is much more dense (about 2.9 grams per cubic centimeter) than halite (about 2.15 grams per cubic centimeter), and anhydrite beds should have considerable potential for sinking into underlying halite. Modeling of similar systems suggests that a rate of deformation of about 0.02 inches (0.05 centimeters) per year is possible and, at that rate, the DZ could have developed over about 700,000 years. The principal difficulty with this hypothesis is that there should exist the same potential for foundering over much of the basin, yet the deformation is localized.

2.7.6.1.4 Timing of Deformation of the Disturbed Zone at the Site

Jones[102] estimated that deformation of the Castile and overlying rocks took place before the Ogallala Formation was deposited, as he believes the unit is undeformed. Anderson and Powers[101] inferred that data from ERDA-6 indicates that the Castile was deformed after the basin was tilted. Though these lines of evidence could be consistent with mid-Miocene deformation, there are other interpretations of tilting consistent with older deformation.[113] There is no known evidence of surface deformation or other features to indicate recent deformation.

A regional first-order, Class I baseline for vertical control was established over much of the WIPP site during 1977[114] and was tied into existing lines of benchmarks in the area. The data along the line from Carlsbad toward El Paso showed vertical movement from Carlsbad consistent with regional geological uplift; relative subsidence over the Salt Flat Graben was consistent with geological structures as interpreted by Reilinger et al.[115] A resurvey of the WIPP area benchmarks in 1981[116] showed subsidence averaging about 0.72 inches (18 millimeters) total, relative to benchmarks at Carlsbad over the 4-year period. Though these short-term results are consistent in direction of relative movement with the geological structure of the area (i.e., uplift on the west, tilting down to the east), the implied rates of movement are very high or improbable for this area over periods of geological time, given the geological history of the area.

The benchmarks can be monitored through resurveys during operation to determine any changes of significance and provide continuing evidence of the stability of the site area.

2.7.6.2 Evaporite Dissolution

Because evaporites are much more soluble than most other rocks, project investigators have considered it important to understand the dissolution processes and rates that take place within the site considered for long-term isolation. These dissolution processes and rates constitute the limiting factor in any evaluation of the site. Over the course of the WIPP project, extensive resources have been committed to identify and study a variety of features in southeastern New Mexico interpreted to have been caused by dissolution. The subsurface distribution of halite for various units has been mapped. Several differing surface features have been attributed to dissolution of salt or karst processes. The processes proposed or identified include point-source (breccia pipes), "deep" dissolution, "shallow" dissolution, and karst. The categories are not well defined. Nonetheless, as discussed in the following sections, dissolution is not considered a threat to isolation of waste at the WIPP.

2.7.6.2.1 Brief History of Project Studies

Well before the WIPP project, several geologists recognized that dissolution is an important process in southeastern New Mexico and that it contributed to the subsurface distribution of halite and to the surficial features. These include Lee,[117] Maley and Huffington,[118] and Olive.[119] Robinson and Lang[56] identified an area under Nash Draw where brine occurred at about the stratigraphic position of the upper Salado–basal Rustler and considered that salt had been dissolved to produce a dissolution residue. Vine[60] mapped Nash Draw and surrounding areas, reporting on various dissolution features. Vine[60] reported surficial domal structures later called "breccia pipes" and identified them as deep-seated dissolution and collapse features.

As the USGS and Oak Ridge National Laboratory (ORNL) began to survey southeastern New Mexico as an area in which to locate a repository site in salt, Brokaw et al.[90] prepared a summary of the geology that included solution and subsidence as significant processes in creating the features of southeastern New Mexico. Brokaw et al.[90] also recognized a solution residue at the top of salt in the Salado,[56] and the unit commonly became known as the "brine aquifer" because it yielded brine in the Nash Draw area. Brokaw et al.[90] also interpreted the east-west decrease in thickness of the Rustler to be a consequence of removal of halite and other soluble minerals from the formation by dissolution.

During the early 1970s, the basic ideas about shallow dissolution of salt (generally from higher stratigraphic units and within a few hundred feet of the surface) were set out in a series of reports by Bachman, Jones, and collaborators.[120,78,84,39,90] Piper[121,122] independently evaluated the geological survey data for ORNL. Claiborne and Gera[123] concluded that salt was being dissolved too slowly from the near-surface units to affect a repository for several million years, at least.

By 1978, shallower drilling around the WIPP site to evaluate potash resources was interpreted by Jones,[65] and he felt the Rustler included "dissolution debris, convergence of beds, and structural evidence for subsidence." Halite in the Rustler has been re-evaluated by Snyder[66] and Powers,[67] but there are only minor differences in distribution among these sources. These investigators have different explanations about how this distribution occurred (see section 2.7.3.5 on Rustler stratigraphy): through extensive dissolution of the Rustler's halite after the Rustler was deposited, or through syndepositional dissolution of halite from saline mudflat environments during Rustler deposition.[49]

Under contract to Sandia, Anderson re-evaluated halite distribution in deeper units, especially the Castile and Salado formations. He identified local anomalies proposed as features developed after dissolution of halite by water circulating upward from the underlying Bell Canyon. In response to Anderson's developing concepts, ERDA-10 was drilled south of the WIPP area during the latter part of 1977.[101] ERDA-10 is interpreted to have intercepted a stratigraphic sequence without evidence of solution residues in the upper Castile.[124] Anderson et al.[24] mapped geophysical log signatures of the Castile and interpreted lateral thinning and change from halite to non-halite lithology as evidence of lateral dissolution of deeper units (part of "deep dissolution"). Anderson[26,27] considered that deep dissolution might threaten the WIPP site.

A set of annular, or ring, fractures is evident in the surface around San Simon Sink,[125] about 18 miles (30 kilometers) east of the WIPP site. Nicholson and Clebsch[125] suggested that San Simon Sink developed as a result of deep-seated collapse. WIPP-15 was drilled at about the center of the sink to a depth of about 811 feet (245 meters) to obtain samples for paleoclimatic data and stratigraphic data to interpret collapse.[126] Anderson[101] and Bachman[81] both interpret San Simon Sink as dissolution and collapse features, and the annular fractures are not considered evidence of tectonic activity.

Following the work by Anderson, Bachman mapped surficial features in the Pecos Valley, (especially at Nash Draw), and differentiated between surface features in the basin which were formed by karst, and deep collapse features over the Capitan reef, WIPP-32, WIPP-33, and two boreholes over the Capitan reef were eventually drilled. Their data, which demonstrated the concepts proposed by Bachman, are documented in Snyder and Gard.[127]

A final program concerning dissolution and karst was initiated following a microgravity survey of a portion of the site during 1980.[128] Based on localized low-gravity anomalies, Barrows et al.[128] interpreted several areas within the site as locations of karst. WIPP-14 was drilled during 1981[129] at a low-gravity anomaly. It revealed normal stratigraphy through the zones previously alleged to be affected by karst. As a followup, Bachman[85] also re-examined surface features around the WIPP and concluded there was no evidence for active karst within the WIPP site. The nearest karst feature is northwest of the site boundary at WIPP-33 and is considered inactive.

2.7.6.2.2 Extent of Dissolution

Within members of the Rustler, the margins of halite have been mapped by differing methods, summarized by Beauheim.[67] There are few differences in interpretations, despite the different methods used (Figure 2.7-7). Lower members of the Rustler are halitic west of the site, and higher members generally show halite only further east. Snyder[66] interprets these margins as a consequence of post-depositional dissolution of halite. Holt and Powers[49] interpret sedimentary structures within the Rustler mudstone as being equivalent to halite in order to indicate that most halite was removed during the depositional process and redeposited in a salt pan in the eastern part of the depositional basin.

Upper intervals of the Salado thin dramatically west and south of the WIPP site (Figures 2.7-16 and 2.7-17) compared to deeper Salado intervals (Figure 2.7-18). There are no cores for further consideration of possible depositional variations. As a consequence, this margin is interpreted as the edge of dissolution of the upper Salado.

2.7.6.2.3 Timing of Dissolution

The dissolution of Ochoan-Epoch evaporites through the near-surface processes of weathering and groundwater recharge has been studied extensively.[26,130,131,40,49] The work of Lambert (1983a)[130] was specifically mandated by the DOE's agreement with the State of New Mexico in order to evaluate, in detail, the conceptual models of evaporite dissolution proposed by Anderson.[26] There was no clear consensus of the volume of rock salt removed. Hence, estimates of the instantaneous rate of dissolution vary significantly. Dissolution may have taken place as early as the Ochoan, during or shortly after deposition. For the Delaware Basin as a whole, Anderson[26] proposed that up to 40 percent of the rock salt in the Castile and Salado formations was dissolved during the past 600,000 years. Lambert[131] suggested that in many places the variations in salt-bed thicknesses inferred from borehole geophysical logs that were the basis for Anderson's calculation were depositional in origin, compensated by thickening of adjacent non-halite beds, and were not associated with the characteristic dissolution residues. Borns and Shaffer[23] also suggested in 1985 a depositional origin for many apparent structural features attributed to dissolution.

Snyder,[66] together with earlier workers (e.g., Vine,[60] Lambert,[131] Bachman[40]), attributes the variations in thickness in the Rustler, which crops out in Nash Draw, to post-depositional evaporite dissolution. Holt and Powers[49] have challenged this view and attribute the east-to-west thinning of salt beds in the Rustler to depositional facies variability rather than post-depositional dissolution. Bachman[78,84,81] envisioned several episodes of dissolution since the Triassic, each dominated by greater degrees of evaporite exhumation and a wetter climate, interspersed with episodes of evaporite burial and/or a drier climate. Evidence for dissolution after deposition of the Salado and before deposition of the Rustler along the western part of the Basin was cited by Adams.[59] Others have argued that the evaporites in the Delaware Basin were above sea level and therefore subject to dissolution, during the Triassic, Jurassic, Tertiary, and Quaternary periods. Because of discontinuous deposition, not all of these times are separable in the geological record of southeastern New Mexico. Bachman contends that dissolution was episodic during the past 225 million years as a function of regional base level, climate, and overburden.

Some investigators have reasoned that wetter climate accelerated the dissolution. Various estimates of middle Pleistocene climatic conditions have indicated that climate was more moist during Gatuña time than during the Holocene. An example of evidence of mass loss from dissolution since Mescalero time (approximately 500,000 years ago) is found in displacements of the Mescalero caliche as large as 180 feet (55 meters) in collapse features in Nash Draw. However, given the variations in Pleistocene climate, it is unrealistic to apply a calculated average rate of dissolution, determined over 500,000 years ago, to shorter periods, much less extrapolate such a rate into the geological future.

There have been several attempts to estimate the rates of dissolution in the basin. Bachman[78] provided initial estimates of dissolution rates in 1974 based on a reconstruction of Nash Draw relationships. Though these rates indicate no hazard to the WIPP related to Nash Draw dissolution, Bachman later reconsidered the Nash Draw relationships and concluded that pre-Cenozoic dissolution had also contributed to salt removal. Thus the initial estimated rates were too high. Anderson[101] concluded in 1978 that the integrity of the WIPP to isolate radioactive waste would not be jeopardized by dissolution within about 1 million years. Anderson and Kirkland[132] expanded on the concept of brine density flow proposed by Anderson[101] in 1978 as a means of dissolving evaporites at a point by circulating water from the underlying Bell Canyon. Wood et al.[133] examined the mechanism and concluded that, while it was physically feasible, it would not be effective enough in removing salt to threaten the ability of the WIPP to isolate TRU waste.

There is local evidence that Cenozoic dissolution occurred at the same time that part of the Gatuña was being deposited in the Pierce Canyon area. Nonetheless, there is no indicator that the rates of dissolution in the Delaware Basin are sufficient to affect the ability of the WIPP to isolate TRU waste.

2.7.6.2.4 Features Related to Dissolution

Bachman[81] separated breccia pipes, formed over the Capitan reef by dissolution and collapse of a cylindrical mass of rock, from evaporite karst features that appear similar to breccia pipes. There are surficial features, including sinks and caves, in large areas of the basin. Nash Draw is the result of combined dissolution and erosion. Within the site boundaries, there are no known surficial features due to dissolution or karst.[85]

South of the WIPP site, there is a clear relationship between a subsurface structure on the Culebra (Figure 2.7-19) and dissolution. Salt has been removed from the underlying Salado to create a general anticline from near Laguna Grande de la Sal to the southeast. Beds generally dip to the east, and salt removed to the west created the other limb of the structure. Units below the evaporites do not apparently show the same structure.

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ERA	PERIOD	EPOCH	YEARS DURATION	YEARS BEFORE PRESENT	MAJOR GEOLOGICAL EVENTS – SOUTHEAST NEW MEXICO REGION
CENOZOIC	Quartenary	Holocene	10,000		Eolian and erosion/solution activity. Development of present landscape.
		Pleistocene	1,590,000	1,600,000	
	Tertiary	Pliocene	3,700,000		Deposition of Gatuna fan sediments. Formation of caliche caprock.
		Miocene	18,400,000		Regional uplift and east–southeastward tilting; Basin–Range uplift of Sacramento and Guadalupe–Delaware Mountains.
		Oligocene	12,900,000		Erosion dominant. No Early to Mid–Tertiary rocks present.
		Eocene	21,200,000		
		Paleocene	8,600,000	66,400,000	Laramide "revolution" Uplift of Rocky Mountains. Mid tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		77,600,000	144,000,000	Submergence intermittent shallow seas. Thin limestone and clastics deposited.
	Jurassic		64,000,000	208,000,000	Emergent conditions. Erosion, formation of rolling terrain. Deposition of fluvial clastics.
	Triassic		37,000,000	245,000,000	Erosion. Broad flood plain develops.
PALEOZOIC	Permian		41,000,000	286,000,000	Deposition of evaporite sequence followed by continental red beds. Sedimentation continuous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		34,000,000	320,000,000	Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		40,000,000	360,000,000	Regional tectonic activity accelerates, folding up Central Basin platform, Matador arch, ancestral Rockies. Regional erosion. Deep, broad basins to east and west of platform develop.
	Devonian		48,000,000	408,000,000	Renewed submergence. Shallow sea retreats from New Mexico; erosion. Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Penninsula emergent until Middle Mississippian.
	Silurian		30,000,000	438,000,000	
	Ordovician		67,000,000	505,000,000	Marathon–Quachita geosyncline, to south, begins subsiding. Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform and carbonates.
	Cambrian		65,000,000	570,000,000	Clastic sedimentation – Bliss sandstone.
	PRECAMBRIAN				Erosion to a nearly level plain. Mountain building, igneous activity, metamorphism, erosional cycles.

2303.1

Figure 2.7-1, Major Geologic Events - Southeastern New Mexico Region

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
RECENT	RECENT		SURFICIAL DEPOSITS	
QUATERNARY	PLEISTOCENE		MESCALERO CALICHE	
			GATUNA	
TERTIARY	MID-PLIOCENE		OGALLALA	
TRIASSIC		DOCKUM	SANTA ROSA	
PERMIAN	OCHOAN	DELAWARE MOUNTAIN	DEWEY LAKE	
			RUSTLER	Forty-niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				Unnamed
			SALADO	Upper
				McNutt Potash Zone
				Lower
	GUADALUPIAN		CASTILE	
			BELL CANYON	
			CHERRY CANYON	
			BRUSHY CANYON	

2304.1

Figure 2.7-2, Site Geological Column

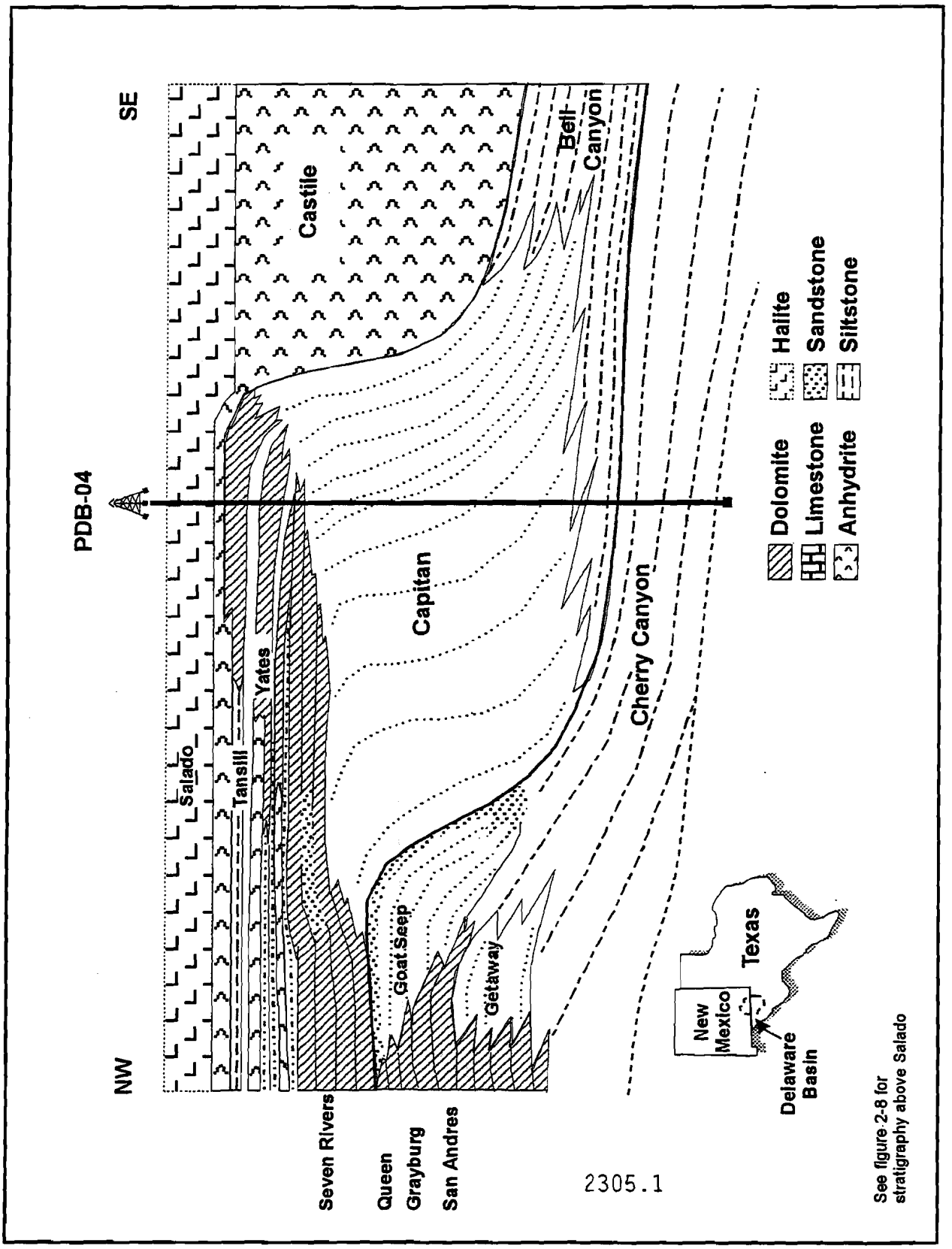


Figure 2.7-3, Cross-Section from Delaware Basin (SE) Through Marginal Reef Rocks to Back-reef Facies

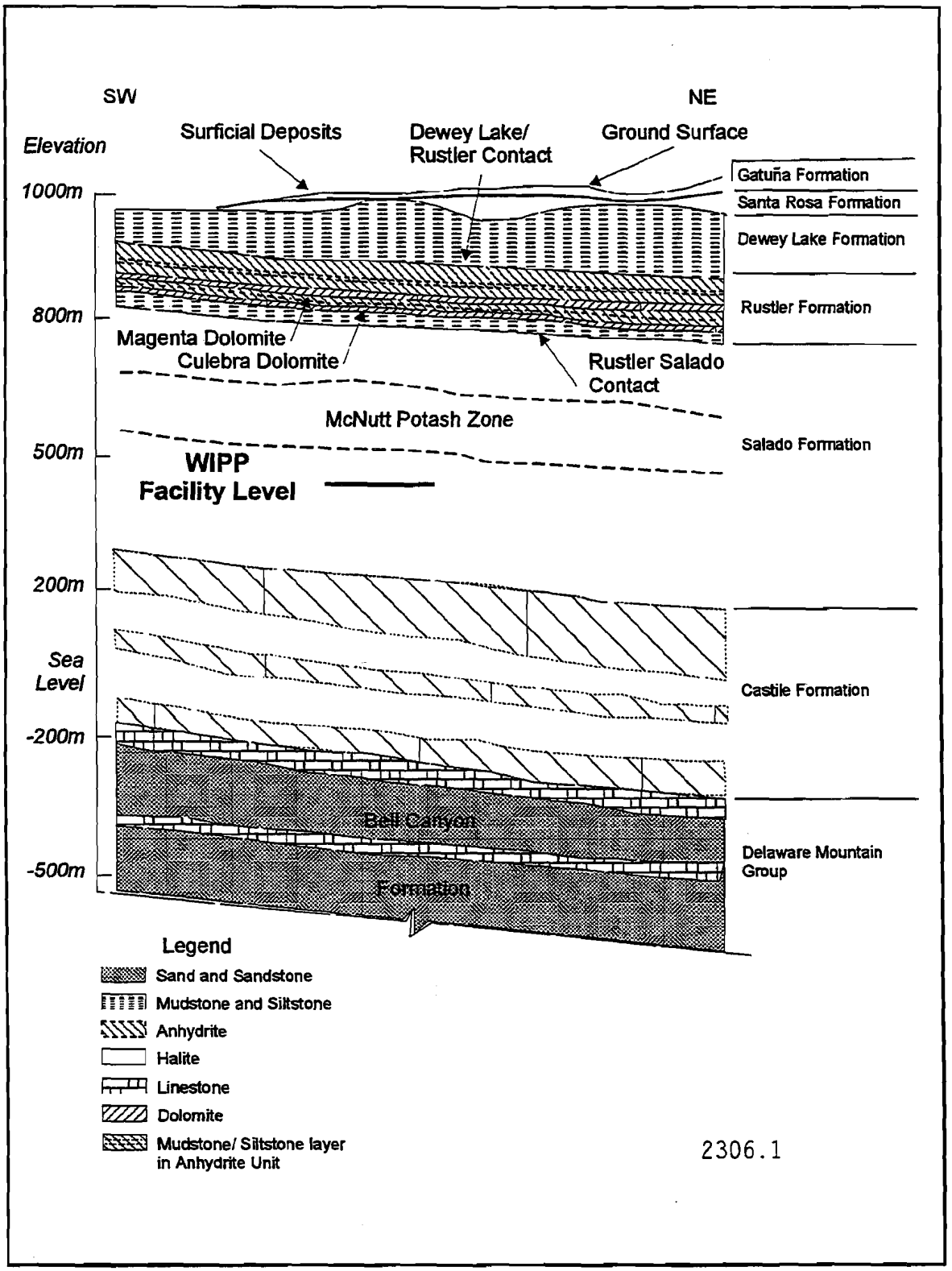


Figure 2.7-4, Generalized Stratigraphic Cross-Section Above Bell Canyon Formation at the WIPP Site

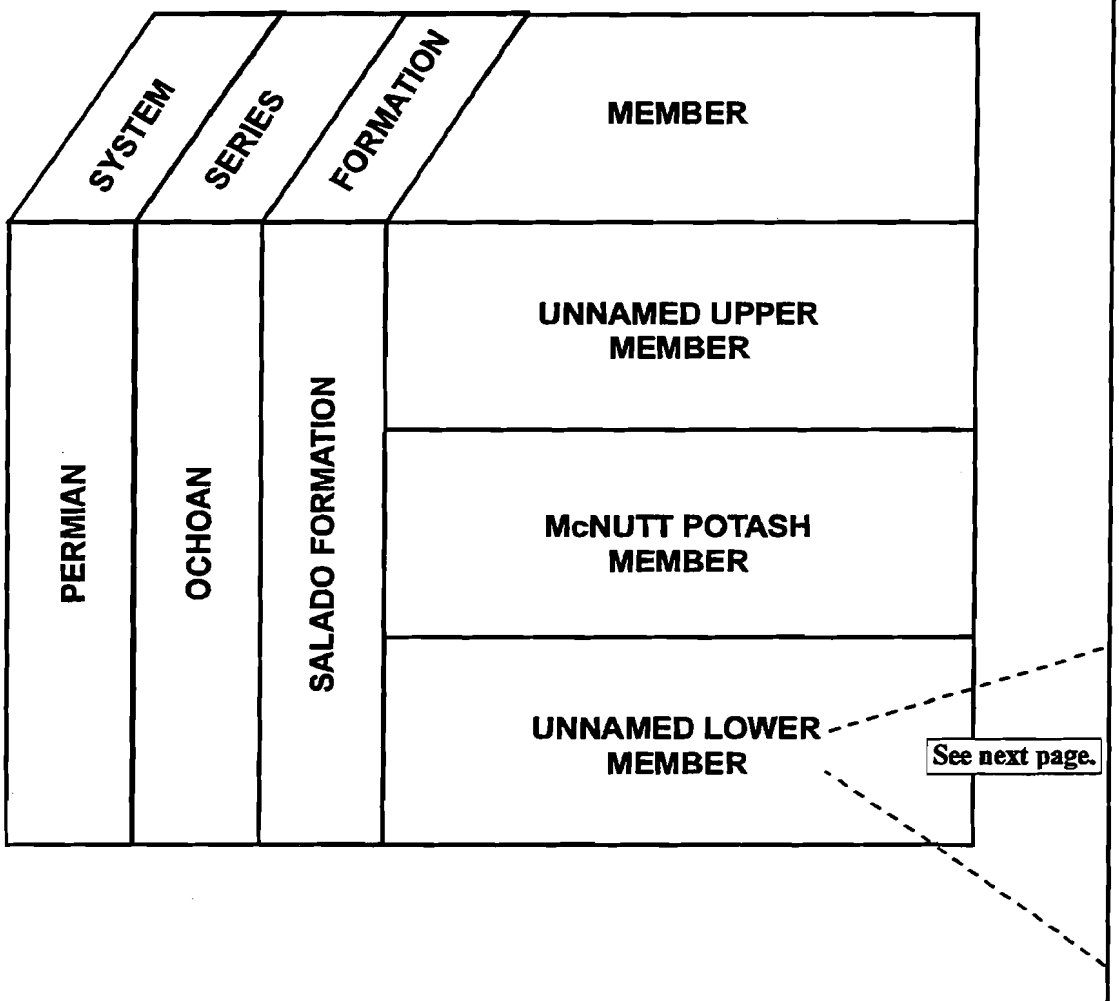


Figure 2.7-5a, Salado Stratigraphy

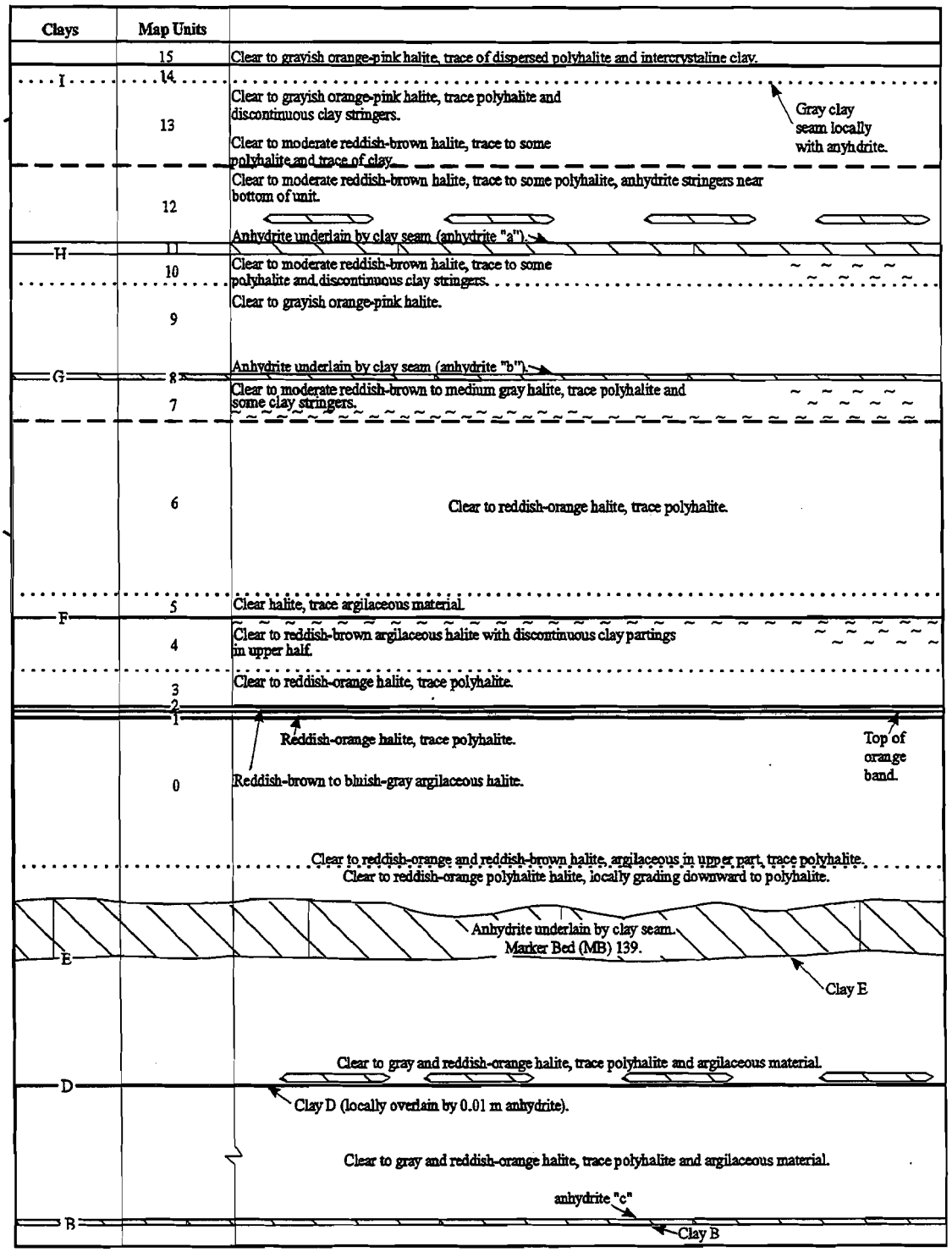
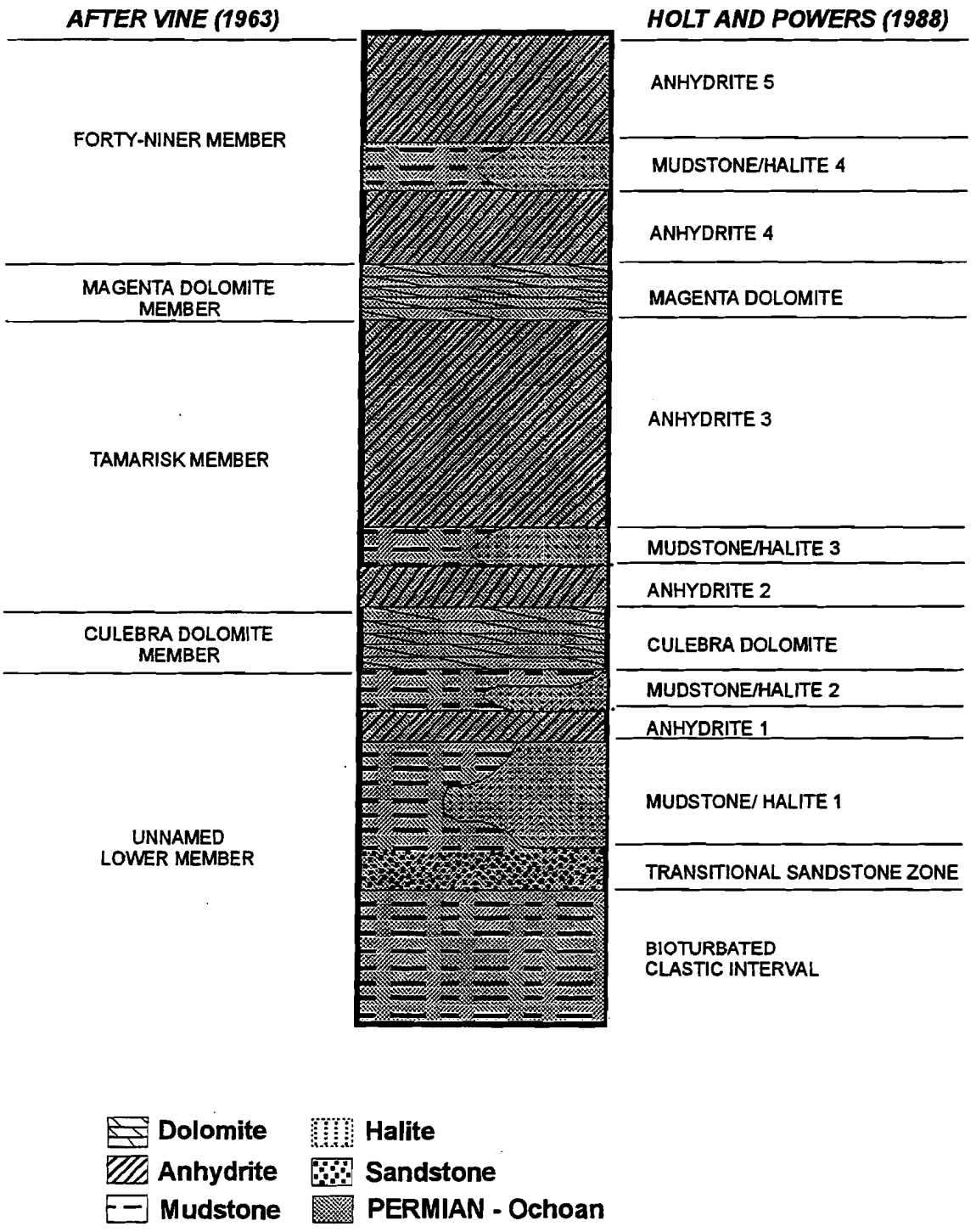


Figure 2.7-5b, Salado Stratigraphy - Detail of Unnamed Lower Member



Modified from Holt & Powers, 1988

Figure 2.7-6, Rustler Stratigraphy

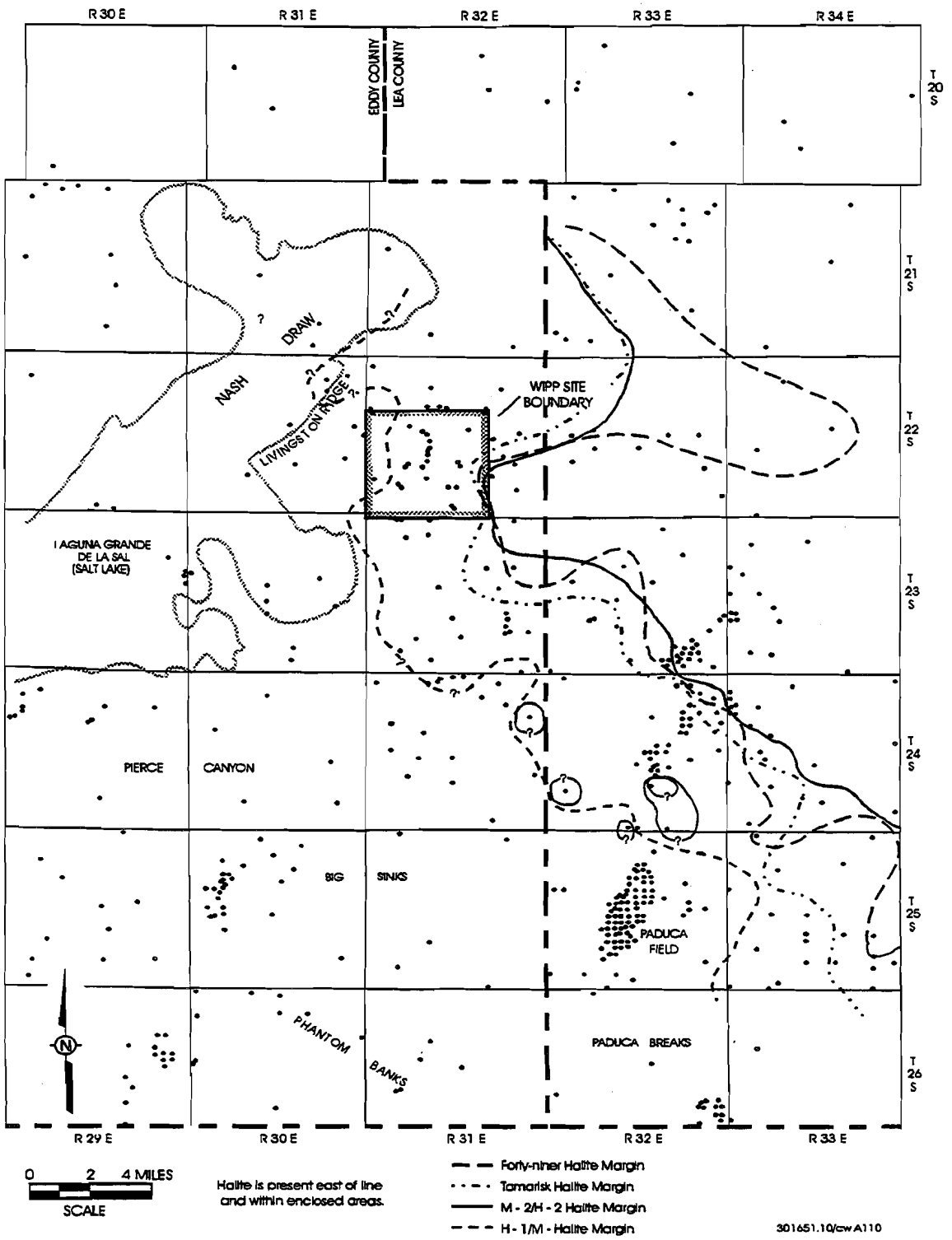


Figure 2.7-7, Halite Margins in Rustler

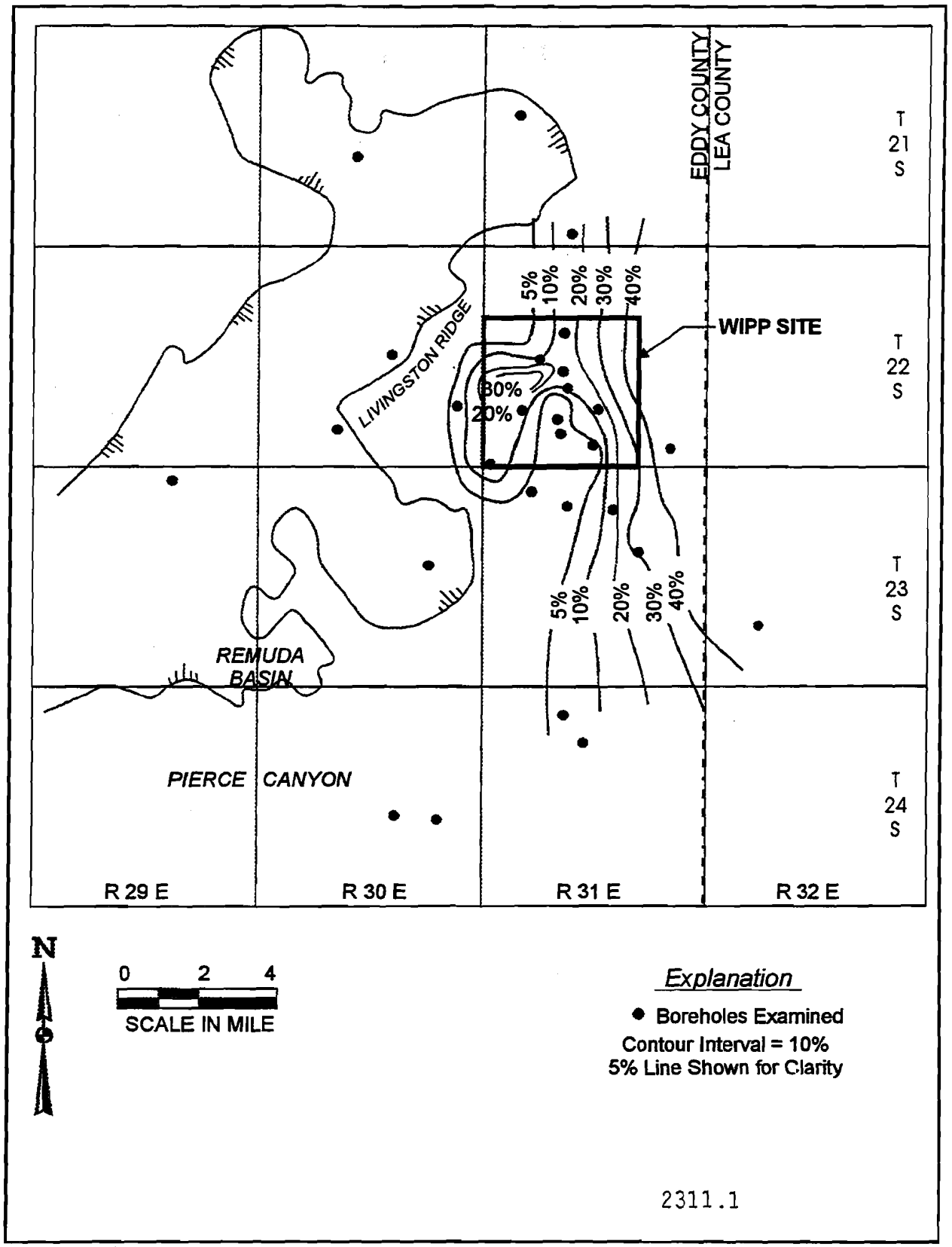


Figure 2.7-8, Percentage of Natural Fractures in Culebra Filled with Gypsum

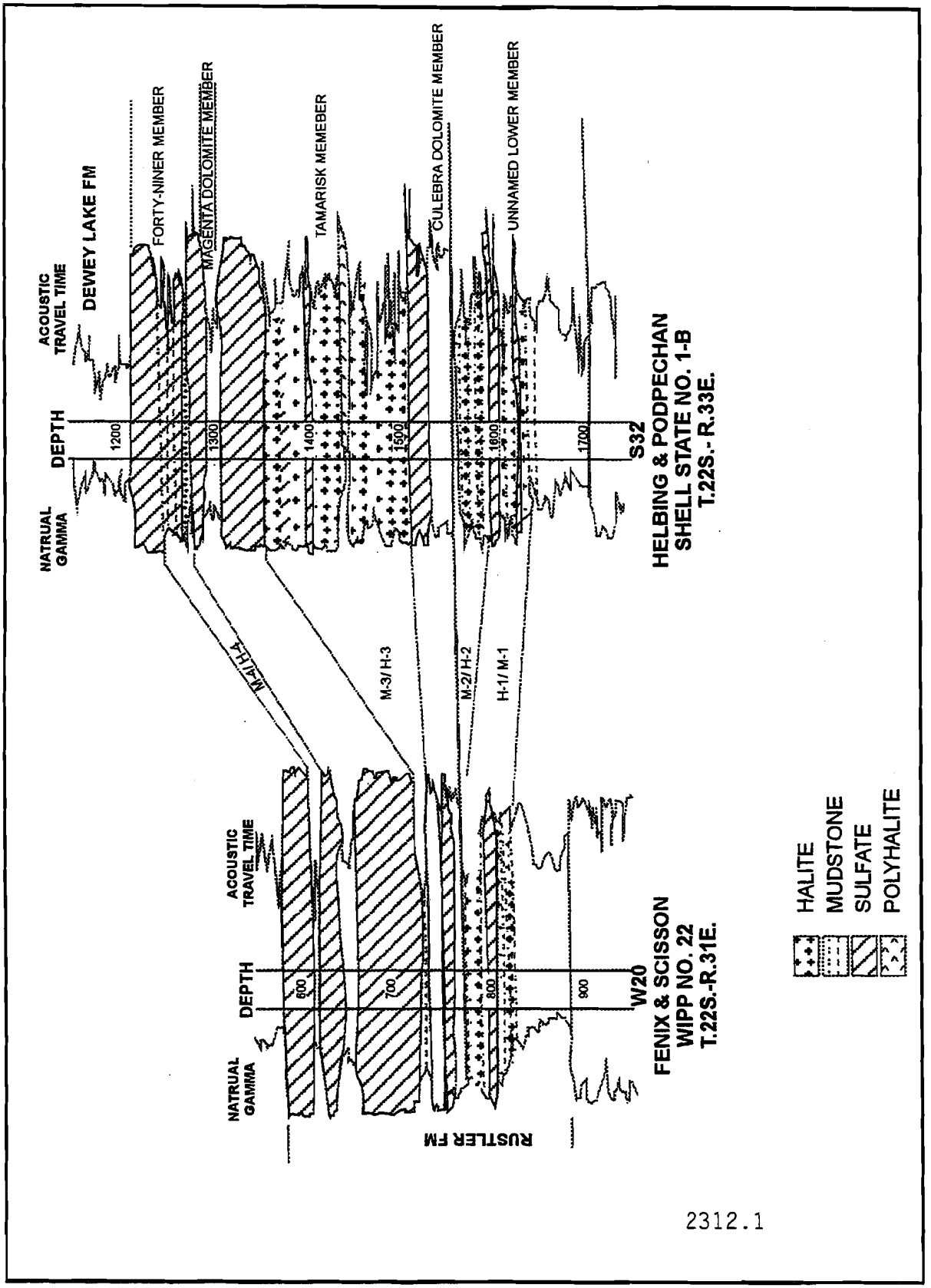


Figure 2.7-9, Log Character of Rustler Formation Showing Mudstone-Halite Lateral Relationships

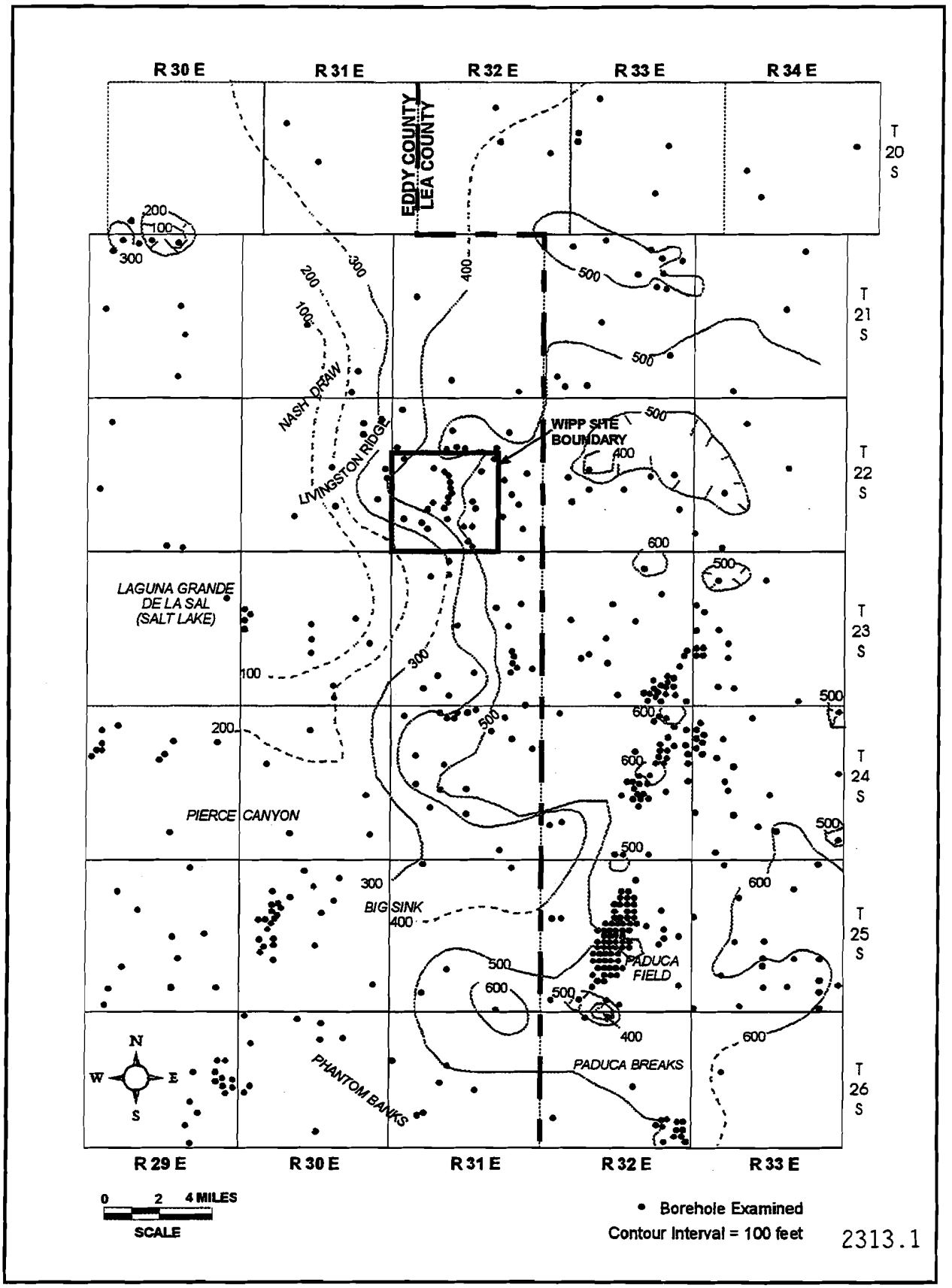


Figure 2.7-10, Isopach of the Dewey Lake Formation

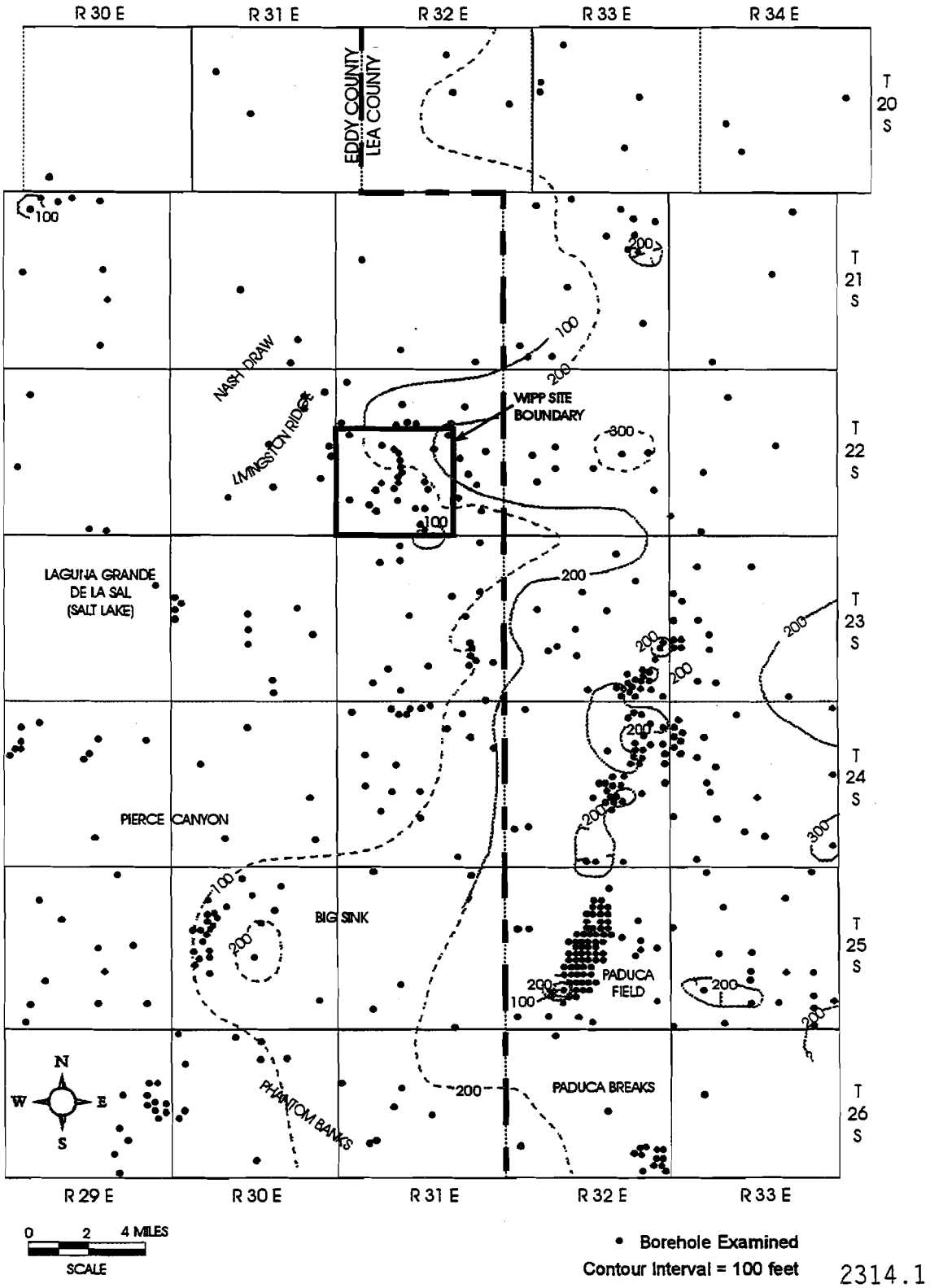


Figure 2.7-11, Isopach of the Santa Rosa

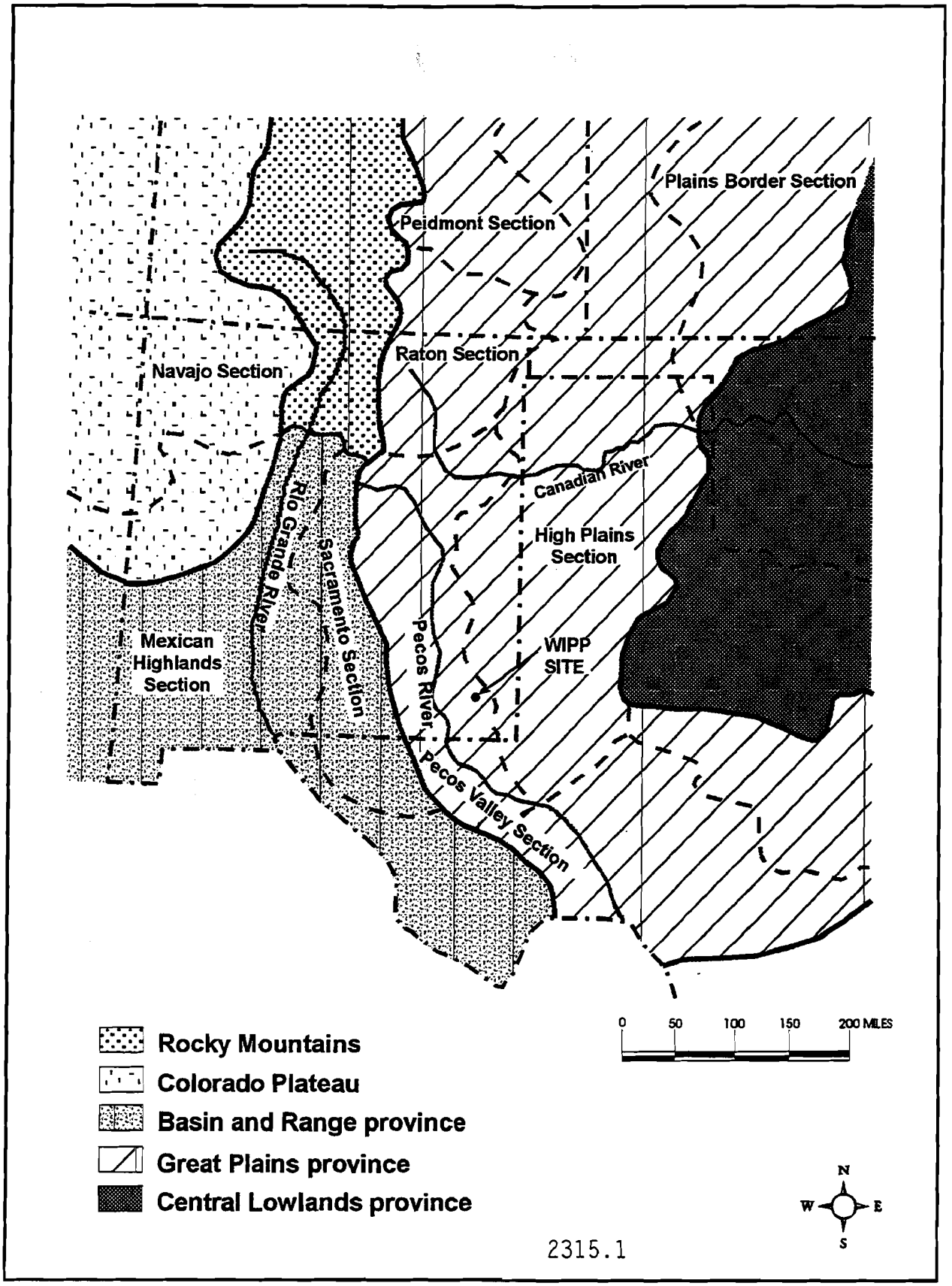


Figure 2.7-12, Physiographic Features of the Northern Delaware Basin

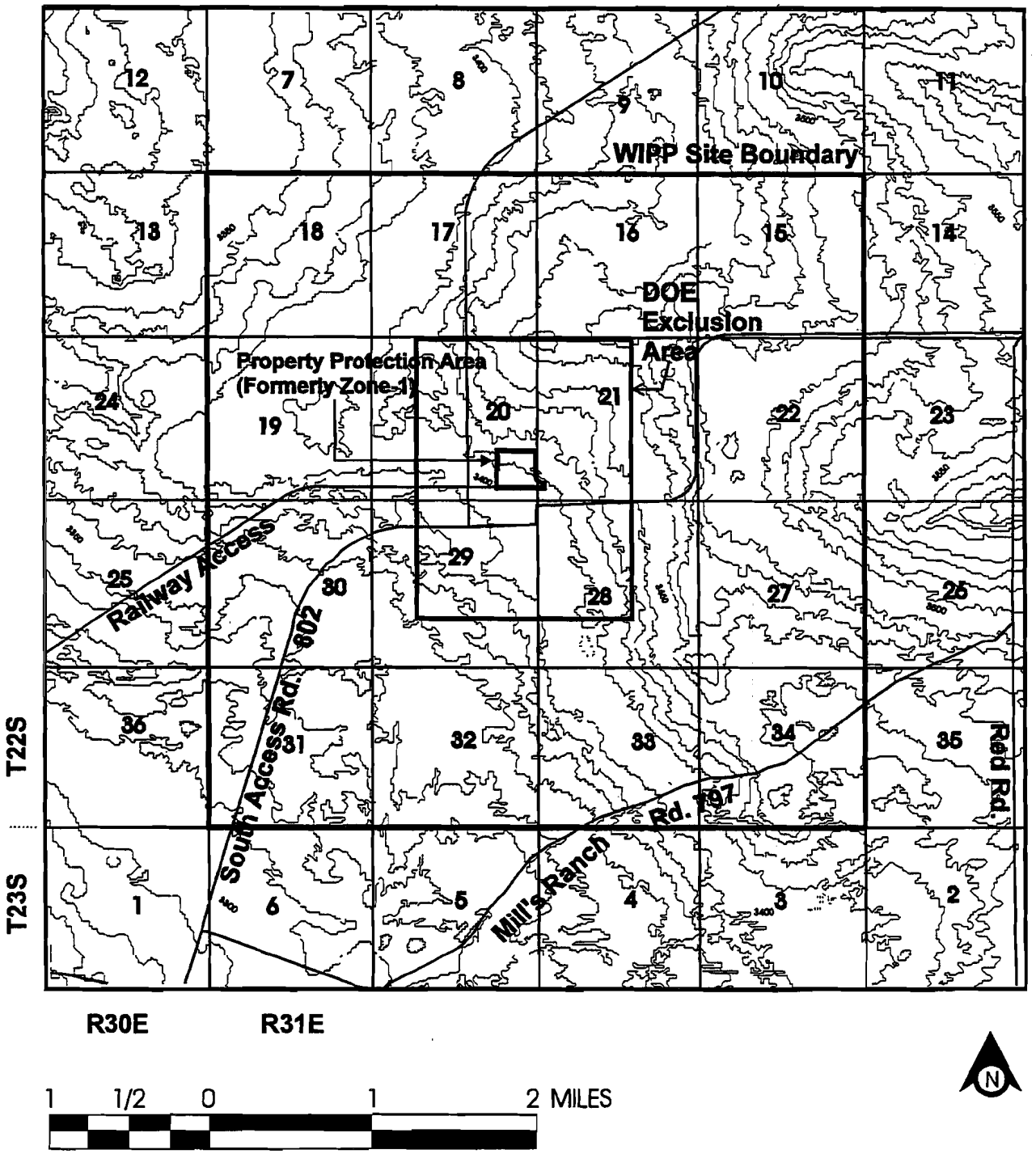


Figure 2.7-13, Site Topographic Map

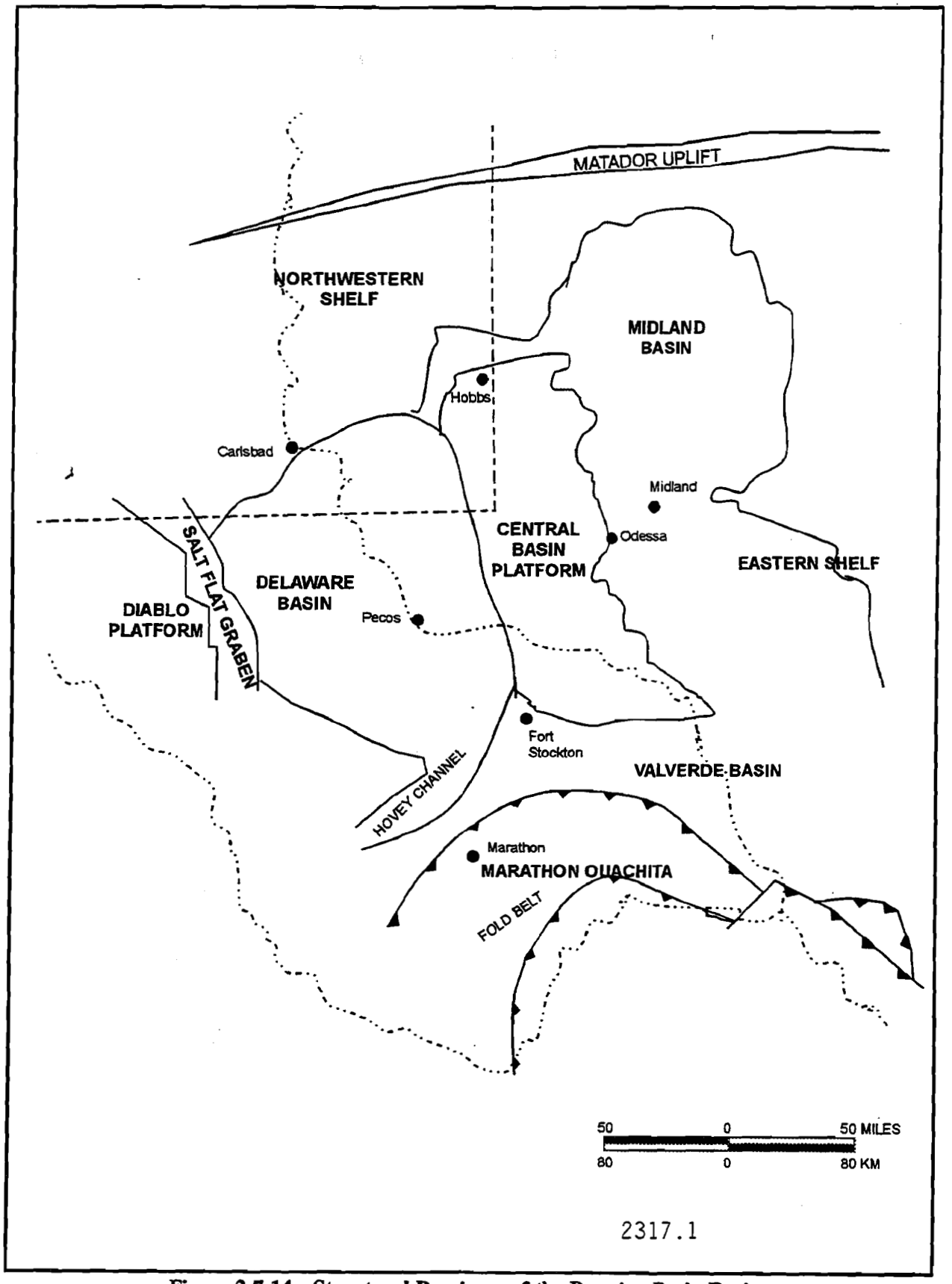


Figure 2.7-14, Structural Provinces of the Permian Basin Region

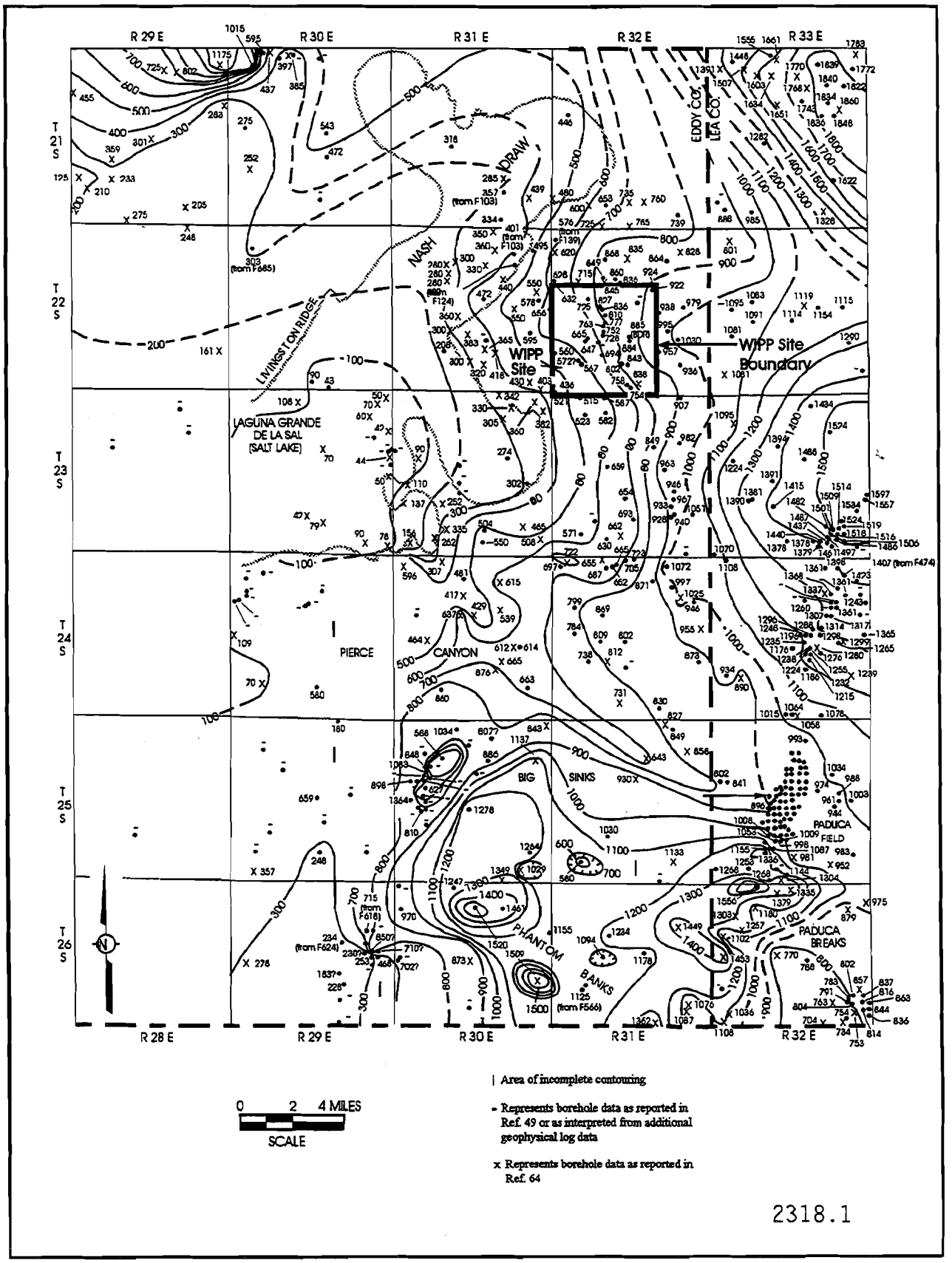


Figure 2.7-15, Depth to the Base of the Culebra

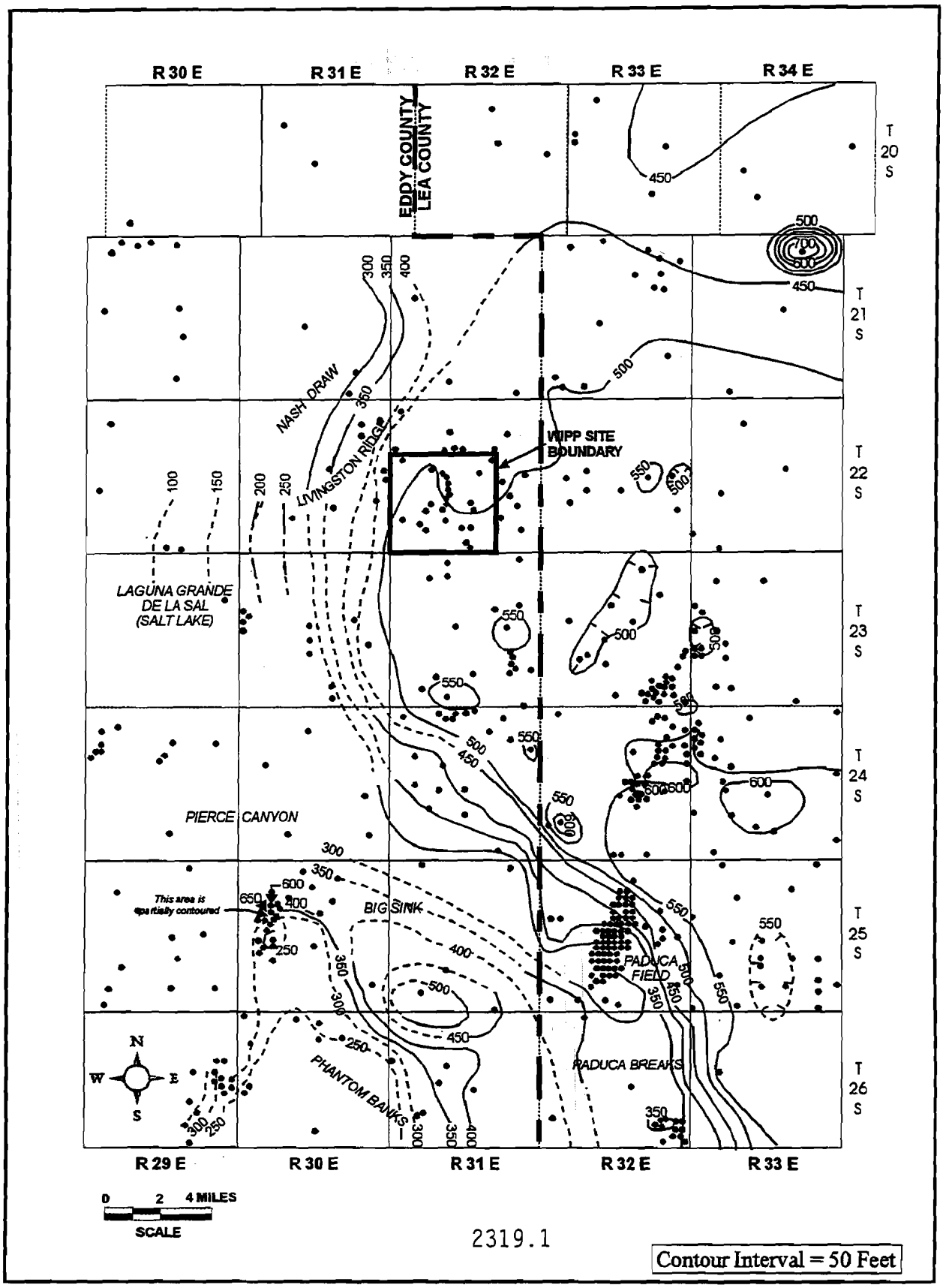


Figure 2.7-16, Isopach from the top of the Vaca Triste to the top of the Salado

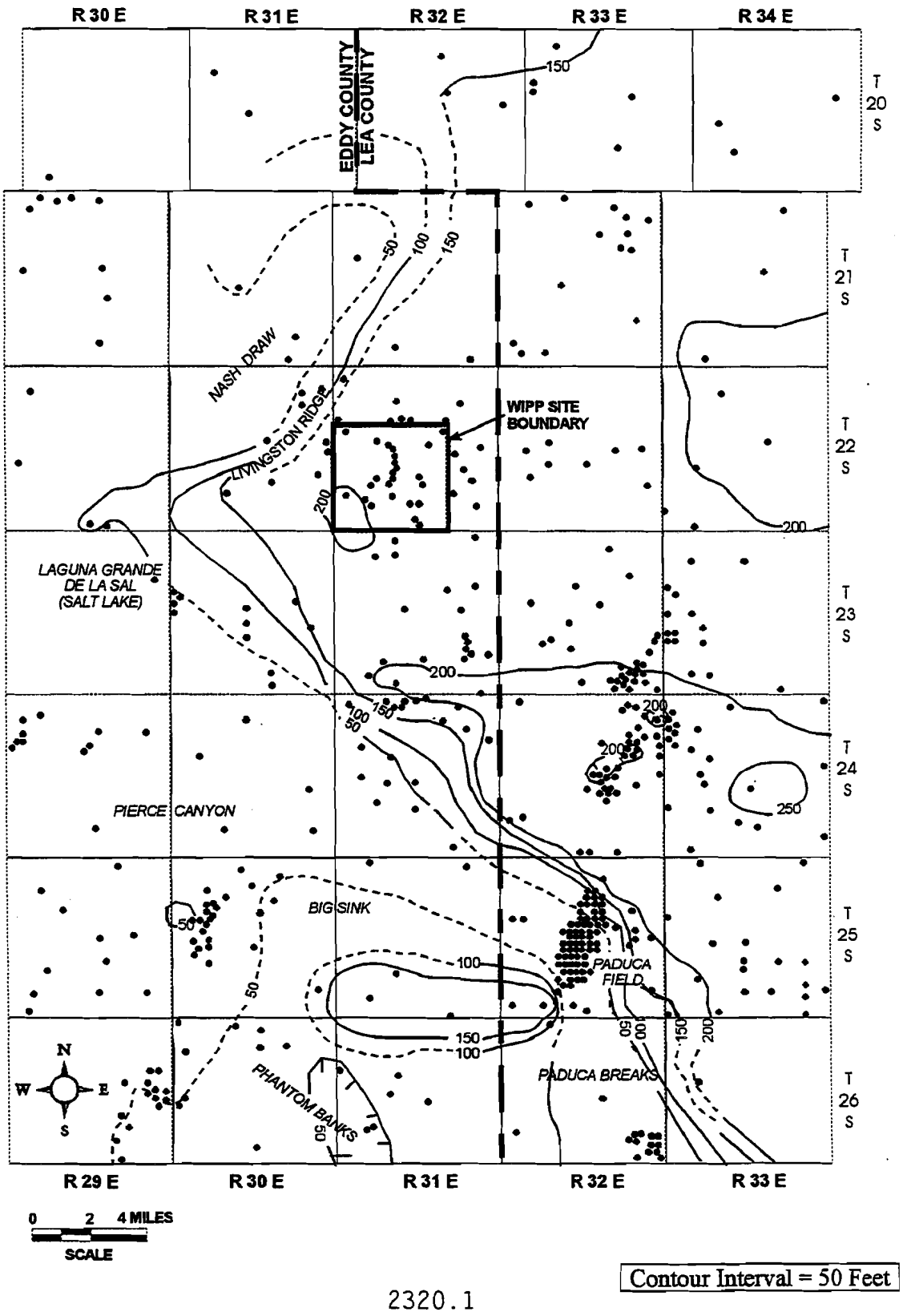


Figure 2.7-17, Isopach from the Base of MB 103 to the Top of the Salado

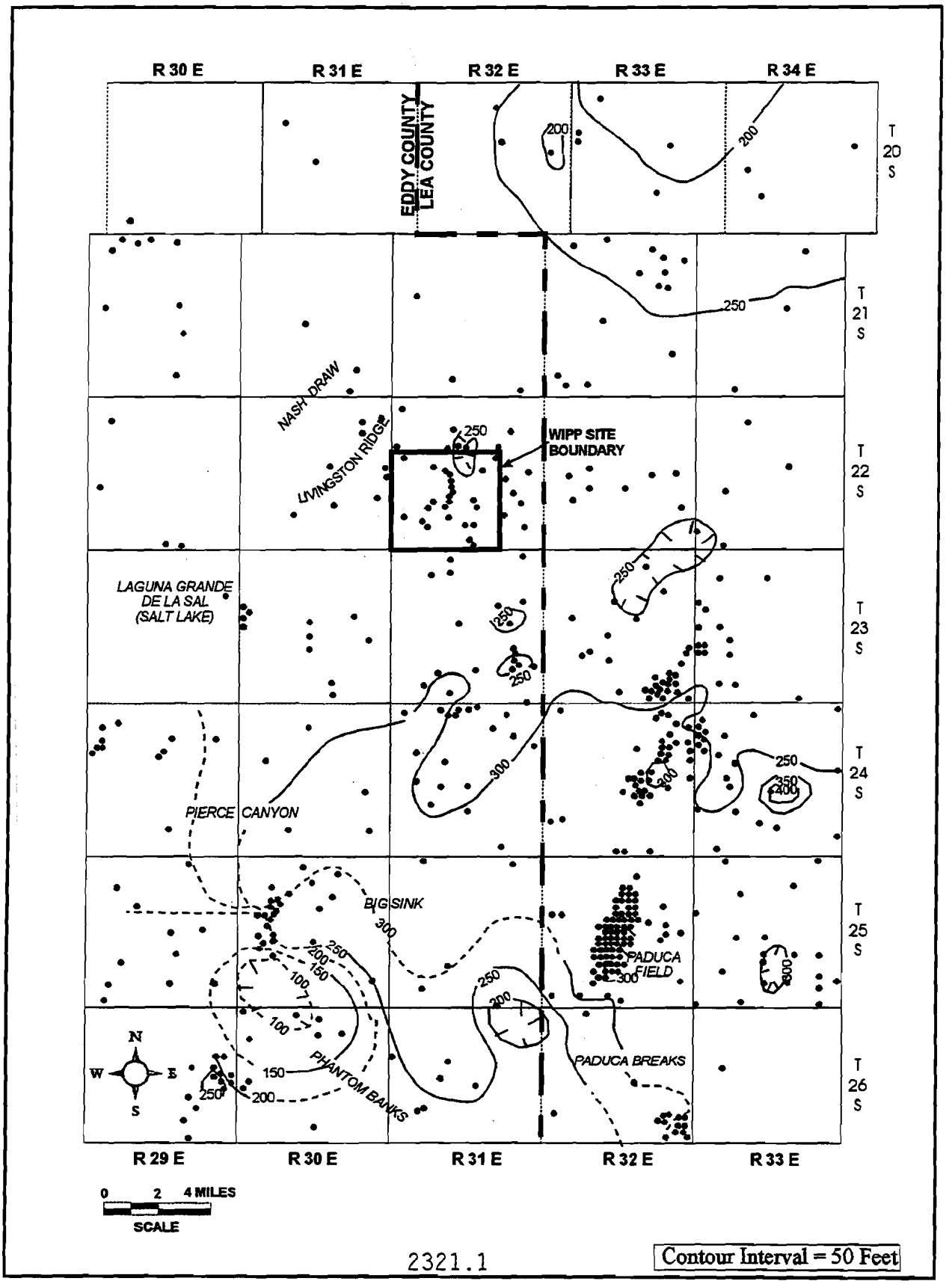


Figure 2.7-18, Isopach from the Base of MB 123/124 to the Vaca Triste

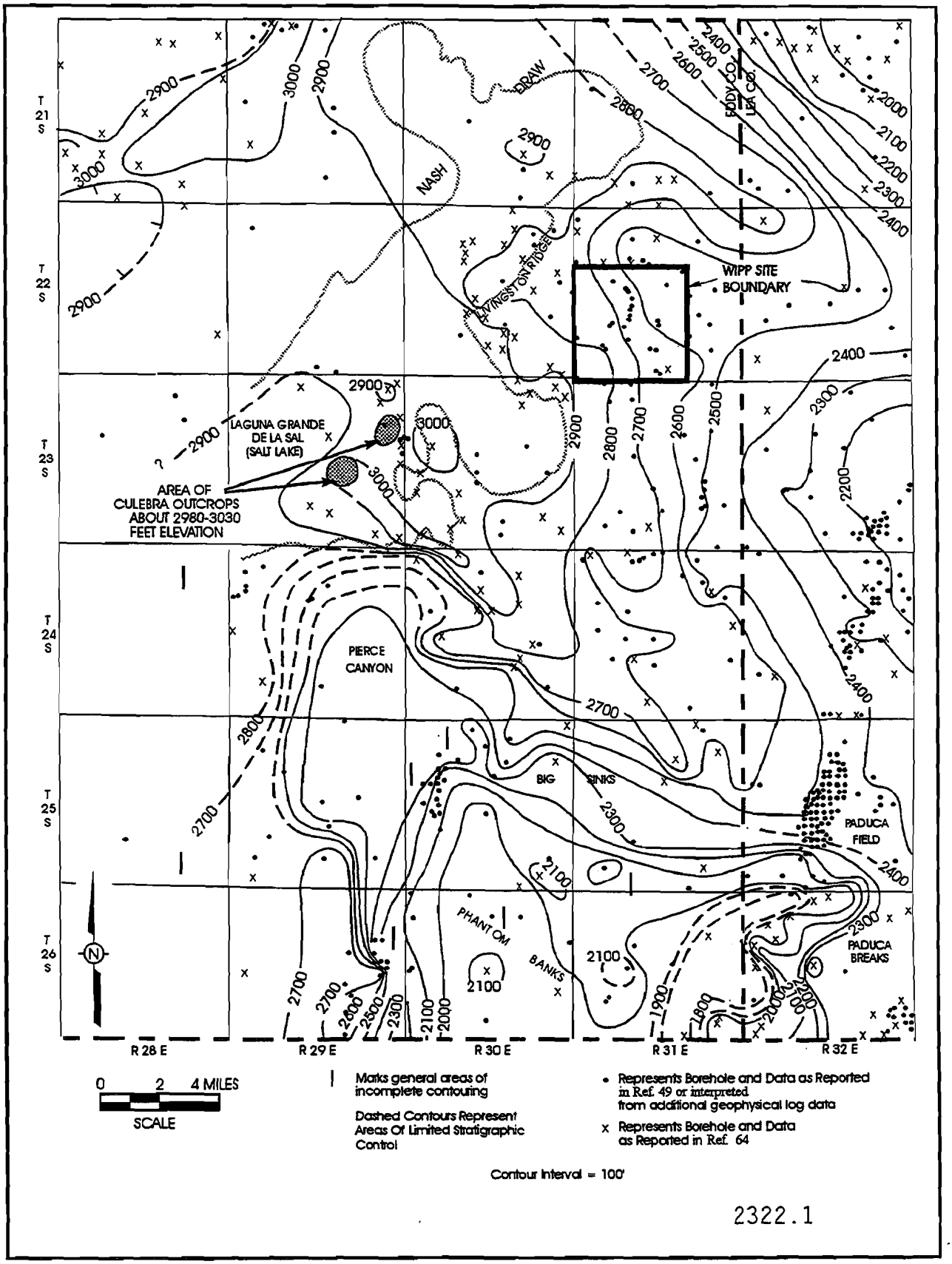


Figure 2.7-19, Structure Contour Map of Culebra Dolomite Base

2.8 Vibratory Ground Motion

This section is directed towards establishing the seismic design basis for vibratory ground motion directly applicable to Design Class I and II confinement structures and components at the WIPP facility. The application of the results contained in this section to seismic design of plant facilities is discussed in Section 3.2.7. This presentation is aimed at conservatively estimating the Design Basis Earthquake (DBE) for the WIPP site facility.

The approach used in this analysis is to develop a probabilistic peak acceleration to be used in design. This peak acceleration is derived from a correlation between historical earthquake activity and various active geologic structures and tectonic provinces. These results are used to establish the site's DBE in Section 2.8.5.

2.8.1 Seismicity

In this section, data are presented for earthquakes within 180 miles of the WIPP facility. This area is defined as the WIPP facility region for this discussion. The information for the WIPP facility region earthquakes before 1962 is based on chronicles of the effects of those tremors on people, structures and land forms (called macroseismic evidence). Virtually all information on earthquakes occurring after the beginning of 1962 in the WIPP facility region is derived from instrumental data recorded at various seismograph stations.

2.8.1.1 Pre-1962 Earthquake Data

Most earthquakes reported in New Mexico before 1962 occurred in the Rio Grande Valley area between Albuquerque and Socorro, a distance of more than 300 kilometers from the WIPP site. About half of the earthquakes of Modified Mercalli Intensity (MMI) V or greater in New Mexico between 1868 and 1973 were in this region. In conformity with previous studies,[1,2,3] those events are not of immediate concern to this study. There has been one earthquake associated with moderate to considerable damage (intensity VIII) prior to 1962 within the WIPP facility region. The Valentine, Texas earthquake of 1931, occurred about 120 miles south-southwest of the location of the WIPP facility. The area within 120 miles of the WIPP facility has experienced only low-intensity earthquakes (intensity V or less).

Figure 2.8-1 shows locations of earthquakes occurring before 1962 within 300 kilometers of the WIPP site. These epicenters were assigned on the basis of macroseismic evidence and are also listed in Table 2.8-1. Supplemental descriptive material for most of those events is provided primarily by Sanford and Toppozada1[1] and other sources,[4,12] provided in Appendix 2D. All intensities listed in Table 2.8-1 are Modified Mercalli Intensities.[13] An abridged version of this scale is presented in Table 2.8-2.

The Valentine, Texas earthquake of August 16, 1931 was large enough to generate significant interest so that much more data are available for that event. A number of isoseismal maps were compiled soon after its occurrence.[5,14] Recently, Sanford and Toppozada assigned MMI on the basis of descriptions of the effects of this event and plotted the resulting isoseismal map reproduced in Figure 2.8-2. Several features of this plot are noteworthy. First, according to Figure 2.8-2, the intensity location of the WIPP facility from this earthquake was V. Second, isoseismal lines close to the zone of the highest intensity are elongated northwest-southeast conforming to the structural integrity of the region.

Two instrumental locations have been published for the Valentine, Texas earthquake. The United States Coast and Geodetic Survey (USCGS) places the epicenter at 29.9N and 104.2W with an origin time of 11:40:15 Greenwich Mean Time (GMT).[5] Byerly[15] made a detailed instrumental investigation of that earthquake and found the epicenter to be 30.9N and 104.2W with an origin time of 11:40:21 GMT. Byerly's[15] epicenter, 66 miles north of the USCGS epicenter, is somewhat closer to the region of highest reported intensity and may for this reason be considered the more accurate of the two.[1] These two instrumental epicenters are plotted in Figure 2.8-2. Although neither of these instrumental locations is particularly close to Valentine, Texas, the USCGS and Byerly epicenters bracket the area of maximum reported intensity fairly well. For the purposes of Figure 2.8-1, Valentine, Texas has been adopted for the location of both the main earthquake and its aftershocks in agreement with Sanford and Toppozada.[1]

The area over which an earthquake is perceptible can be used to estimate its magnitude.[16,17] If a felt area of 4.5×10^5 mi^2 is accepted as reported by the USCGS,[6] and a magnitude felt area formula for the central United States and Rocky Mountain region is used,[17] a magnitude of about 6.4 is calculated for the Valentine, Texas earthquake. This result is compatible with the maximum intensity reported for the shock[1] and is the same as the magnitude for this event calculated at Pasadena, California.[18]

2.8.1.2 Comprehensive Listing of Earthquakes From All Studies - January 1, 1962 through September 30, 1986

Presented in Table 2.8-3 is a listing of earthquake origin times, locations, and magnitudes, based on instrumental data gathered and analyzed by a number of different organizations. The listing is for earthquakes within the WIPP facility region for the 24 3/4 year interval from January 1, 1962 through September 30, 1986. The organization providing the earthquake parameters listed in the table is identified by an X in the appropriate column. Organizations providing data for the table were as follows:

- New Mexico Institute of Mining and Technology (NMT)
- U.S. Geological Survey (USGS)
- Los Alamos National Laboratory (LANL)
- Albuquerque Seismological Laboratory (ASL)
- University of Texas at Austin (UTA)
- University of Texas at El Paso (UTEP).

2.8.1.2.1 Magnitudes

Recent seismic events occurred at WIPP on January 2, 1992 and April 13, 1995. These events had magnitudes of 5.0 and 5.4 respectively. The January 2, 1992 Rattlesnake Canyon Earthquake had an epicenter located 60 kilometers east southeast of the WIPP site. The Rattlesnake Canyon Earthquake and the April 13, 1995 earthquake had no effect on any of the structures at WIPP, as documented by post event inspections by the WIPP staff and the New Mexico Environment Department. These events were within the parameters used to develop the seismic risk assessment of the WIPP structures (Section 2.8.5). The Rattlesnake Canyon event likely was techtonic in origin based on a 7 +/- mile (12+/- km) depth. (Ref Part B Permit Application, Rev. 5, Section D6-4 Seismicity page D6-66)

Up to August 1981, NMT calculated magnitudes differently than other organizations. As a result, systematic differences in calculated magnitudes were observed. In Table 2.8-3, all magnitudes calculated by organizations other than NMT were modified by applying corrections. In all cases, these modifications reduced the reported magnitude by amounts ranging from 0.3 to 0.5.

After August 1981, NMT started using a magnitude scale based on the duration (t_D) of the recorded signal from onset of the P phase to when the trace amplitude approaches background noise. The equation used,

$$M_D = 2.79 \log t_D - 3.63$$

was derived by LANL researchers[31] and determined to be equivalent to the Richter local magnitude scale for earthquakes in northern New Mexico. Ake and Sanford[28] established that the LANL formula can be applied to earthquakes in central New Mexico which fall in the local magnitude range of 1.1 to 4.2. A careful study of the applicability of the formula to earthquakes in southeastern New Mexico and west Texas has not been made.

However, random comparisons between magnitudes calculated from the amplitude of S_g (Shear Wave) and duration of ground motion in the time period 1962 to 1974 indicate general consensus good agreement (within 0.3 magnitude units) between the two methods.

Most recurrence formulas in Section 2.8.4.2 are based on the earthquake data set included in Table 2.8-3, but at lower magnitudes. Therefore, the latest listing of events within the WIPP facility region does not require an upward revision in earthquake risk or the DBE.

2.8.1.2.2 Completeness of the Earthquake Data Set

From January 1, 1962 to April 5, 1974, events in the WIPP facility region were located by readings from stations generally several hundred miles from the epicenter. On April 5, 1974, a single station (CLN) was established near the center location of the WIPP facility which continued operation to September 1980. These stations are plotted in Figure 2.8-3. From November 1975 to late 1979, a seismograph array was in operation near Kermit, Texas. These are shown in Figure 2.8-4.

A small network of stations centered in the Davis Mountains of West Texas was operated by the UTA from July 1977 to July 1978. No stations were running near the location of the WIPP facility from shutdown of station CLN in September 1980 to startup of a three station network in August 1982. The WIPP seismograph network was not fully operational until March 1983.

The histograms in Figure 2.8-5 illustrate how the shifts in instrumentation affected the completeness of the earthquake data set presented in Table 2.8-3. The period from January 1, 1962 through September 30, 1986 was divided into eight time intervals of 1130 days, and the number of events greater than 3.0, 2.5, 2.0, and 1.5 were determined for each interval. The first four intervals (from January 1, 1962 through May 17, 1974) cover the period prior to installation of any stations at, or near the location of the WIPP facility. The fifth and sixth intervals (from May 18, 1974 through July 24, 1980) cover the period when station CLN, the Kermit array, and the UTA networks were in operation. Most of the seventh interval (from July 25, 1980 to August 28, 1983) covers the period between shutdown of station CLN and startup of the WIPP seismographic network. During the last interval (from August 29, 1983 through September 30, 1986) the WIPP array was fully operational.

The histogram in Figure 2.8-5 for events with M3.0 (upper left) suggests a complete data set of this magnitude level. The greatest number of events (6) occurred during the second interval (from February 4, 1965 through March 9, 1968), a period when no seismograph was operating within 135 miles of the location of the WIPP facility except station FOTX during the first 67 days of the interval. (Station FOTX was located 72 miles southeast of the WIPP facility). The least number of earthquakes occurred in the first, third, and eighth intervals. The WIPP seismographic network was fully operational during the eighth interval, but no seismic instrumentation within 135 miles of the location of the WIPP facility existed during the first and third intervals except station FOTX (in operation the last 228 days of the first interval). Because the number of observed quakes with M3.0 does not correlate with the presence or absence of instrumentation at or near the WIPP facility, the data set is believed to be complete at that strength level. If the data set is complete, then the variations in activity observed in the histogram represent true temporal changes in the activity rate for earthquakes with M3.0.

In the lower two histograms of Figure 2.8-5, the period of maximum instrumentation is even more clearly defined by the increase in numbers of earthquakes during the fifth and sixth time intervals. In summary, the general shape of the histograms relative to temporal changes in instrumentation indicates the data set is probably complete above magnitude 2.7, and that it becomes progressively less complete at lower magnitudes.

2.8.1.2.3 Recurrence Interval Formulas

Many studies have demonstrated a linear relation between the logarithm of the cumulative number of earthquakes (N) and the magnitude (M), i.e.,

$$\log N = a - bM.$$

The values of the constants "a" and "b" are derived from existing earthquake data by plotting log N versus M and performing linear regression on those points that fall above the minimum magnitude where the data set is complete. The formulas obtained in this manner can be extrapolated to determine the recurrence interval for the maximum probable earthquake in the region. Section 2.8.4.2 describes in some detail how these relations can be used in establishing risk and ultimately the DBE.

Shown in Figures 2.8-6 and 2.8-7 is a log N versus M plot for the combined time periods from January 1, 1962 through September 30, 1986. Seismographs were not in operation near the WIPP facility from July 24, 1980 to August 29, 1983. Linear regression for data points greater than magnitude 1.9 yields the recurrence equation,

$$\log N = 4.05 - 1.01\ M.$$

The value of "b," 1.01, is three percent less than the obtained by Sanford et al.[3] (1.04) using data for the 3 1/4 year period, April 1974 through June 1977. The "a" values cannot be compared because (1) the magnitudes in Table 2.8-3 are on the average approximately 0.4 less than those listed in Sanford et al.,[69] (2) the time period is approximately three times greater here than in Sanford et al,[3] and (3) the degree of activity at the M2.0 strength level was not as great in later periods as it was from April 1974 through June 1977 (see histograms in Figure 2.8-5).

2.8.1.2.4 Geographic Distribution of Earthquakes

Table 2.8-3 differs in another important way from earlier listings of earthquakes within 180 miles of the WIPP facility. All but a few shocks in the table have epicenters determined by the algorithm HYPO 71 Revised,[29] rather than by the circle-arc method. The locations from the latter method were retained only when a satisfactory solution could not be obtained from HYPO 71.[29] Inclusion of crustal shear wave (Sg) arrival time readings in the HYPO 71[29] program probably makes it superior to the circle-arc method.

The accuracy of locations in Table 2.8-3 depends on many variables: the number, distance, and distribution of stations providing readings for the solution, and the quality of crustal compressional wave (Pg) and Sg phases picked. For the events that occurred within or near arrays of stations, primarily during the period April 1974 through September 1980, the accuracy of locations is reliable. However, for most of the earthquakes during the 24 3/4 year period, the locations depended on readings from stations several hundred kilometers away, falling in a narrow azimuthal range relative to the epicenter. The error in location under these circumstances can be considerable. However, even in the worst case (generally earthquakes in the far southern and southeaster regions of the study area) the locations are believed to be within ± 25 kilometers.

Figure 2.8-8 is a map showing all epicenters listed in Table 2.8-3. The distribution of earthquake activity in this figure is compatible with the boundaries of source regions discussed in Section 2.8.4.1. On the basis of the seismic activity, the eastern boundary of the Rio Grande rift source zone can be placed at the boundary proposed by Algermissen and Perkins[32] or at the alternate boundary proposed in Section 2.8.4.1. The later boundary is clearly less well-defined by seismic activity than the Algermissen and Perkins boundary.

All boundaries proposed for the Central Basin Platform (CBP) in Section 2.8.4.1 are generally compatible with the distribution of earthquake activity in Figure 2.8-8, but none are totally satisfactory. The earthquake epicenters in the vicinity of the CBP appear to require enlargement of the source zone to the southwest and contraction to the east and northeast. The nearest approach of CAP seismicity to the WIPP site appears to be east of boundaries proposed by Algermissen and Perkins[32] and those suggested by geologic and tectonic consideration.

Figure 2.8-9 is a map showing epicenters from Table 2.8-3 that fall in the time period April 5, 1974 through October 6, 1978. To some extent, the maps presented in Figures 2.8-8 and 2.8-9 distort the distribution of seismic activity. Detection of smaller quakes in the data set was variable in space and time as a result of changes in the numbers and distribution of seismograph stations. To avoid this problem, Figure 2.8-10 shows only epicenters for earthquakes with $M \geq 2.5$, a cut-off level only slightly below the magnitude at which the data set is believed complete.

The temporal variability of earthquake activity on the CAP and elsewhere within 180 miles of the WIPP facility is illustrated in Figures 2.8-11 through 2.8-18. Plotted in these figures are epicenters for events with M2.5 which occurred in eight sequential time periods, each of 1130 days duration from January 1, 1962 to September 30, 1986.

2.8.1.3 The Events of July 26, 1972 and November 28, 1974

Questions on tectonism and seismic activity very near or at the WIPP facility are of great interest. For this reason, the single most important seismic event to occur from January 1, 1962 through September 30, 1986 near the location of the WIPP facility is the earthquake at 03:35:30 GMT on November 28, 1974 (see Table 2.8-3 and Figure 2.8-3). That earthquake whose most recently estimated magnitude is 3.8, had an epicenter about 32±5 km northwest of station CLN.[3] If it is an indication of normal background seismicity in the immediate area, this event might cause a re-evaluation of previous estimates of seismic risk at the WIPP site by Sanford and Toppozada[1] who considered the likely principal sources of site vibratory ground motion to be a major earthquake to the west, no closer than about 70 miles, and a strong earthquake in the Central Basin Platform. Because of its potential importance, this event has attracted considerable notice. It was prominently mentioned in two studies[2,26] and was the main topic of another.[27]

The event of November 28, 1974 was located by the NMT at about 32.6N, 104.1W by using phase readings from six stations.

Independently, the USGS located this earthquake at 32.3N, 104.1W. Both solutions give virtually the same origin time. At the time of this earthquake, a rockfall and considerable ground cracking were reported at the National Potash Co. Eddy County Mine. The rockfall was located at 32.55N, 104.04W and occurred within about 1 min of the calculated earthquake origin time. In view of this rather remarkable coincidence, the question naturally arose whether the earthquake may have been induced somehow by the mining operations at that location. A simple calculation indicates that the earthquake could not have been caused by the mass and distance of fall of the material actually involved in the rockfall.[27] The issue was whether the cause of this event and of the rockfall was related to a nontectonic strain release such as might be associated with mine collapse in overlying mined-out areas at the Eddy County Mine, or whether both should be considered the result of a release of strain energy accumulated in association with a natural geologic process. Clearly, the epicentral uncertainty grossly implied by the different formal solutions found by the NMT and the USGS allowed actual spatial coincidence of rockfall and seismic disturbance. Therefore, it was decided that a more careful determination of location would be worthwhile.

As information was being collected for this redetermination effort, it was discovered that a rockfall had occurred previously at the Eddy County mine on July 26, 1972. A check of past seismograph records revealed that a seismic event had also been recorded at a number of regional seismograph stations. A subsequent location using these readings put this event at 32.6N, 104.1W and assigned a magnitude of $M_L = 2.8$. Thus, this event, although weaker, was found to be located very near the event of November 28, 1974, and a study of the individual station records indicated that its code was nearly identical to the later event. Since more records were available for the earlier event, it was decided that a detailed relocation effort would be attempted for that location first. The question of the nature of its source was still of primary concern.

Using a station-dependent model and a preferred origin time to accomplish the relocation, 95 percent confidence interval arcs were drawn from each station. The results are shown in Figure 2.8-19. As can be see, the intersecting arcs define a rather large area of about 1,900 km^2. Although the Eddy County mine lies very near this area, other locations within the same area have the same formal likelihood of being the epicentral location.

The seismic event on November 28, 1974 was not relocated in the same way. Instead, another fundamental question was asked. That is, could the two events, July 1972 and November 1974, have occurred at the same focus based on existing seismographic evidence. If the events had the same hypocenter, the differences in arrival times of specific phases at common stations should be the same for all stations. As may be seen from Table 2.8-3, this is not the case for the limited data set available. The interval between the smallest and largest time difference is 1.4 seconds.

Caravella and Sanford[27] believe that this interval is too large to be explained by reading errors. The time differences indicate, under this conclusion, that the two events did not have the same hypocenter, even though location uncertainties are such that one of the events may or may not have occured at the rock fall site. The time differences can be explained by locating the hypocenter of the November 28, 1974 event about 10 kilometers northwest or southwest of the shock on July 26, 1972.[27] At present, the best available analysis indicates that both of these small events did not occur at the Eddy County Mine nor were they caused by mining related phenomena at that location.

2.8.2 Geologic Structures and Tectonic Activity

A study of the WIPP facility region suggests a fundamental geologic and tectonic separation into two significantly different subregions: (1) the Permian Basin and (2) the Basin and Range subregions. The geologic structures and tectonism of the Permian Basin are dominantly associated with large-scale basin, interbasin and basin margin subsidence or emergence that occurred during the Paleozoic era. Basin and Range structures and tectonism to the west are those associated with Basin and Range topography. The activity characteristic of this subregion began in middle to late Tertiary time and is probably still occurring to some extent.

The Permian Basin subregion is defined as that part of the Permian Basin within the site region. The WIPP facility is slightly more than 60 miles from the western margin of the Permian Basin (Figure 2.8-20). The Permian Basin is a broad structural feature made up of a series of Paleozoic sedimentary basins whose last episodes of large-scale subsidence during late Permian time were associated with a thick accumulation of evaporites. This basin now exists as a subsurface structural feature extending roughly from the Amarillo uplift on the north to the Marathon thrust belt on the south and some 300 miles eastward from the Diablo platform and Sacramento and Guadalupe Mountain areas into west-central Texas.[33]

The development of the Permian Basin began with the formation of a broad sag (named the Tobosa basin[34]) following deposition of lower Ordovician strata. Prior to the late Mississippian, several periods of minor folding, faulting and uplift with erosion occurred. Nevertheless, general structural stability prevailed.[73,74,75] Subsequently, tectonic activity accelerated in the area climaxing in late Pennsylvanian and was split into two rapidly subsiding basins (the Midland to the east and the Delaware to the west) by the medial Central Basin Platform.[36] Structural development of the Permian Basin within this framework continued until late Permian when broad-scale basement stabilization occurred concurrently with evaporite deposition.

Thus, the major tectonic elements of the Permian Basin were completely formed before the deposition of Permian salt-bearing rocks, and relative crustal stability of the region has been maintained since Permian time. Since then, the Permian Basin has been characterized throughout the Mesozoic and Cenozoic eras by erosional processes interrupted by only minor episodes of terrestrial and shallow water deposition. Regionally, the Permian Basin has been tilted and warped, but deep-seated faults since Permian time are rare except along the western margin of the basin outside the area of salt preservation. In areas where salt is near the surface, such as southeastern New Mexico, there are no indication of younger deep-seated faulting and only a few isolated igneous intrusives of post-Permian age.[36]

The Basin and Range subregion is defined as that part of the Basin and Range physiographic province within the site region. As shown in Figure 2.8-20, this subregion borders the western margin of the Permian Basin subregion to the west and southwest of the site. The Basin and Range subregion is characterized by fault block mountain ranges, many of which are bounded on the west by major high-angle normal fault systems. Uplift along these fault systems has resulted in gentle eastward tilting of the mountain blocks and the formation of intermontane or graben-like valleys. Major development of these characteristic structural features occurred from late Tertiary into early Pleistocene time.[73,74,75] Continued tectonism in the Basin and Range subregion is suggested by widely scattered Quaternary fault offsets on the order one to several meters. A number of fault offsets of this age along the western flanks of the Guadalupe, Delaware, Sacramento and San Andres mountains are described in the literature.[37,45,73,74,75] More recently, additional but similar fault systems have been found and described within the Basin and Range physiographic province in Trans-Pecos, Texas.[46]

The different physiographies of the two site subregions, as defined and briefly described above, are closely related to their distinctive geologic histories and structural configurations. This is suggested by Figure 2.8-21 which shows the boundary between the great Plains and Basin and Range physiographic provinces.[73,74,75] For this reason, Figure 2.8-20 as a good approximation to the boundary between the Permian Basin and Basin and Range subregions as suggested by the geologic evidence just outlined.

The results of a 1978 leveling survey between El Paso, Texas and Carlsbad, New Mexico,[47] are consistent with this geologically suggested regional separation. Comparison of this survey with previous leveling surveys along the same route carried out in 1934, 1943 and 1958, indicates that the Diablo Plateau region of Trans-Pecos, Texas (in the Basin and Range subregion as defined above) has been uplifted approximately 4 to 5 centimeters during this interval in archlike fashion in relation to the end points of the survey. Extending east from El Paso, the leveling route traverses Basin and Range subregion-type structures including the Hueco Basin, the Hueco Mountains, the Diablo Plateau, the Salt Basin and the Guadalupe Mountains before terminating on the High Plains in the Permian Basin subregion near Carlsbad. The observed relative uplift correlates well with the broad aspects of the tectonic evolution of the Diablo Plateau. The observed elevation changes are most easily attributed to deep-seated tectonic activity.[47]

The observed movements along the El Paso - Carlsbad line are not the largest in the area. Movements along the Roswell-Pecos line, which is entirely within and near the western margin of the Permian Basin region, are larger (Figure 5 of Reference 65). However, the movements on this route, which runs g a railroad near the Pecos River, are probably dominated by artificial water withdrawal.[70,71] Carlsbad appears to be relatively "inactive" with respect to Roswell, which is located well outside regions of known neotectonic activity.[47]

In summary, the WIPP facility region leveling data are consistent with the geologic evidence in that they suggest current tectonic activity in the Basin and Range subregion and current stability in the Permian Basin subregion. Because current tectonic activity implies crustal movement that in turn implies elastic strain accumulation and release, earthquakes are often considered a barometer of tectonic activity. The occurrence of more frequent and larger earthquakes is thus consistent with a higher level of tectonism.

Earthquakes occurring between 1923 and 1979 and between April 1974 and February 1979 are superimposed on the suggested site subregions in Figures 2.8-20 and 2.8-22, respectively. From Figure 2.8-20 it may be seen that most pre-instrumental and a substantial proportion of 1962 to 1977 instrumental earthquakes are located in the Basin and Range subregion. In the Permian Basin subregion, an important cluster of instrumental epicenters occurs on the Central Basin Platform, and a thin scattering of both instrumental and pre-instrumental events appears throughout the rest of this subregion. In the case of pre-instrumental events in the WIPP facility region, this distribution of shocks may be at least partly controlled by a population density that has always been greatest along the Rio Grande rift (within the Basin and Range subregion). A somewhat similar pattern appears in Figure 2.8-22, although in this figure (for which the smaller magnitude events on the Central Basin Platform have been made recordable by the inclusion of data from station CLN at the location of the WIPP facility) the recent predominance of the Central Basin Platform in terms of the total number of recorded events is apparent. The largest recorded earthquake in the Basin and Range subregion is the 1931 Valentine, Texas event whose magnitude is estimated to be about 6.4. The largest event on the Central Basin Platform is of magnitude 3 to 4 depending upon precisely how magnitudes of events in these areas are calculated. The largest event in the Permian Basin subregion but, not on or near the Central Basin Platform, was the 16 June 1978 event near Snyder, Texas, at the extreme eastern margin of the site region. This event, discussed further in Section 2.8.3, was about 4.7 in magnitude.

Based on 11 years of instrumental data (1962 - 1972 inclusive), analysis of earthquakes throughout New Mexico of magnitude greater than or equal to 2.5 (which are believed to have been uniformly located during this interval) indicates a roughly comparable level of earthquake activity in the inactive and in the active physiographic provinces.[2,28] This result must further qualify the confidence with which the modest differences in historical seismicity levels (in terms of number of events) in the (inactive) Permian Basin and (active) Basin and Range subregions can be argued to be significant.

Thus, in light of geologic evidence and consistent recent leveling survey data, the Basin and Range subregion, as shown in Figures 2.8-20 or 2.8-22, exhibits a higher level of recent tectonism than the Permian Basin subregion. This is supported by the maximum magnitude earthquakes occurring in these subregions during historical time. The distribution of all known site region earthquakes shows that, with the exception of the Central Basin Platform area, the Permian Basin subregion has experienced marginally fewer events than the Basin and Range subregion. A significant cluster of small events is located along the Central Basin Platform.

2.8.3 Correlation of Earthquake Activity with Geologic Structures or Tectonic Provinces

The best available evidence does not suggest that recorded earthquakes have been well correlated with faults anywhere in the WIPP facility region. This is true for both the surface faults of the Basin and Range subregion (a number of which show evidence of Quaternary movement) and for the geologically older subsurface faults in the Permian Basin subregion.

Although no earthquakes in the WIPP facility region are known to be correlated to specific faults, a substantial cluster of seismic activity has occurred on and near the Central Basin Platform since about the mid-1960s. The suggests division of the Permian Basin subregion into a Central Basin Platform portion and a background portion. The seismicity pattern leading to this suggestion is made fairly explicit in Figures 2.8-20 and 2.8-22. There is no known evidence of any differences since late Permian time in the geologic histories of the Central Basin Platform and surrounding portions of the Permian Basin (Sections 2.8.2). In addition, there does not appear to be enough data at present to convincingly determine the direction of tectonic forces and the type of faulting on the Central Basin Platform;[4] therefore, this information could not be used to distinguish the Central Basin Platform.

First Shurbet,[20] and later Sanford and Toppozada[1] and Rogers and Malkiel[23] suggested that Central Basin platform earthquakes are not tectonic but are instead related to water injection and withdrawal for secondary recovery operations in oil fields in the Central Basin Platform area. Such a mechanism for the Central Basin Platform seismic activity could provide a reason why the Central Basin Platform is separable from the rest of the Permian Basin on the basis of seismicity data but not by using other common indicators of tectonic character. Both the spatial and temporal association of Central Basin Platform seismicity with secondary recovery projects at oil fields in the area are suggestive of some cause and effect relationship of this type.[23]

In summary, the best available evidence does not suggest that known earthquakes are well correlated with faults in the WIPP facility region. A substantial number of earthquakes have occurred on and near the Central Basin Platform since about the mid-1960s. The cause of the spatial coincidence of recent seismicity with this buried large-scale Paleozoic structure is not known. With this exception, WIPP facility region earthquakes may be correlated with two tectonic provinces for the purposes of this study. The first is a relatively inactive province made up of the eastern and northeastern two-thirds (approximately) of the WIPP facility region (and encompassing the WIPP facility). The other WIPP facility region tectonic province is a relatively inactive province made up of the rest of the WIPP facility region. A simple and reasonable model of these two general WIPP facility region tectonic provinces is furnished by the Permian Basin/Basin and Range subregion characterization of Section 2.8.2.

2.8.4 Probabilistic Earthquake Potential

In recent years, several procedures have been developed that allow formal determination to be made of earthquake probabilistic design parameters[51,52] and a number of studies have been performed incorporating these procedures[32,53,54] In typical seismic risk analyses of this kind, the region of study is divided into seismic source areas within which future events are considered equally likely to occur at any location. For each seismic source area, the rate of occurrence of event above a chosen threshold level is estimated using the observed frequency of historical events. The sizes of successive events in each source are assumed to be independent and exponentially distributed; the slope of the log number versus frequency relationship is estimated from the relative frequency of different sizes of events observed in the historical data. This slope, often termed the b value,[25] is determined either for each seismic source individually or for all sources in the region jointly. Finally, the maximum possible size of events for each source is determined, using judgment and the historical record.[60] Thus, all assumptions underlying a measure of earthquake risk potential derived from this type of analysis are explicit, and a wide range of assumptions may be employed in the analysis procedure.

In this section, the particular earthquake risk parameter calculated is peak acceleration expressed as a function of annual probability of being exceeded at the WIPP site. The particular analysis procedure applied to the calculation of this probabilistic peak acceleration is taken from a computer program written by McGuire.[54] In that program the seismic source zones are modeled geometrically as quadrilaterals of arbitrary shape. Contributions to site earthquake risk from individual source zones are integrated into the probability distribution of acceleration, and the average annual probability of exceedence then follows directly. The theory and mechanics of McGuire's computer program may be found in a number of papers,[51,56,68] so they are not outlined here.

In the analysis, input parameters at each stage of the development are taken from the best conservative estimates. Where more than one good estimate exists, alternative values are examined. The principal input parameters are: site region acceleration attenuation, source zone geometry, recurrence statistics, and maximum magnitudes. Based on theses parameters, several curves showing probabilistic peak acceleration are developed, and the conclusions that may be drawn from these curves are considered. The data treated in this way are used to arrive at a general statement of risk from vibratory ground motion at the site during its active phase of development and use.

2.8.4.1 Acceleration Attenuation

The first input parameters considered are those having to do with acceleration attenuation in the site region as a function of earthquake magnitude and hypocentral distance. The risk analysis used in this study employs an attenuation law of the form,

$$a = b_1 \exp(b_2 M_L) R\text{-}b^3$$

where a is acceleration in cm/s^2, M_L is Richter local magnitude, and R is the distance in Kilometers. A number of relationships of the above from exist in the literature.[59,61] In all these studies, however, the constants b_1,b_2, and b_3 are found for data collected exclusively, or almost exclusively, west of the Rocky Mountains and are therefore perhaps not directly applicable at eh WIPP facility region. Theoretical and empirical evidence indicates fundamental difference in acceleration attenuation between the western and central parts of the United States.[30,62,63]

The particular formula used in this study is based on a central United States model developed by Nuttli.[64,65] The formula coefficients $b_1 = 17$, $b_2 = 0.92$, and $b_3 = 1.0$ were selected as the best ones. Curves using these coefficients are shown in Figure 2.8-23. This adopted attenuation law represents a conservative compromise between the estimated curves of various authors and the required form.[32,60,64,67]

Seismic Source Zones

Geologic, tectonic and seismic evidence indicates that three seismic source zones may be used to adequately characterize the region. These are well approximated by the Basin and Range subregion, the Permian Basin subregion exclusive of the Central Basin Platform, and the Central Basin Platform itself. The seismic source zones are outlined in Figures 2.8-20 and 2.8-22. However, specific boundaries are only intended to be simply defined approximations. For the purpose of earthquake risk analysis at the WIPP facility, some measure of the effect of the likely uncertainty in these source zone boundaries is desirable. Rather than allow the source zone boundaries to vary randomly by some amount, alternative boundaries are used based on an independent analysis of the WIPP facility region. These are taken from the study by Algermissen and Perkins of earthquake risks throughout the United States,[32] and were used in a previous analysis of WIPP site seismic risk by SNL.[24] A detailed discussion of how this characterization was developed and how it best fits recent estimates of site region seismic properties may be found in that reference.

Site region seismic source zones after Algermissen and Perkins are shown in Figure 2.8-24. Superposed on this figure are the earth-quake epicenters of Figure 2.8-1. It is clear from this superposition that the zonation presented generally conforms with historical seismicity. The source zonation of Figure 2.8-24 has no explicit analog to the Permian Basin subregion exclusive of the Central Basin Platform. This is considered part of the broad background region.

Another estimate of the appropriateness of the source zones as drawn in Figure 2.8-24 can be obtained from a consideration of Quaternary faulting. As shown in Figure 2.8-25, evidence of Quaternary fault offset is almost, but not quite completely, contained within the two western seismic source zones of Algermissen and Perkins. These two zones may be combined under the name "Rio Grande rift" since they include the parts of those provinces significant to the evaluation of probabilistic acceleration at the WIPP facility.

The general Algermissen and Perkins model, then, consists of three sources:

- The Rio Grande rift zone drawn by combining the western source zones as discussed above.

- The Central Basin Platform zone as shown in Figure 2.8-8 to 2.8-27.

- A WIPP site source zone centered at the site to model background seismicity in the High Plains.

The manner in which the irregular Algermissen and Perkins sources zones are adapted to the quadrilateral source zone configuration, which is required for the application of the seismic risk analysis method as discussed above, is straightforward (Figure 2.8-26).

For the purposes of this study, some minor modifications of the Algermissen and Perkins source zones were made. Geologic and tectonic evidence suggests that the physiographic boundary between the Basin and Range and Great Plains provinces provides a good and conservative approximation of the source zones as discussed in Sections 2.8.2 and 2.8.3. In addition, refined information from the Kermit array[23] indicates that the geometry used to model the limits of the Central Basin Platform source zone may be modified somewhat from the original preferred model for the WIPP site region seismic source zones in this study. This model is preferred because it is based more completely on consideration of geologic and tectonic information, as well as seismic data, and because it results in more conservative development of risks at the WIPP facility.

There is one purely geometrical issue to be resolved. It involves specifying a focal depth for events in each of the model source zones. There is little doubt that the focal depths of earthquakes in the WIPP facility region should be considered shallow. Early instrumental locations were achieved using an arc intersection method employing travel-time-distance curves calculated from a given crustal model, and the assumption of focal depths of five kilometers, 10 kilometers, or for later calculations, eight kilometers. Good epicentral locations could generally be obtained under these assumptions.

Within the range discussed, (that is, focal depths to 10 kilometers) the issue of selecting a proper depth for the probabilistic acceleration analysis at the WIPP site may be shown to be important only in the site source zone itself. For example, the difference in hypocentral distance (the distance to be used in the acceleration attenuation formula) for a closest a approach event in the Central Basin Platform is only 1.05 kilometers in this depth range, assuming that the closest approach of this source zone is 35 kilometers as indicated by Figures 2.8-26 and 2.8-27. This is clearly the greatest difference of this kind outside the WIPP facility source zone. Within the WIPP facility source zone the selection of focal depth can be very important simply because the form of the attenuation law used asymptotically approaches infinite acceleration at very small distances. This is certainly not mechanically realistic and is not the intent of the empirical fitting process to an attenuation law of this form. A focal depth of five kilometers is used in all source zones of this study including that of the site. For smaller hypocentral distances, the form of the attenuation law adopted here severely exaggerates the importance of very small, very close shocks, in the estimation of probabilistic acceleration at the WIPP site (Figure 2.8-23).

2.8.4.2 Source Zone Recurrence Formulas and Maximum Magnitudes

The risk calculation procedure used in this study requires that earthquake recurrence rates for each seismic source zone be specified. This is done formally by computing the constants "a" and "b" in the equation,

$$\log N = a - b M$$

where N is the number of earthquakes of magnitude greater than or equal to M within a specified area occurring during a specified period.

For the WIPP facility region, three formulas of this type are needed—one for the active province west and southwest of the site (the Basin and Range subregion or Rio Grande rift source zone), another for the inactive province of the WIPP facility exclusive of the Central Basin Platform (the Permian Basin subregion or background source zone), and a final one for the Central Basin Platform. In practice, the difficulties in finding meaningful recurrence formulas for such small areas in a region of low historical earthquake activity are formidable.

Several estimates of recurrence rates in the WIPP facility region have been published.[1,21,32] For earthquakes within 180 miles of the WIPP facility, exclusive of shocks form the Central Basin Platform and aftershocks of the 1931 Valentine, Texas earthquake, Sanford and Toppozada[1] find recurrence formulas of the form:

$$\log N_o = 1.65 - 0.6 M_L$$

using instrumental data only, and

$$\log N_o = 1.27 - 0.6 M_L$$

using both historical and instrumental data. In these and following recurrence formulas in this section, M_L is the Richter local magnitude and N_o is the number of earthquakes in the area of interest normalized to a time period of one year and an area of 3.6×10^4 miles^2.

Because the numbers of shocks used to establish the linear portions of these curves are very small (16 and 25, respectively), and the total time intervals over which data were collected are very short (11 and 50 years, respectively), an error in the slope (or b value) is quite possible. In fact, a certain dissatisfaction with these results on the part of Sanford and Toppozada[1] is indicated by their development of alternative curves defined to have a slope of 1.0 instead of 0.6. To the problems imposed by the spatially and temporally restricted data set available must be added the fundamental uncertainty associated with the definition of magnitude in the WIPP facility region. However, Sanford et al.[3] indicate that data collected since the Sanford and Toppozada[1] study of 1974 do not change any of the original conclusions regarding the magnitude, location, and recurrence intervals of major earthquakes within 180 miles of the WIPP facility.

Recent work[21] allows a preliminary treatment of the data. This work is based on 11 years of instrumental seismicity data which have been reinterpreted with respect to magnitude. In addition, recurrence formulas are computed for broad physiographic regions of New Mexico vastly increasing the data base. For example, Sanford et al.[21] find

$$\log N_o = 2.4 - 1.0\ M_L$$

for the High Plains physiographic province of the Permian Basin subregion or background source zone, and

$$\log N_o = 2.5 - 1.0\ M_L$$

for the Basin and Range - Rio Grande rift region. The b value in these equations is further substantiated by very recent work[68] in which all instrumental data on New Mexico earthquakes from 1962 through 1977 has been considered. The general criterion used in this earthquake risk analysis for the Rio Grande rift/Basin and Range subregion and Permian Basin/background source zones is the Sanford et al.[21] recurrence formula for the physiographic province. For this recurrence formula, an individual source zone occurs with the "a" value scaled to reflect area difference. The area of the High Plains province of interest for this analysis is approximately a 60 mile radius (1.2×10^4 miles^2) are surrounding the WIPP facility, but exclusive of part of the Central Basin Platform. Thus, the proper recurrence formula for site area background seismicity becomes,

$$\log N_o = 1.93 - M_L \text{Site source zone.}$$
$$\text{(background)}$$

Similarly, the part of the Southern Basin and Range - Rio Grande rift region of interest has been referred to in the above discussion as the Algermissen and Perkins[32] Rio Grande rift source zone and has an area of about 4.1×10^4 miles^2. The proper recurrence formula for the Algermissen and Perkins Rio Grande rift source zone becomes,

$$\log N = 2.56 - 1.0\ M_L.$$

The Basin and Range subregion as shown in Figure 2.8-15 has an area of about 6.4×10^4 mi^2. Thus, the proper recurrence formula for the Basin and Range Subregion becomes,

$$\log N = 2.75 - 1.0\ M_L.$$

This leaves only the Central Basin Platform, which is treated somewhat differently. Although the initial formulas[21] above were developed for areas near 7.2 x 10^4 miles^2 (with some increased confidence in their validity because of the relatively large areas of data collection), this cannot be done for the Central Basin Platform source zone because it is unique and of very limited area. Therefore, it cannot be treated as a scaled-down version of some broader region. Although recent work using data from the Kermit array[23] is available for this source zone, the recurrence formulation of Sanford et al.[2] is used in this risk analysis primarily for consistency in approach. Based on the seismicity detected in the Central Basin Platform since the installation of station CLN in April 1974, the cumulative number of shocks versus magnitude may be expressed as,

$$\log N_o = 3.84 - 0.9\, M_L.$$

If the active portion of the Central Basin Platform is assumed to have an area of 2.9 x 10^3 miles^2 during this period,[2] the proper recurrence relation for the Central Basin Platform source zone becomes,

$$\log N = 2.74 - 0.9\, M_L.$$

Because the Central Basin Platform seismicity is so a really limited, this same recurrence formula is used for all alternative geometric characterizations. This has the effect of maintaining a constant activity rate for the Central Basin Platform as an entity.

These are the primary recurrence relationships used in the current risk analysis for the WIPP site. However, whereas magnitudes as used in the site region attenuation law above, or in consideration of maximum magnitude for a give source zone below, are by definition Richter local magnitudes, M_L, the earthquakes used to determine the recurrence formulas have measured magnitudes crucial to formula development. Some apparent disagreement exists in how site region magnitudes should be computed, with some suggestion [23] that the local magnitudes determined by Sanford et al.[2] may be, in some sense, too low. In order to test the effect of this possibility, an alternate set of recurrence formulas is derived by incrementing the M_L values in the above relationships by 0.5, in general agreement with the suggested relation between a "corrected" magnitude[23] and the local magnitude of Sanford et al.[2] The effect of this process is clearly to increase the activity rate of all source zones.

The four formulas now become:

$\log N = 2.43 - M_{CORR}$	Site source zone (background)
$\log N = 3.06 - M_{CORR}$	Algermissen & Perkins Rio Grande rift source zone
$\log N = 3.25 - M_{CORR}$	Basin & Range subregion
$\log N = 3.19 - 0.9\, M_{CORR}$	Central Basin Platform

The final parameter to be determined before WIPP facility risk may be computed is source zone maximum magnitude. A simple consideration of maximum historical magnitude within each of the three general source zones is not conservative. This is particularly true of the northern part of the Rio Grande rift source zone (Zone 43 of Algermissen and Perkins[32]) where a maximum historical intensity of only V is known. As discussed above, the fault scarps in this areas, particularly along the margins of the San Andres and Sacramento mountains, imply that major earthquakes have occurred in this region within the past 5 x 10^5 years. The length of the faulting in these two areas (about 36 to 60 miles) suggests the possibility of earthquakes comparable in strength to the Sonoran earthquake of 1887.[1]

That Sonoran earthquake (M - 7.8) produced 50 miles of fault scarp with a maximum displacement of about 28 feet extending southward from the U.D. - Mexico border at about 109W longitude. Sanford and Toppozada[1] assume that a similar future event is possible west of a line whose location is in good general agreement with the eastern boundary of either the Rio Grande rift zone as shown in Figure 2.8-24, or the Basin and Range subregion as shown in Figure 2.8-27. This eclipses the more southerly Valentine, Texas earthquake, whose magnitude was about 6.4. For this analysis, a maximum magnitude event of 7.8 is assumed possible anywhere within the Rio Grande rift/Basin and Range subregion source zone.

The selection of maximum magnitude events for the WIPP facility source zone and the Central Basin Platform source zone is more difficult. Algermissen and Perkin[32] assign a maximum historical intensity of VI to the Central Basin Platform. This is presumably the earthquake of August 14, 1966 which has been assigned this intensity in United States Earthquakes 1966.[69] On the basis of this intensity and the empirical relationship of Gutenberg and Richter,[66] a maximum magnitude event of 4.9 has been selected for the Central Basin Platform by Algermissen and Perkins as appropriate for their probabilistic acceleration analysis. The magnitude scale was designed to give some indication of the elastic energy released at the earthquake source, and in this context a 4.9 value is almost certainly an exaggeration of the energy really released during that particular earthquake. This conclusion is based on both macroseismic and instrumental evidence. In addition, several magnitudes have been published for this earthquake (USCGS-3.4; Sanford et al.[2] - 2.8) which are substantially lower than the 4.9 value used by Algermissen and Perkins. As discussed above, the maximum historical magnitude in the Central Basin Platform source zone is probably between 3.0 and 4.0, even after uncertainty in magnitude calculation methods is considered.

The features of this source zone that might bear on its possible maximum magnitude are the lack of recent geologic evidence of tectonism and the high activity rate that may or may not be directly associated with secondary oil recovery efforts. Sanford and Toppozada[1] conjecture that the maximum magnitude might be 6.0 for this source zone, and in this study of risks, their example is followed for one set of calculations. Because this value may be exceptionally conservative, an alternative maximum magnitude of 5.0 is also considered.

With regard to the WIPP facility zone, there is even less indication that significant magnitude events are reasonably likely. There is no Quaternary fault offset,[70] and seismic activity is low. However, recent studies[27] show that some level of background seismicity must currently be considered for the site area if conservatism is to be served. Apparently, an earthquake that current best evidence indicates was tectonic in origin, and with a magnitude of 3.6 has, occurred within the site source zone itself, within about 40 kilometers of the WIPP facility. In addition, the June 16, 1978 event with an approximate magnitude of 4.7 occurred within the Permian Basin subregion although near its extreme eastern margin. That event may have been induced by secondary oil recovery operations. Two maximum magnitudes are considered for the WIPP facility source zone in the risk analysis of this section: 4.5, that is, maximum historical event near the site of tectonic origin plus about one magnitude unit; and 5.5, the maximum event recorded anywhere within the Permian Basin subregion, plus about one magnitude unit.

2.8.4.3 Calculation of Risk Curves

Risk Curves for the WIPP facility calculated using the McGuire[57] formulation are presented in this section; first for individual model WIPP facility region source zones, and then for a few illustrative combinations of risks from all source zones in the WIPP facility region to form total WIPP facility risk curves. In particular, a set of curves is calculated for the WIPP facility source zone, another set for the Central Basin Platform and a third set for the Basin and Range or Rio Grande rift source zone to the west of the site. With a presentation of this type, the effect of earthquake source parameter variation may be explored source by source, and the inherent complexity of the broad spectrum parameter approach is thereby somewhat compartmentalized. The strength of the broad spectrum approach is that it allows an objective (although not precisely formulated) estimate of the uncertainty in risk values associated with given peak accelerations under the suite of possible geologic and seismic assumptions discussed above.

For the Basin and Range subregion or the Rio Grande rift source zone, two geometries (Figures 2.8-24 and 2.8-27) and two recurrence formulas (Section 2.8.4.2), but only one maximum magnitude are considered. Thus, a total of four risk curves, for this general source area to the west of the site, are presented in Figure 2.8-28. The specific parameters associated with each of the four curves are listed in Table 2.8-4.

In the case of the Central Basin Platform source zone, three geometries (Figures 2.8-24 and 2.8-27), two maximum magnitudes, and two recurrence formulas are considered, so that a total of 12 risk curves are implied. However, preliminary calculations for the Central Basin Platform source zone as suggested by recent seismicity (Central Basin Platform source zone is outlined by heavy dashed lines in Figure 2.8-27) show that risks from this particular model of the Central Basin Platform source zone geometry are generally less at low accelerations and much less at higher accelerations than those derived from the two alternative geometries for given maximum magnitude and recurrence formula conditions. For example, considering the case of a maximum Central Basin Platform source zone with a magnitude of 6.0 , and a recurrence formula of the form $\log N = 3.19\text{-}0.9\ M_{CORR}$ annual risks of $3.07\text{x}10^{-3}$, $6.80 \text{ x } 10^{-3}$, and $1.50\text{x}10^{-3}$ at the 40 cm/s^2 acceleration level and $5.89\text{x}10^{-4}$, $1.46\text{x}10^{-3}$ and $3.67\text{x}10^{-5}$ at about the 60 cm/s^2 acceleration level are computed at the site using the Algermissen and Perkins,[32] Central Basin Platform geology and recent Central Basin Platform seismicity suggested source geometries, respectively. Thus, the four risk curves for the seismically implied Central Basin Platform source geometry as shown in Figure 2.8-27, in association with the two maximum magnitudes and recurrence formulas for this source zone discussed above, cannot produce the most conservative estimation of risk at the WIPP facility. Because of the way risks from various source zones are combined to derive total risk curves, the do not lead to significantly lower estimates of total WIPP facility risks than those obtained using the Algermissen and Perkins geometry, given the particular form of the individual source zone risk curves in this study. Therefore, corresponding to the two alternative geometries are shown in Figure 2.8-29.

Finally, two maximum magnitudes and two recurrence formulas are considered for the background seismicity of the site source zone. The four risk curves thereby implied are shown in Figure 2.8-30. To aid in the task of keeping the assumptions underlying all these curves accessible, the parameters associated with each curve in Figures 2.8-28 through 2.8-30 are listed in Table 2.8-4.

The effects of varying the maximum magnitude within a given source zone are straightforward, although the details of these effects at the WIPP facility depend on the specific source-site geometric configuration. The general effect of increasing the maximum magnitude in any source zone is to increase the maximum acceleration at the WIPP facility attributable to that source zone, and to increase the WIPP facility risks from that source zone at all lower acceleration levels. In the case of the Central Basin Platform source zone, increasing the maximum source magnitude from 5.0 to 6.0 has the effect of increasing the WIPP facility risk from this source by a factor of 12.7 for the case of the Algermissen and Perkins[32] geometry, and about 18.5 for the geologically suggested source geometry at the 40 cm/s^2 acceleration level. This may be seen by comparing curves (1,2), (3,4), (5,6), and (7,8) of Figure 2.8-29. At low risk levels, the asymptotic approach of the lower maximum magnitude curves (the odd numbered curves of Figure 2.8-29) to an acceleration of just under 50 cm/s^2, and of the higher maximum magnitude (or even numbered) curves to an acceleration of about 120 cm/s^2, is clear. Very similar behavior is exhibited in Figure 2.8-30 for the background seismicity of the WIPP facility source zone. In this case, the ratio of site risks at the 40 cm/s^2 acceleration level due to curves generated using maximum magnitudes of 4.5 and 5.5 is 1.21, and somewhat over twice this at the 140 cm/s^2 level.

The effect of different recurrence formulas may be seen in any of Figures 2.8-28 through 2.8-30. As discussed above, the reason for considering different recurrence formulas is primarily to address the issue of uncertainty in the WIPP facility region magnitude determination, since the way in which magnitudes of recently recorded earthquakes are determined has a direct bearing on the form of the recurrence formulas derived for source zones in the WIPP facility region. In contrast, the maximum magnitudes specified for each of these source zones do not depend critically on calculated magnitudes, and therefore, are not dependent on the method of magnitude determination. For a given source zone geometry, maximum magnitude, and acceleration attenuation law, all risk curves approach the same maximum acceleration asymptote. The effect of any uncertainty in magnitude determination (acting through differences in recurrence formulas) is most noticeable at relatively higher risk levels. This may be seen by comparing curve pairs (1,2) or (3,4) in Figure 2.8-28, pairs (1,3), (2,4), (5,7) or (6,8) in Figure 2.8-29, or pairs (1,3) or (2,4) in Figure 2.8-30. For each of these risk curve pairs, the curves differ only in recurrence formula. The risk level at which convergence occurs for each of these pairs is clearly dependent on the risk level at which asymptotic behavior becomes evident under a given set of conditions. Convergence is not evident under the parameters used for the site source zone at the probabilities considered. For the two Central Basin Platform source zone geometries, convergence takes place at probabilities near 10^{-5} for a maximum source zone magnitude of 5.0, and at lower probabilities for the higher 6.0 maximum magnitude. This relatively simple behavior of curves from two different geometries occurs because the closest approach to the site is virtually identical for each of the two alternate Central Basin Platform source zones whose risk curves are platted in Figure 2.8-29. for earthquakes in the Basin and Range subregion or Rio Grande rift source zone, convergence is not evident at the lowest annual risk level calculated. For each of the cases discussed, different recurrence formulas lead to significantly different accelerations at risks lower than the convergence values. The final effect of parameter variation on the individual source zone risk curves has to do with the variation of the geometries of these zones. This effect is most easily seen in Figure 2.8-28 where effects of maximum magnitude variation do not occur. Curve pairs (1,3) and (2,4) in this figure differ only in source zone geometry characterization. The ratio of these curve pairs is not greatly dependent on risk level, being near 2.1, 3.4, and 2.6 for accelerations of 40, 80 and 120 cm/s^2, respectively. In both cases, risks from the Basin and Range subregion characterization are somewhat higher at a given acceleration level than those from the Rio Grande rift source zone of Algermissen and Perkins, because a slightly greater proportion of the Basin and Range subregion is closer to the WIPP facility, as may be seen by comparing Figures 2.8-24 and 2.8-27. For the Central Basin Platform source zone curve pairs (1,5), (2,6), (3,7), and (4,8) differ only by source geometry. The asymptotic convergence of these risk curve pairs closely approximates the behavior of convergence under recurrence formula variation discussed above, and at about the same risk levels for given maximum magnitude conditions. Again, variation is greatest at high risk levels. Ratios of risk levels for the curve pairs above are almost independent of the recurrence formula being 1.5 for curve pairs (1,5) and (3,7) and 2.2 for pairs (2,6) and (4,8) at the 40 cm/s^2 acceleration level.

In very general terms, increasing the maximum magnitude of any source zone using the recurrence formulas suggested by the magnitude calculation of Rogers and Malkiel,[23] or selecting the geology implied Central Basin Platform and Basin and Range subregion source zone geometries, has the effect of increasing site risk levels. Using these observations, several extreme WIPP facility risk curves are generated below.

Although much can be learned by considering each WIPP facility region source zone separately, several important issues cannot be addressed until total risk curves are generated combining the contributions from the individual source zones. The process is illustrated graphically in Figure 2.8-31. In this figure are shown the individual source zone curves for the Algermissen and Perkins[32] Central Basin Platform and Rio Grande rift zones (Figure 2.8-24) for maximum magnitudes of 6.0 and 7.8 respectively, and for the site source zone using a maximum magnitude of 5.5. In each case, the Sanford et al.[2] recurrence formulas are used. These are curve 2 of Figure 2.8-29, 1 of figure 2.8-28, and 2 of Figure 2.8-30. The total WIPP facility risk curve calculated by combining these three individual curves is shown as a solid light line in Figure 2.8-31. This particular total risk curve closely approximates the most conservative curve calculated in the WIPP Geological Characterization Report (Figure 5.3-6 of Reference 33, curve 4), except that a maximum WIPP facility source zone magnitude of 5.5 instead of 5.0 is used. One point is clear from Figure 2.8-33, under the assumptions used to calculate the source zone risks shown in this figure, the significance of the Rio Grande rift source zone to the total risk at the WIPP facility is relatively small at all acceleration levels. In fact, this is a general result for all combinations of source zone parameters considered. For the earthquake recurrence relationships considered for the various source zones, this will be true at lower acceleration levels no matter what assumptions are made about the maximum magnitudes in the WIPP facility and Central Basin Platform source zones. At higher acceleration levels, this will be true unless the lowest maximum magnitude proper for the WIPP facility source zone is lower than the 4.5 value considered here.

Note further that for the case considered in Figure 2.8-31, where 6.0 is the maximum magnitude event for the Central Basin Platform source zone, probabilities are largely controlled by earthquakes in this zone up to accelerations of around 0.04 g. For higher accelerations, the WIPP facility source zone is more important. The cross-over acceleration is clearly a function of the relative maximum magnitudes in the Central Basin Platform and WIPP facility source zones. For a lower maximum magnitude in the WIPP facility source zone relative to the Central Basin Platform source zone, the latter zone would be expected to dominate the WIPP facility total risk curve to higher acceleration levels. If the Central Basin Platform source zone maximum magnitude is lower relative to the WIPP facility source zone, its significance is totally eclipsed by the WIPP facility source zone at all acceleration levels. Perhaps the most obvious feature of the total risk curve of Figure 2.8-32 is its dominance by the WIPP facility source zone at higher accelerations. Consideration of different combinations of source zone parameters indicates that this feature of risk curves at the WIPP facility is universal for all cases derivable from the parameters considered. Therefore, if the probabilities at which these higher acceleration levels occur are thought to be of interest, it is the assumptions made about the immediate WIPP facility area that are most critical.

The question of total WIPP facility risk at a number of acceleration levels and under a number of assumptions about source zone parameters is addressed graphically in Figure 2.8-32, where several extreme cases are considered. Four curves in all are shown. Curves 1 and 2 both assume maximum source zone magnitudes of 7.8, 6.0, and 5.5 for the Basin and Range subregion (or Rio Grande rift), Central Basin Platform, and WIPP facility source zones, respectively, and recurrence formulas suggested by the Roger and Malkiel[23] magnitudes. That is, curve 1 of Figure 2.8-32 is the result of combining individual source zone risks at the WIPP facility represented by curve 4 of Figure 2.8-28, curve 8 of Figure 2.8-29, and curve 4 of Figure 2.8-30. Similarly, curve 2 of Figure 2.8-32 is the result of combining individual source zone risks at the site represented by curves 2 and 4 of Figures 2.8-28 through 2.8-30, respectively. The difference between curves 1 and 2 of Figure 2.8-32 is that curve 2 uses source zone geometries taken from Algermissen and Perkins,[32] while curve 1 uses the slightly more conservative alternate source zone geometries discussed in Section 2.8.4.2. Curves 3 and 4 of Figure 2.8-32 both assume smaller maximum source zone magnitudes of 7.8, 5.0, and 4.5 for source zones taken in the same order as above and recurrence formulas suggested by Sanford et al.[21] The individual risk curves used to generate these two total risk curves may be deduced from the above description and Table 2.8-4. The differences between curves 3 and 4 are precisely the geometric differences between curves 1 and 2.

It is clear from the four total site risk curves of Figure 2.8-32 that the geometric differences considered for the source zones do not introduce important differences in total WIPP facility risk at any acceleration level, although what small differences do exist are most evident at low accelerations. More importantly, for all parametric variations allowed in this study, extremum curves as shown in this figure imply accelerations associated with 10^{-3}/y risks ranging between about 40 and 75 cm/s^2, accelerations associated with 10^{-4}/y risks between 75 and 130 cm/s^2, and 10^{-5}/y risk accelerations between 130 and 245 cm/s^2.

2.8.5 Design Basis Earthquake

The stringent seismic criteria for nuclear power plants do not apply to the WIPP facility due to the unique character of the design and function of the facility. In particular, the terms "Operating Basis Earthquake" (OBE) and "Safe Shutdown Earthquake" (SSE) are not applied to the WIPP facility. Rather, the term "Design Basis Earthquake" (DBE) is used for the design of Class II and IIIA confinement structures and components (Section 3.2.7). As used here, the DBE is equivalent to the design earthquake used in Regulatory Guide 3.24 (U.S. Nuclear Regulatory Commission).[71] That is, in view of the limited consequences of seismic events in excess of those used as the basis for seismic design, the DBE is such that it produces ground motion at the WIPP facility with a recurrence interval of 1,000 years (Section 3.1.3). In practice the DBE is defined in terms of the 1,000-year acceleration and design response spectra.

The generation of curves expressing probability of occurrence or risk as a function of peak WIPP facility ground acceleration is discussed in detail in Section 2.8.4 for a number of possible characterizations of WIPP facility region source zones and source zone earthquake parameters. The most conservative (and the least conservative) risk curves are shown in Figure 2.8-32.

From this figure, the most conservative calculated estimate of the 1000 year acceleration at the WIPP facility is seen to be approximately 0.075g. The geologic and seismic assumptions leading to this 1000-year peak acceleration include the consideration of a Richter magnitude 5.5 earthquake at the site, a 6.0 magnitude earthquake on the Central Basin Platform, and a 7.8 magnitude earthquake in the Basin and Range subregion. These magnitudes correspond roughly to equivalent epicentral intensity events of VII, VIII and XI on the Modified Mercalli intensity scale.[13] These values, especially the first two, are considered quite conservative, and the other parameters used in the 0.075g derivation are also very conservatively chosen. For additional conservatism, a peak design acceleration of 0.1g is selected for the WIPP facility DBE. The design response spectra for vertical and horizontal motions are taken from Regulatory Guide 1.60 (U.S. Nuclear Regulatory Commission)[72] with the high frequency asymptote scaled to this 0.1g peak acceleration value. These response spectra are shown in Figures 3.2-2 and 3.2-3.

This DBE and the risk analysis that serves an important role in its definition are directly applicable to Design Class II and IIIA confinement structures and components at the WIPP Facility. Underground structures and components are Design Class IIIB and as such are not subject to DBE. Mine experience and studies on earthquake damage to underground facilities[73] show that tunnels, mines, wells, etc., are not damaged for sites having peak accelerations at the surface below 0.2g.

Design Class IIIB underground facilities do not require the consideration of seismic effects based on the above, and seismic load combinations with increased allowable stresses will not control the design.

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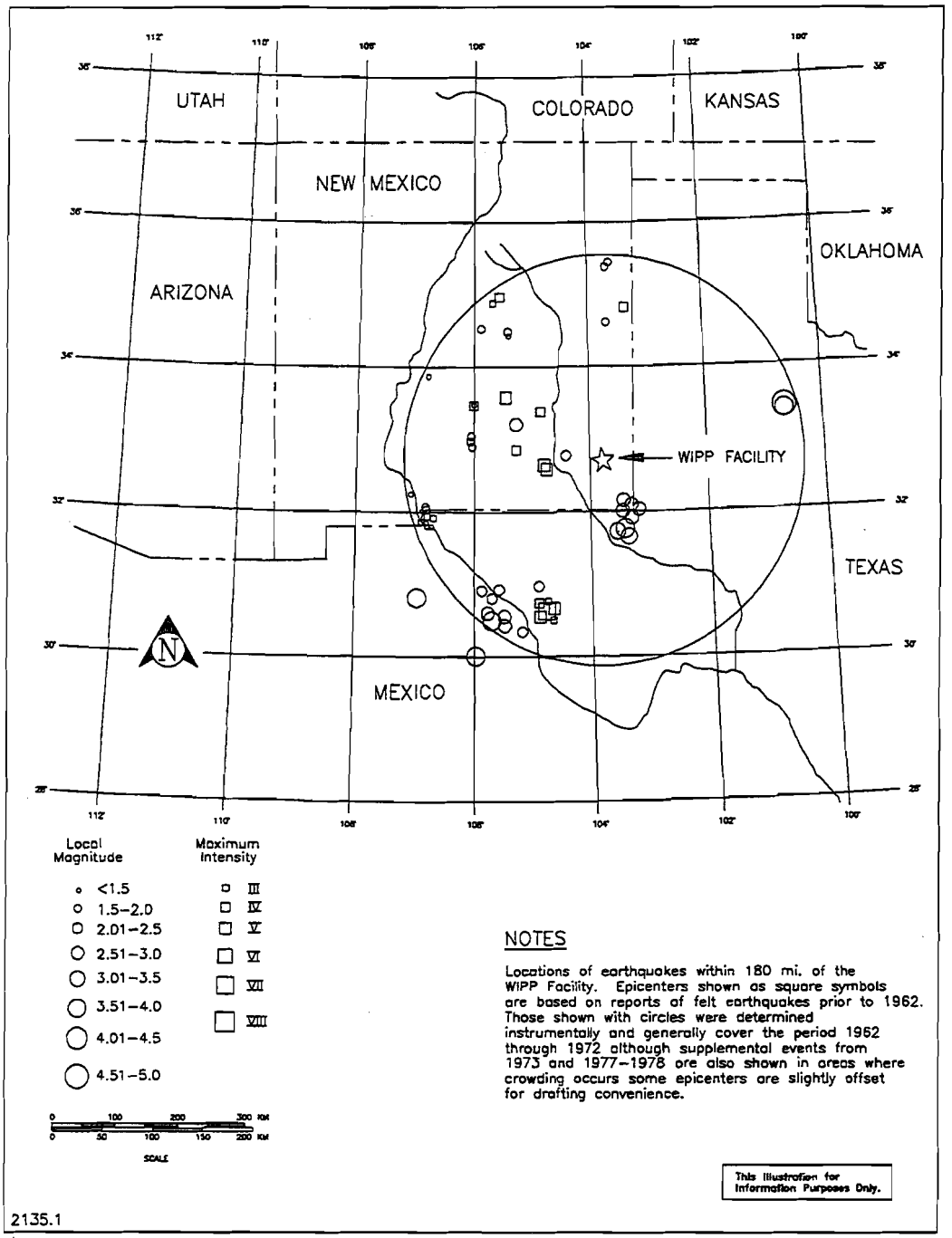

Figure 2.8-1, Earthquakes Located Using Macoseismic or Regional Seismographic Data 1923 - 1977

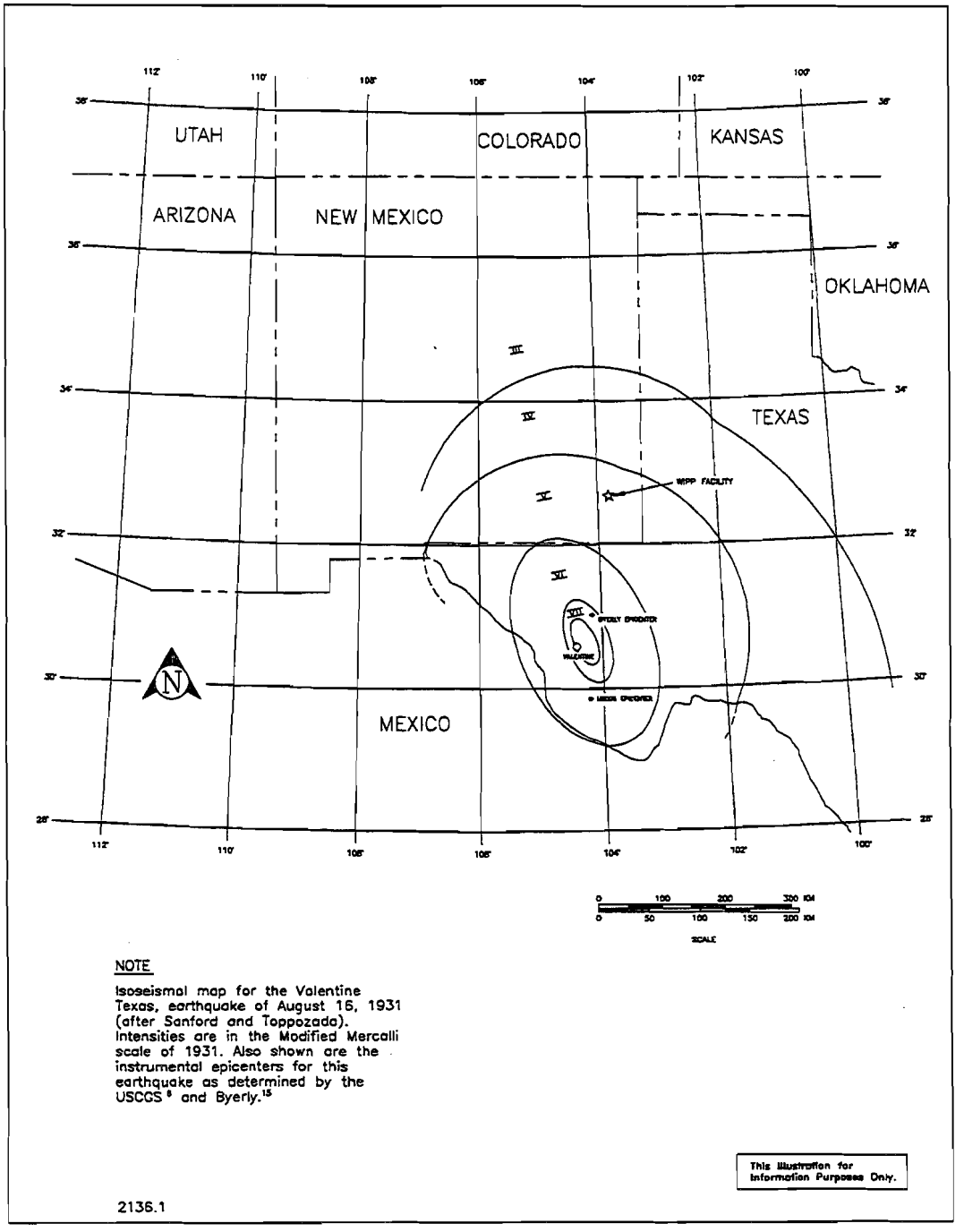

Figure 2.8-2, Valentine, Texas, Earthquake Isoseismals

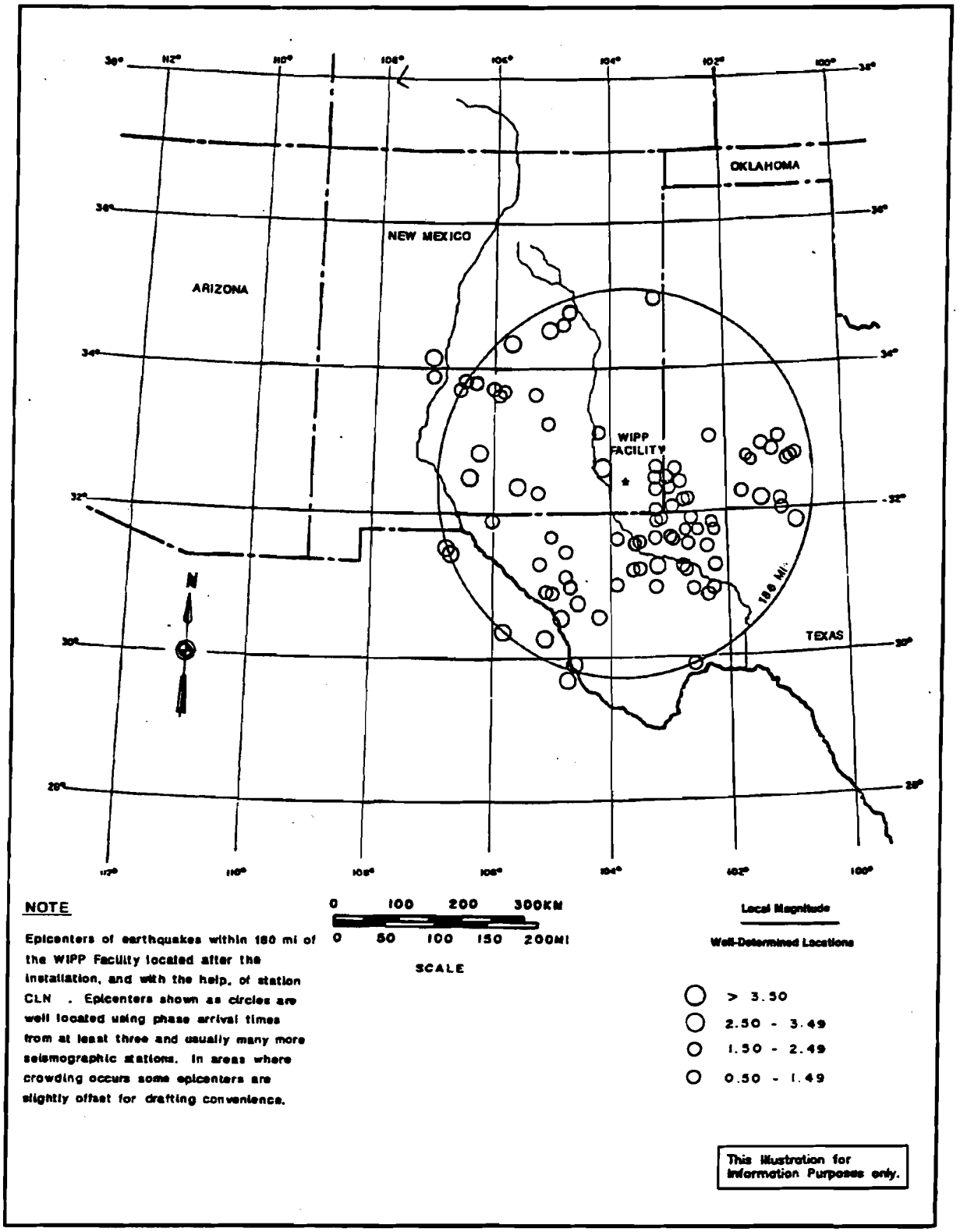

Figure 2.8-3, Earthquakes Located with the Help of Data from Station CLN(April 1974 - February 1979)

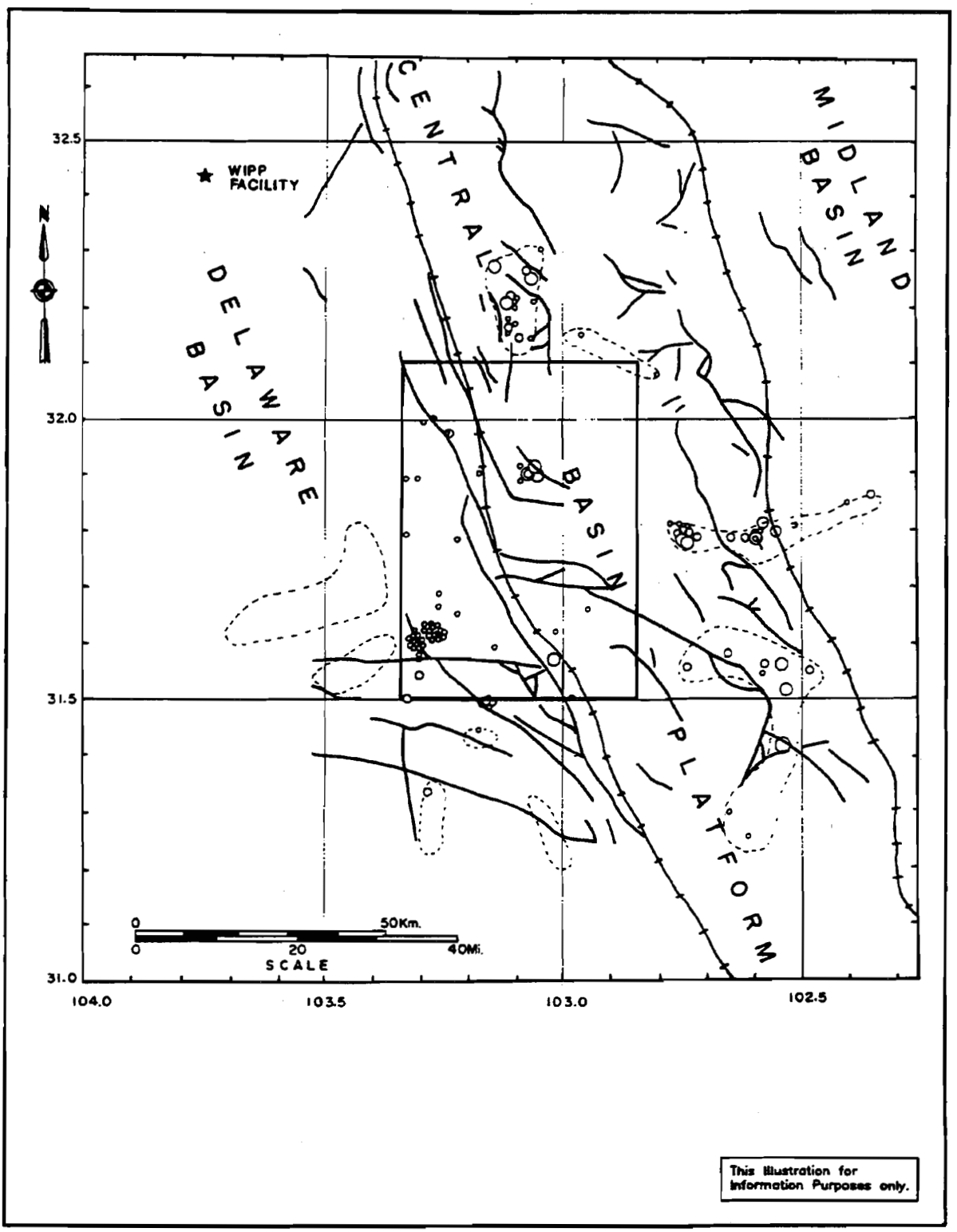

Figure 2.8-4a, Earthquakes Location Using Kermit Array Data November 1975 through July 1977

NOTE

Earthquakes located using the Kermit array network.[23] All located events within the array (denoted by the small rectangular area in the map to the left and in the regional scale inset above) are shown, as well as those shocks on the array's periphery located by five or more array stations. The light dashed lines enclose peripheral epicenters whether or not they satisfy the five station criterion. Solid lines are pre–Permian faults, and the cross hatched lines the approximate boundary of the Central Basin Platform, both after Rogers and Malkiel.[23] The regional location map below shows the total map area to the left as well as the Kermit array limits in a large scale context.

Magnitude (M_{LD})

- ∘ ≤ 2.35
- ∘ 2.36–2.85
- ○ 2.86–3.35
- ○ ≥ 3.36

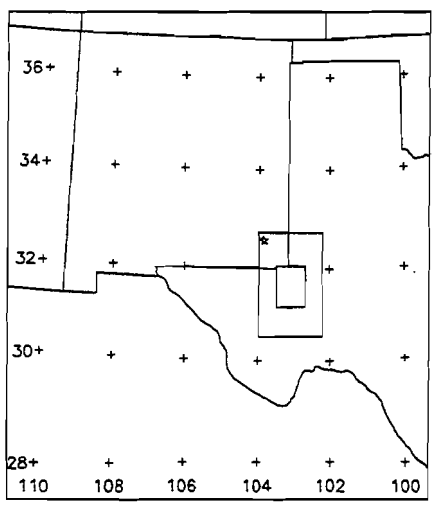

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Figure 2.8-4b, Explanation to Figure 2.8-4a

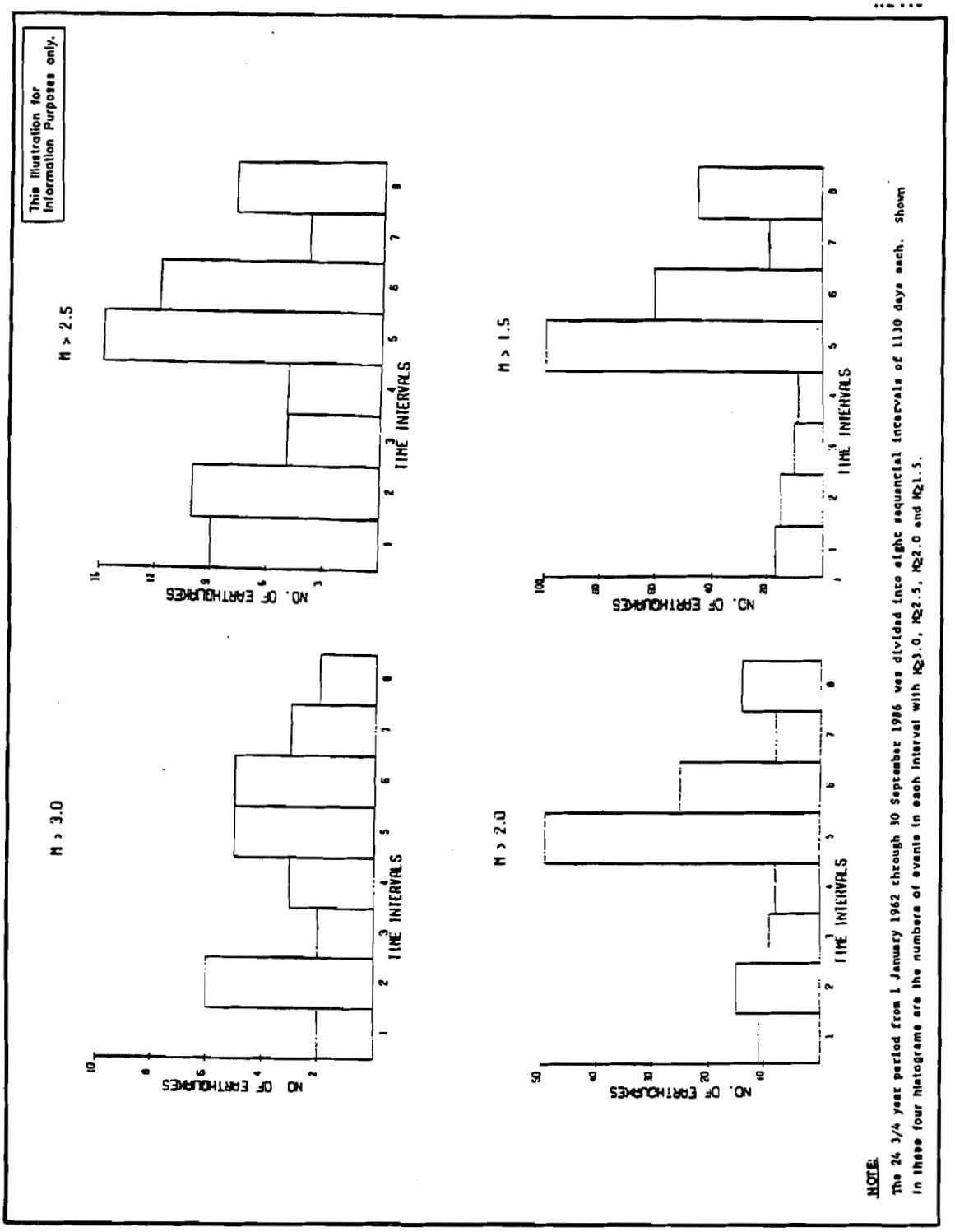


Figure 2.8-5, Histograms of Number of Earthquakes: 1 January 1962 through 30 September 1986

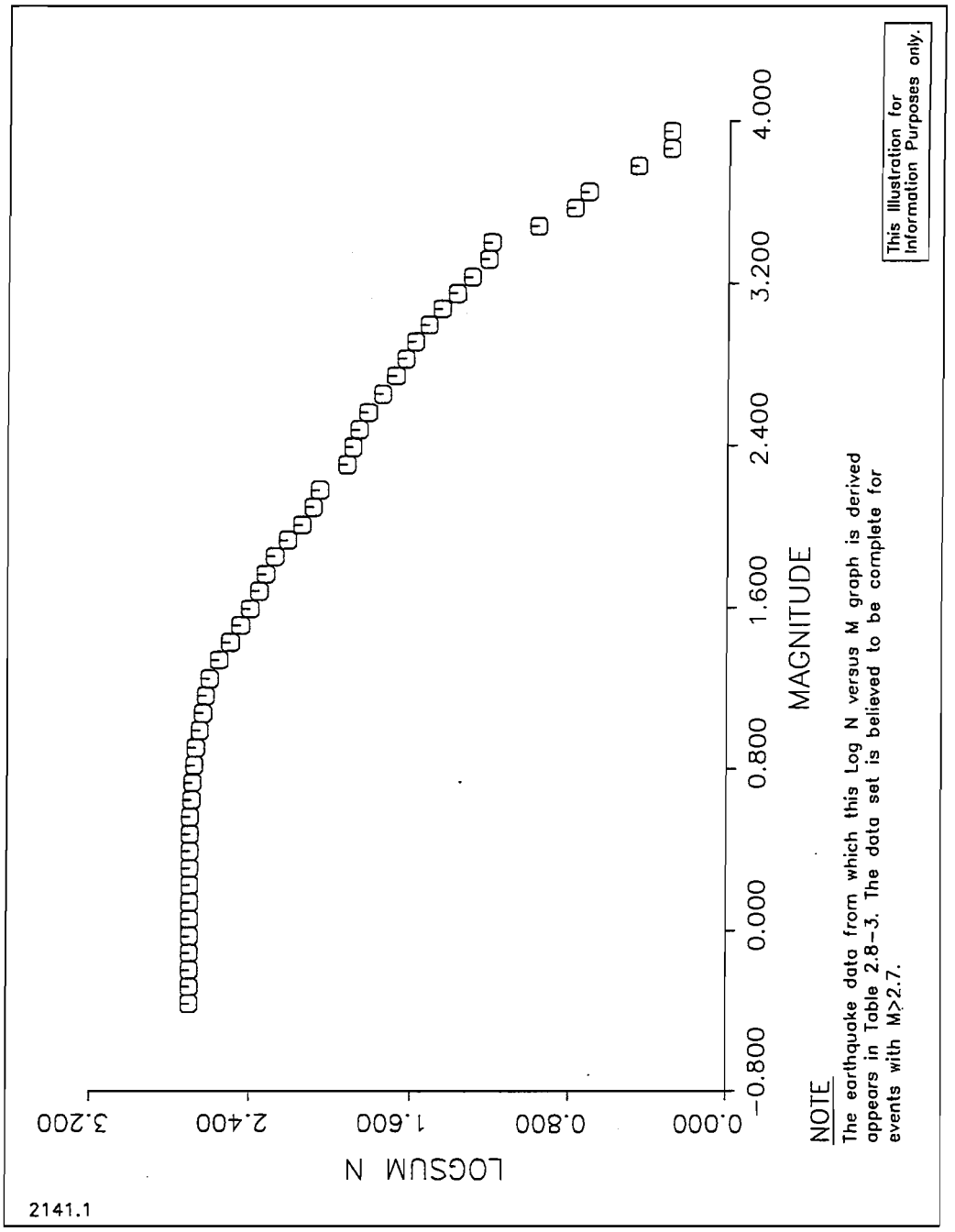


Figure 2.8-6, Earthquakes Recurrence Data (Log N versus M): 1 January 1962 through 30 September 1986

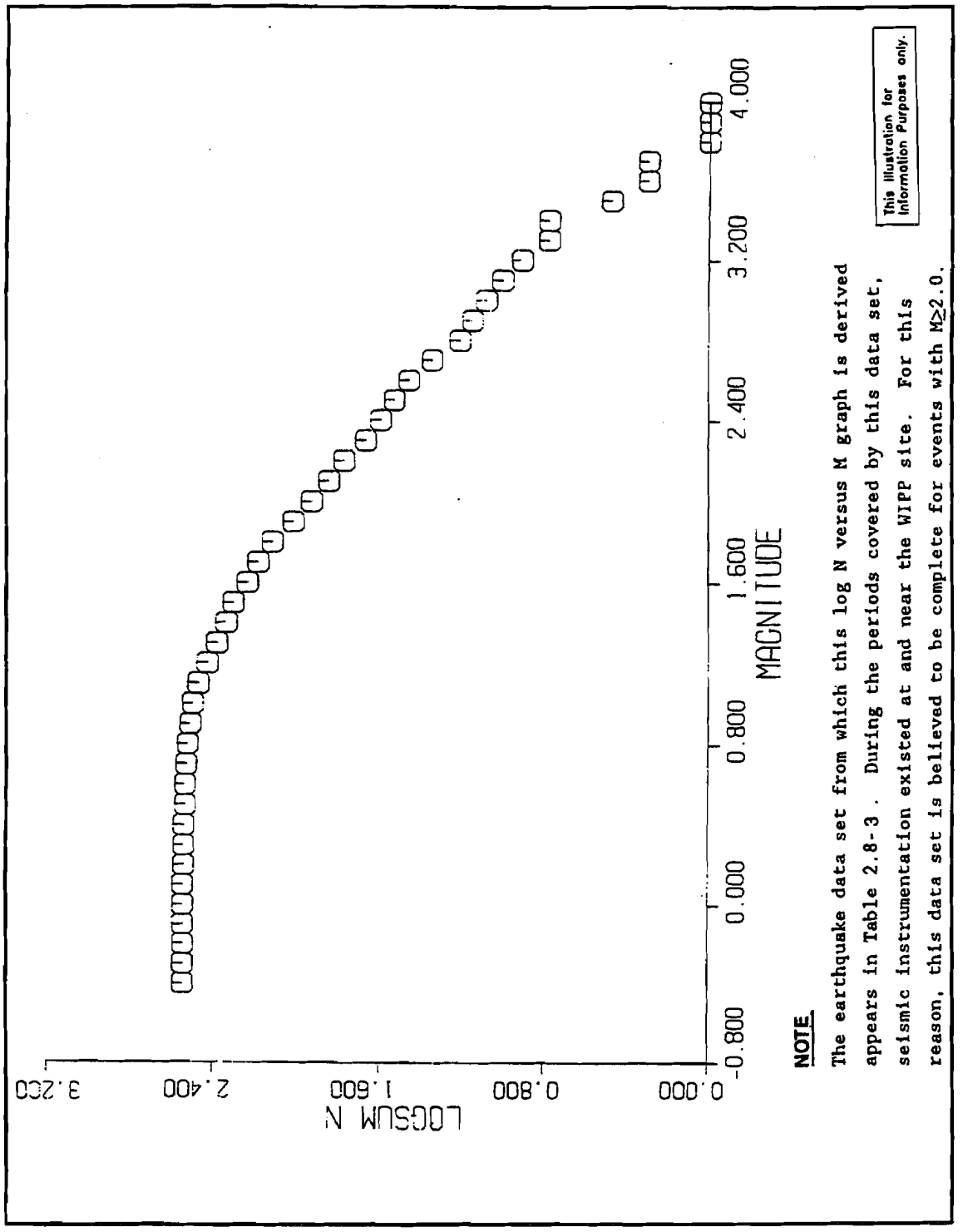


Figure 2.8-7, Earthquake Recurrence Data (Log N versus M): 18 May 1974 through 24 July 1980 and 29 August 1983 through 30 September 1986

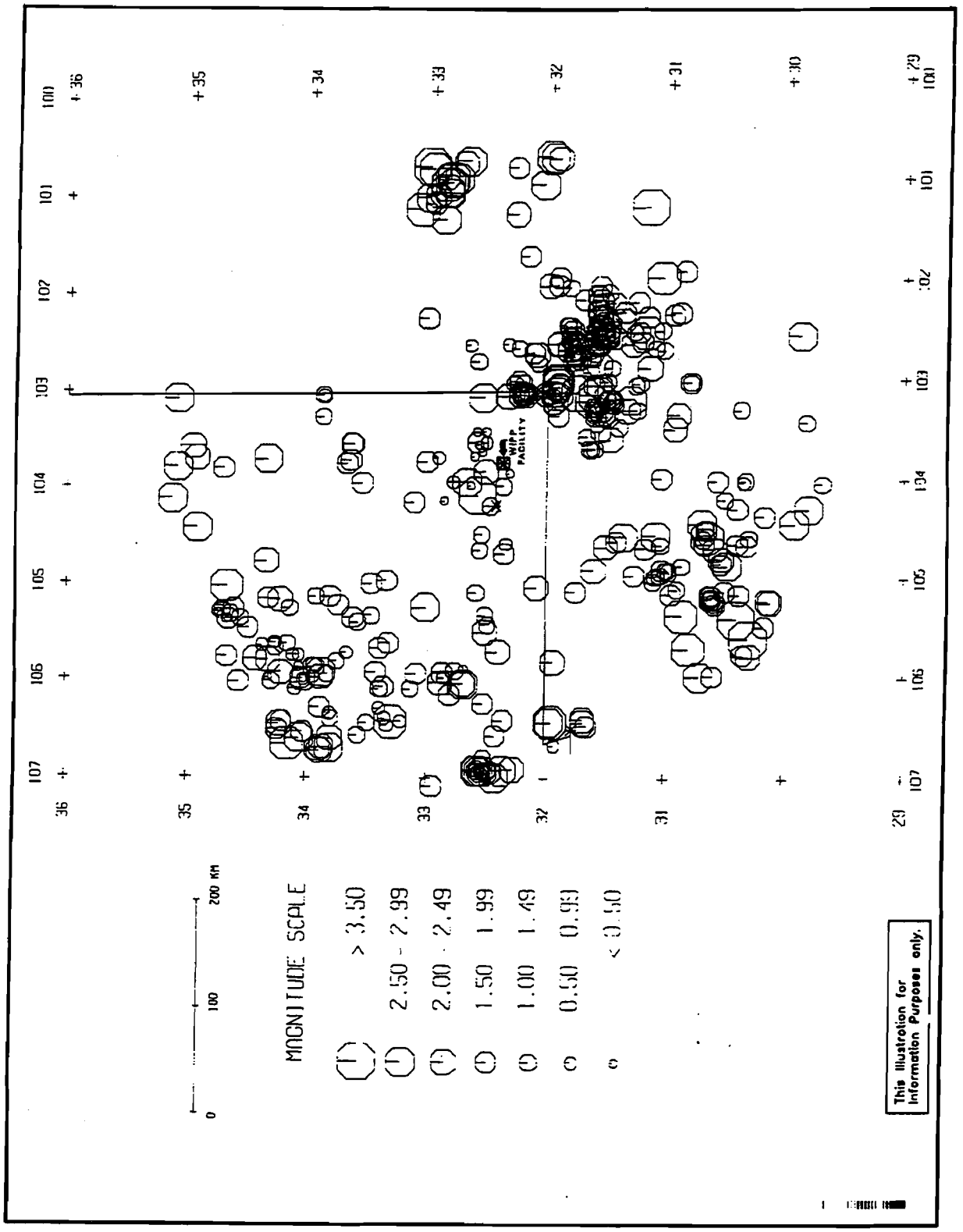


Figure 2.8-8, Epicenters for All Located Earthquakes: 1 January 1962 through 30 September 1986

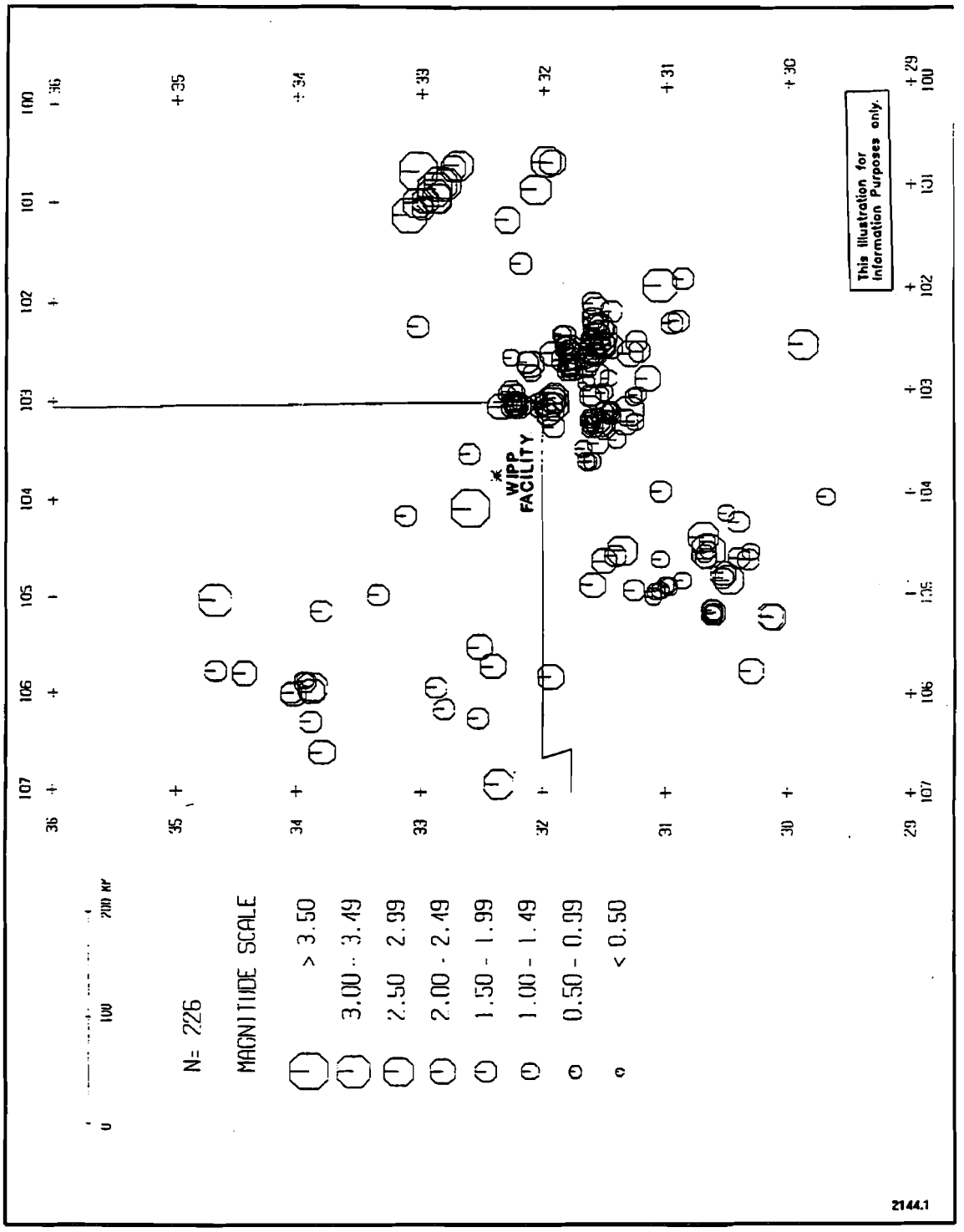


Figure 2.8-9, Epicenters for All Located Earthquakes: 5 April 1974 through 6 October 1978

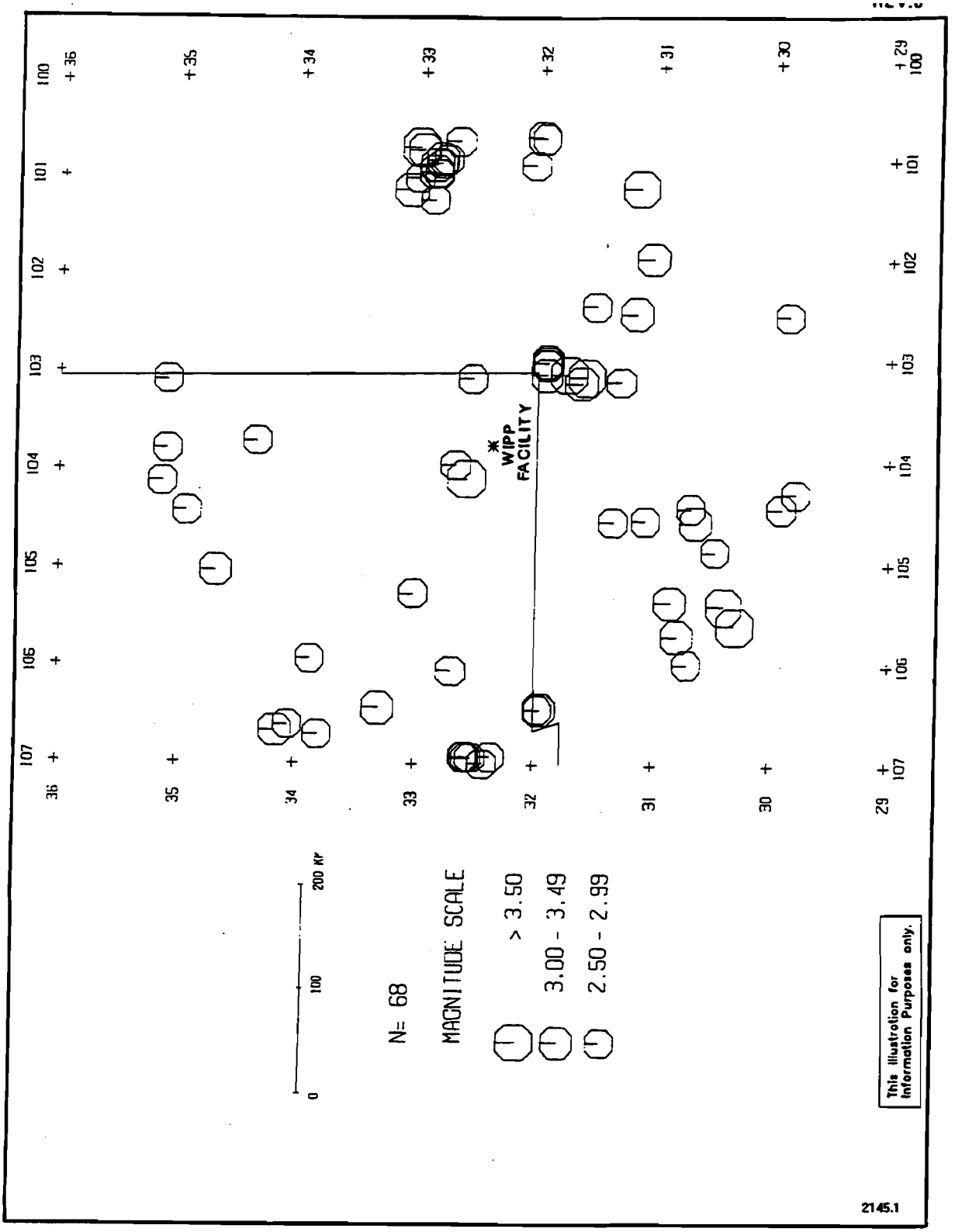


Figure 2.8-10, Epicenters for Located Earthquakes with M≥2.5: 1 January 1962 through 30 September 1986

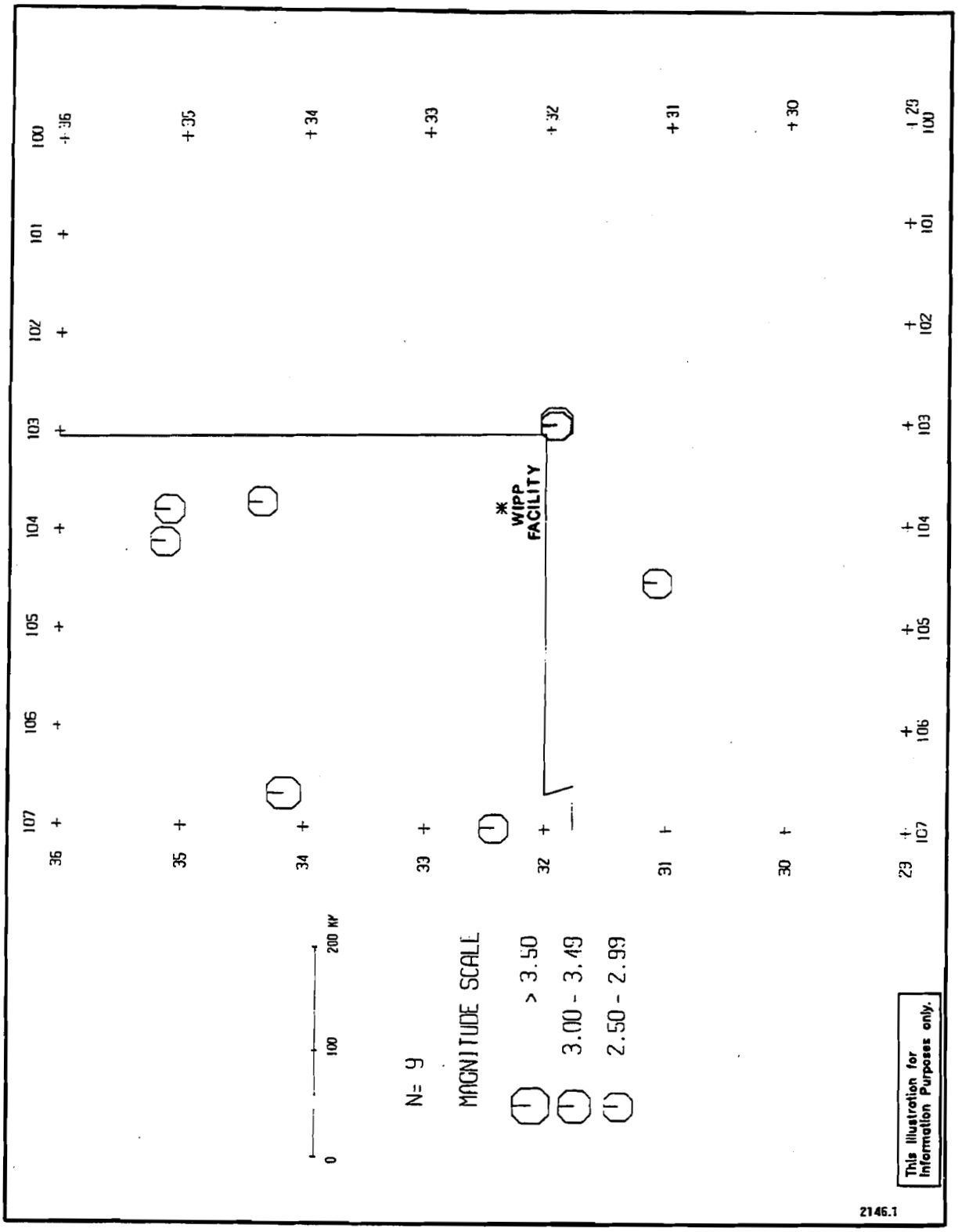


Figure 2.8-11, Epicenters for Located Earthquakes with M≥2.5: 1 January 1962 through 3 February 1965

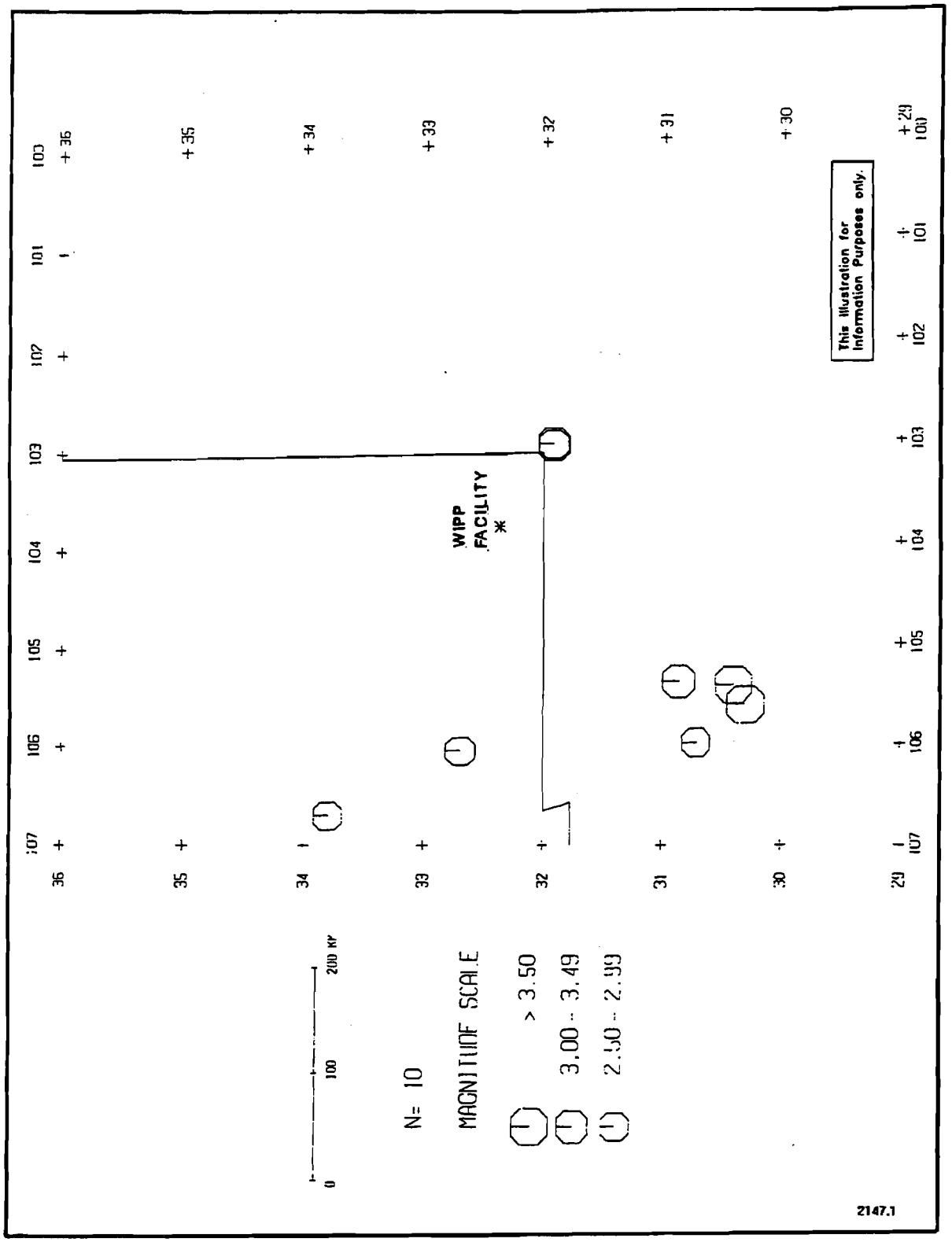


Figure 2.8-12, Epicenters for Located Earthquakes with M≥2.5: 4 February 1965 through 9 March 1968

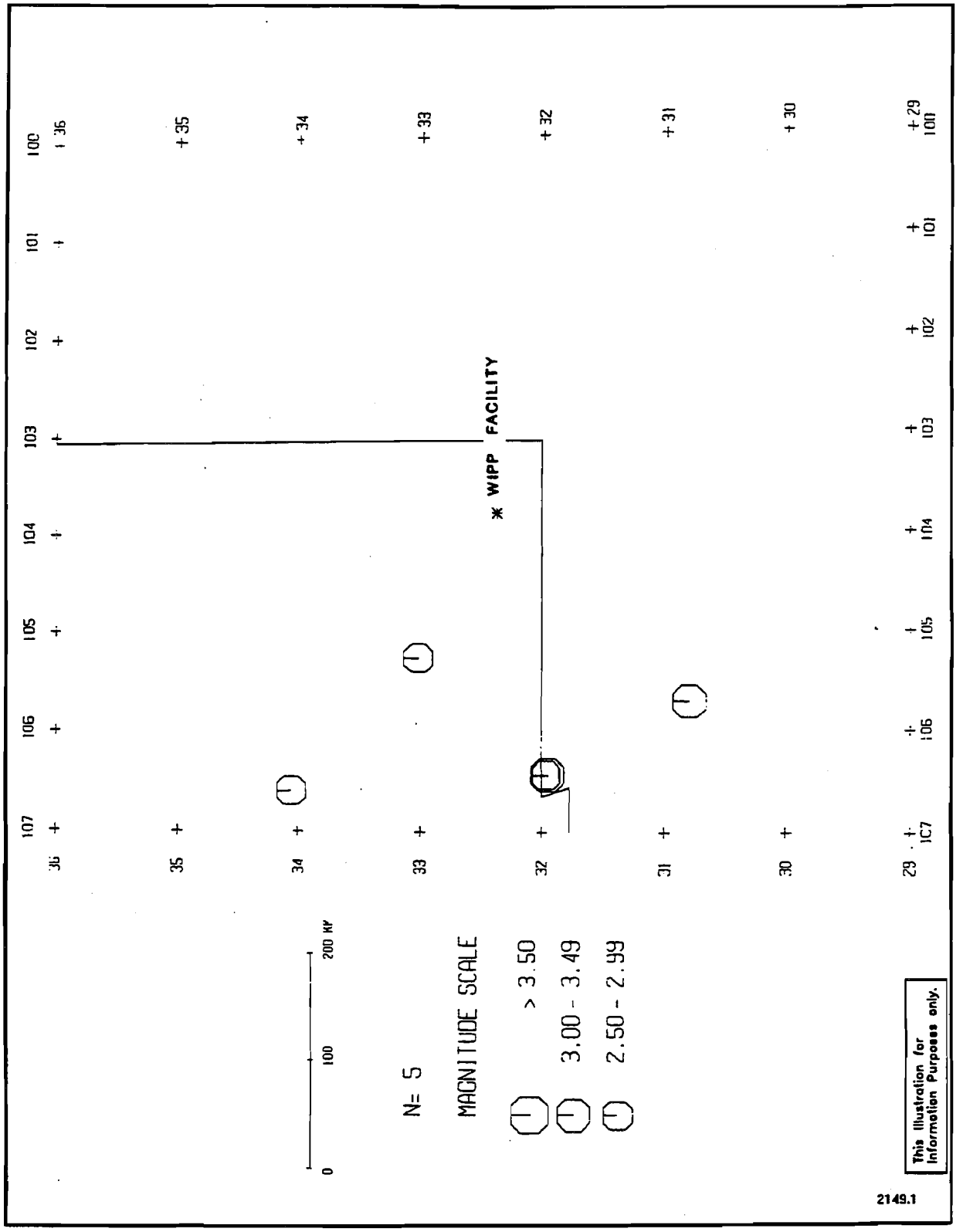


Figure 2.8-13, Epicenters for Located Earthquakes with M≥2.5: 10 March 1968 through 13 April 1971

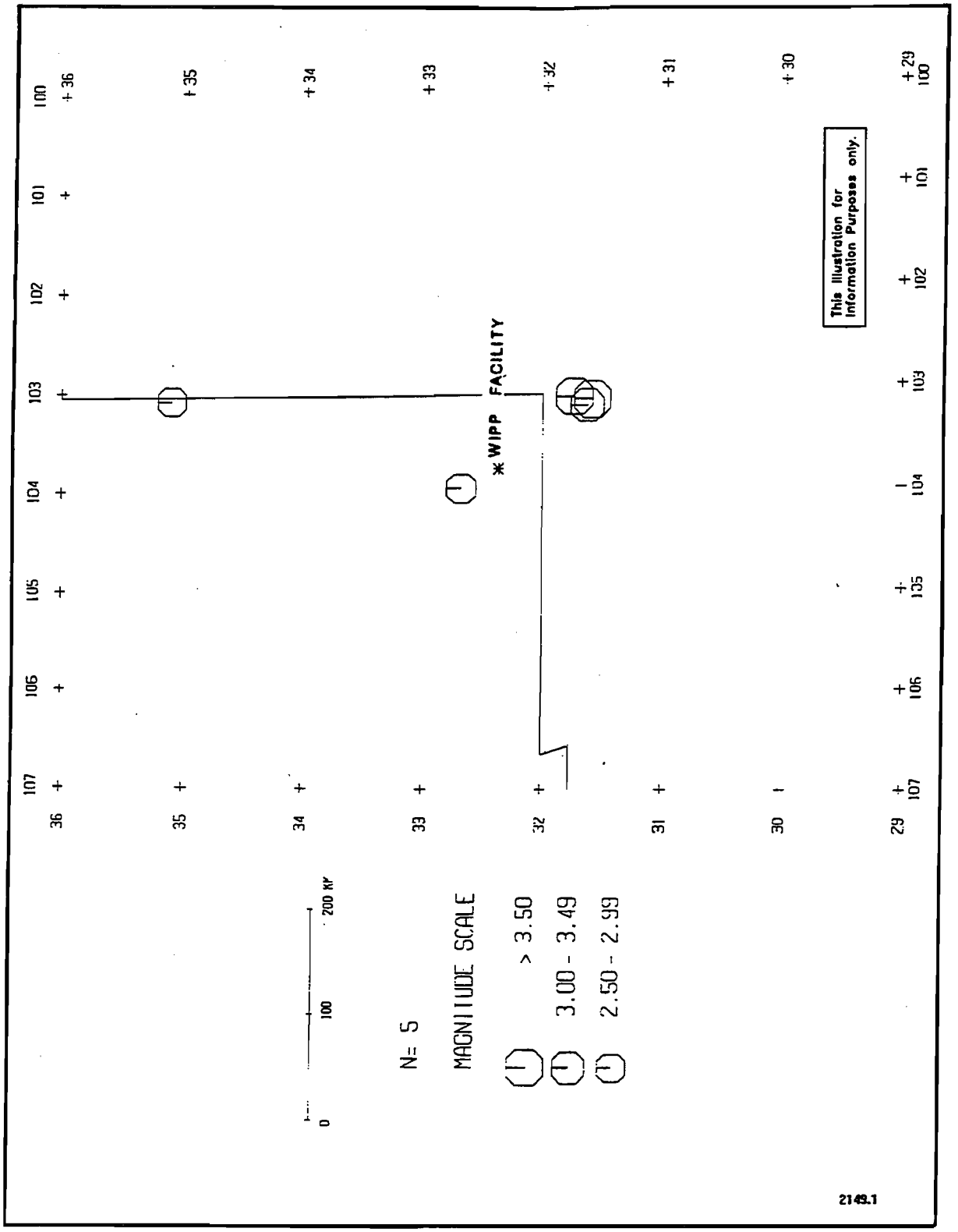


Figure 2.8-14, Epicenters for Located Earthquakes with M≥2.5: 14 April 1971 through 17 May 1974

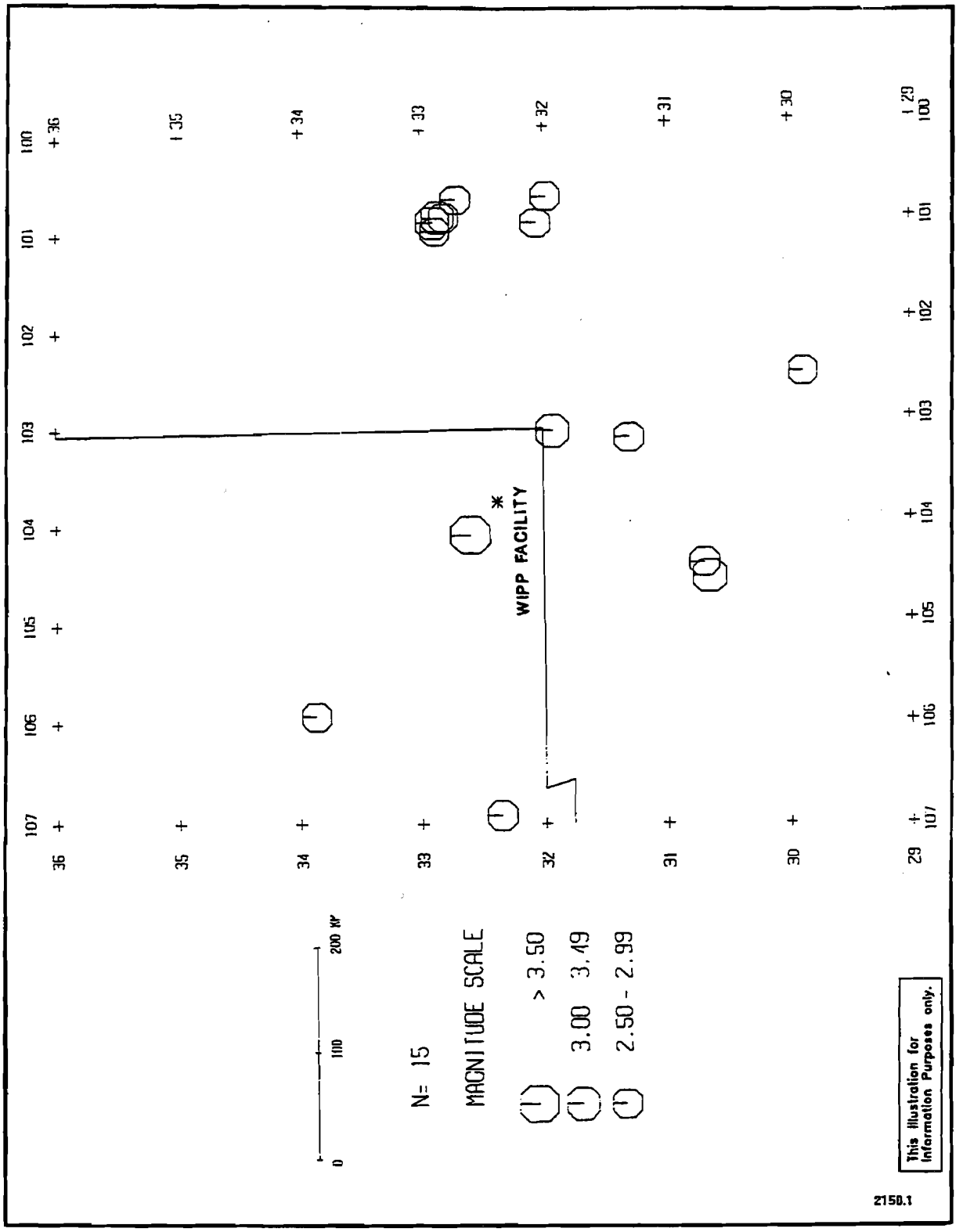


Figure 2.8-15, Epicenters for Located Earthquakes with M≥2.5: 25 July 1980 through 28 August 1983

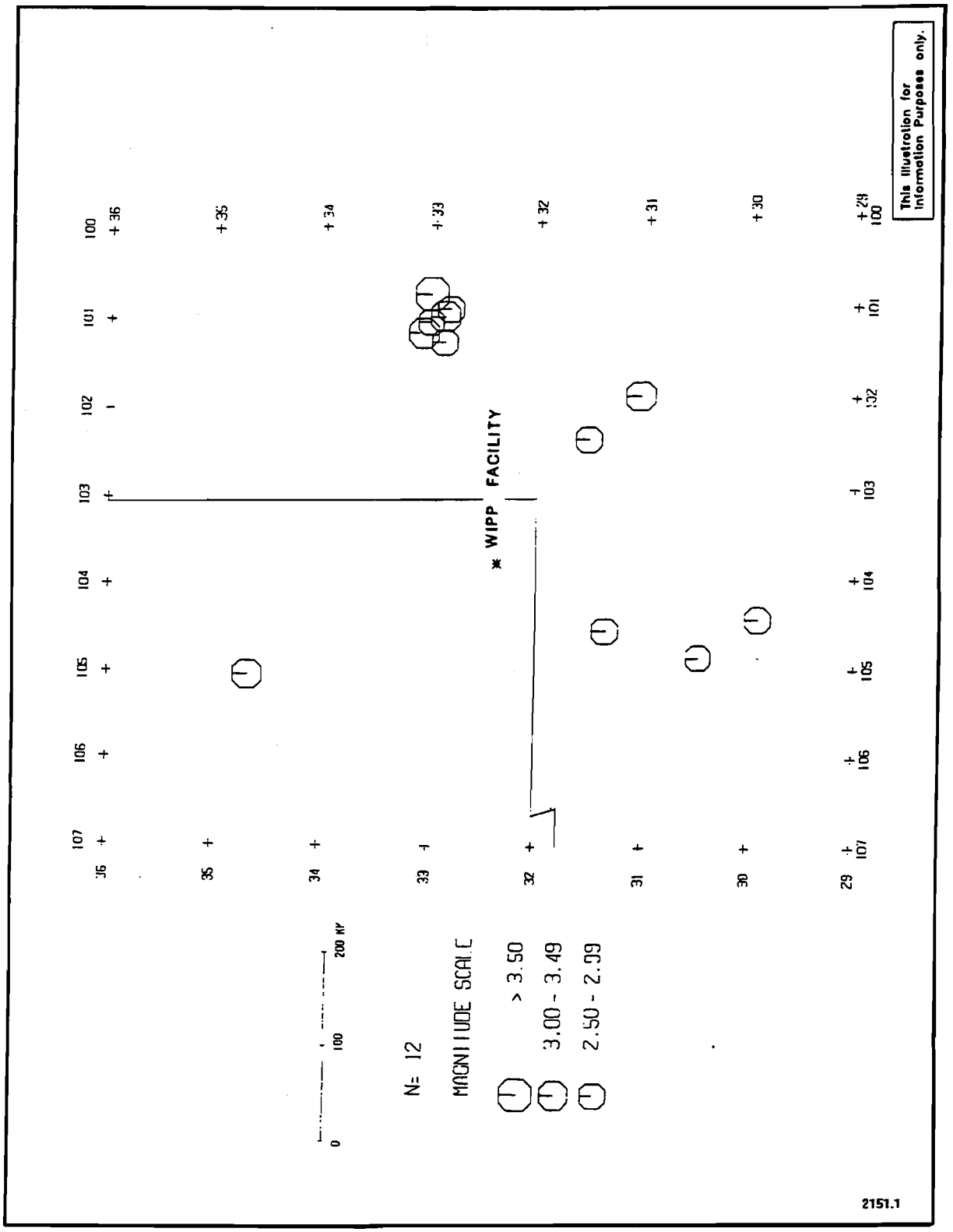


Figure 2.8-16, Epicenters for Located Earthquakes with M≥2.5: 22 June 1977 through 24 July 1980

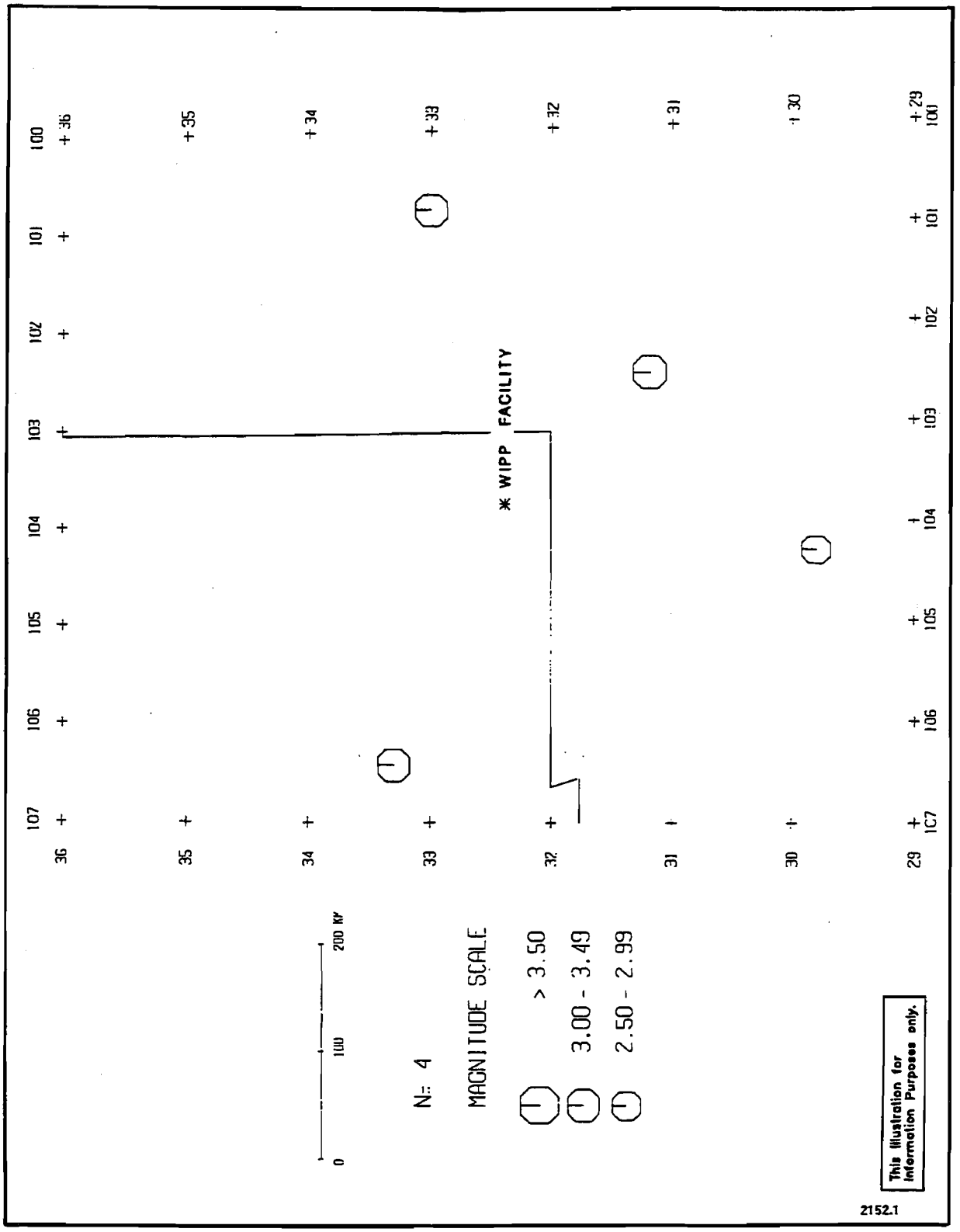


Figure 2.8-17, Epicenters for Located Earthquakes with M≥2.5: 25 July 1980 through 28 August 1983

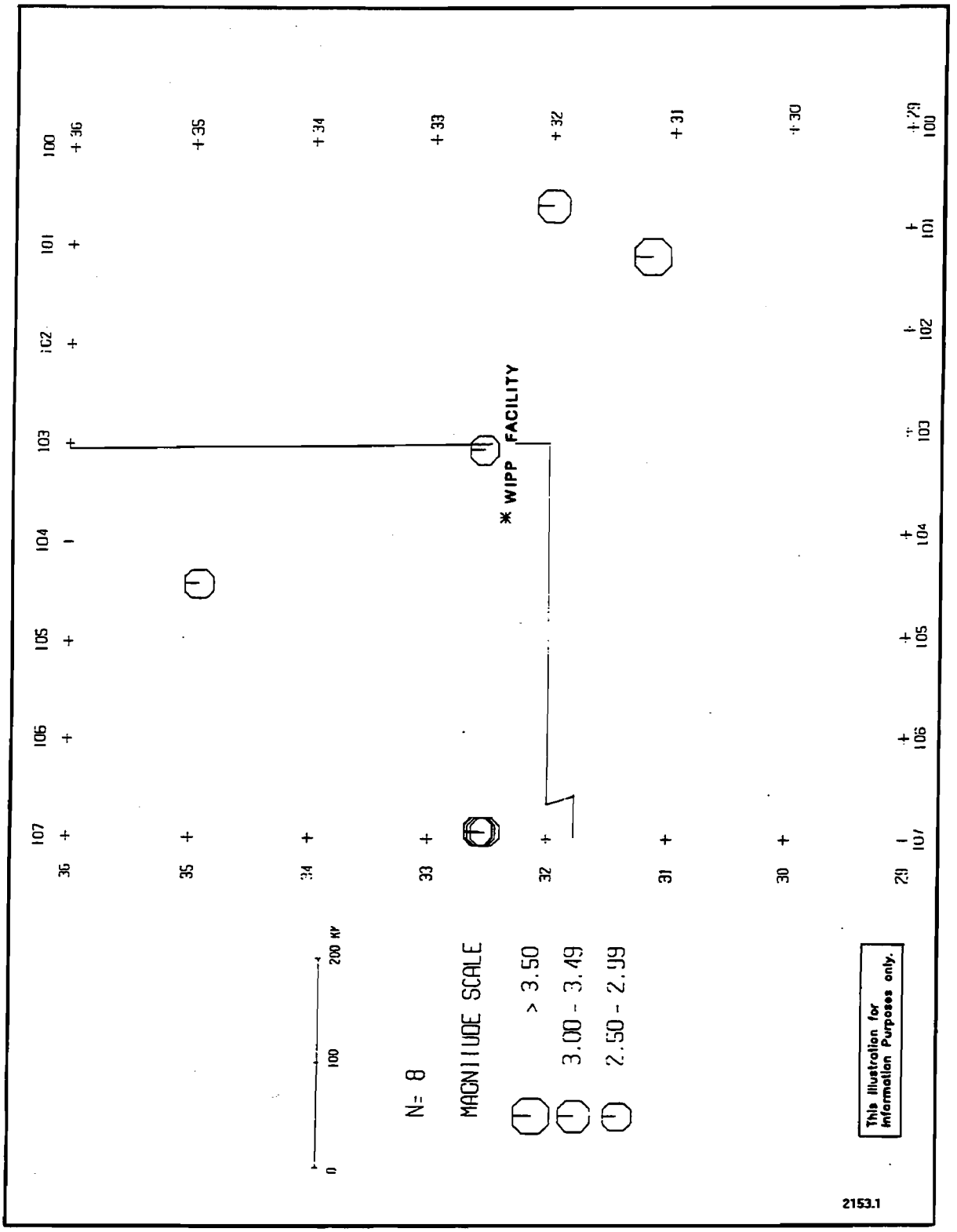


Figure 2.8-18, Epicenters for Located Earthquakes with M≥2.5: 29 August 1983 through 30 September 1986

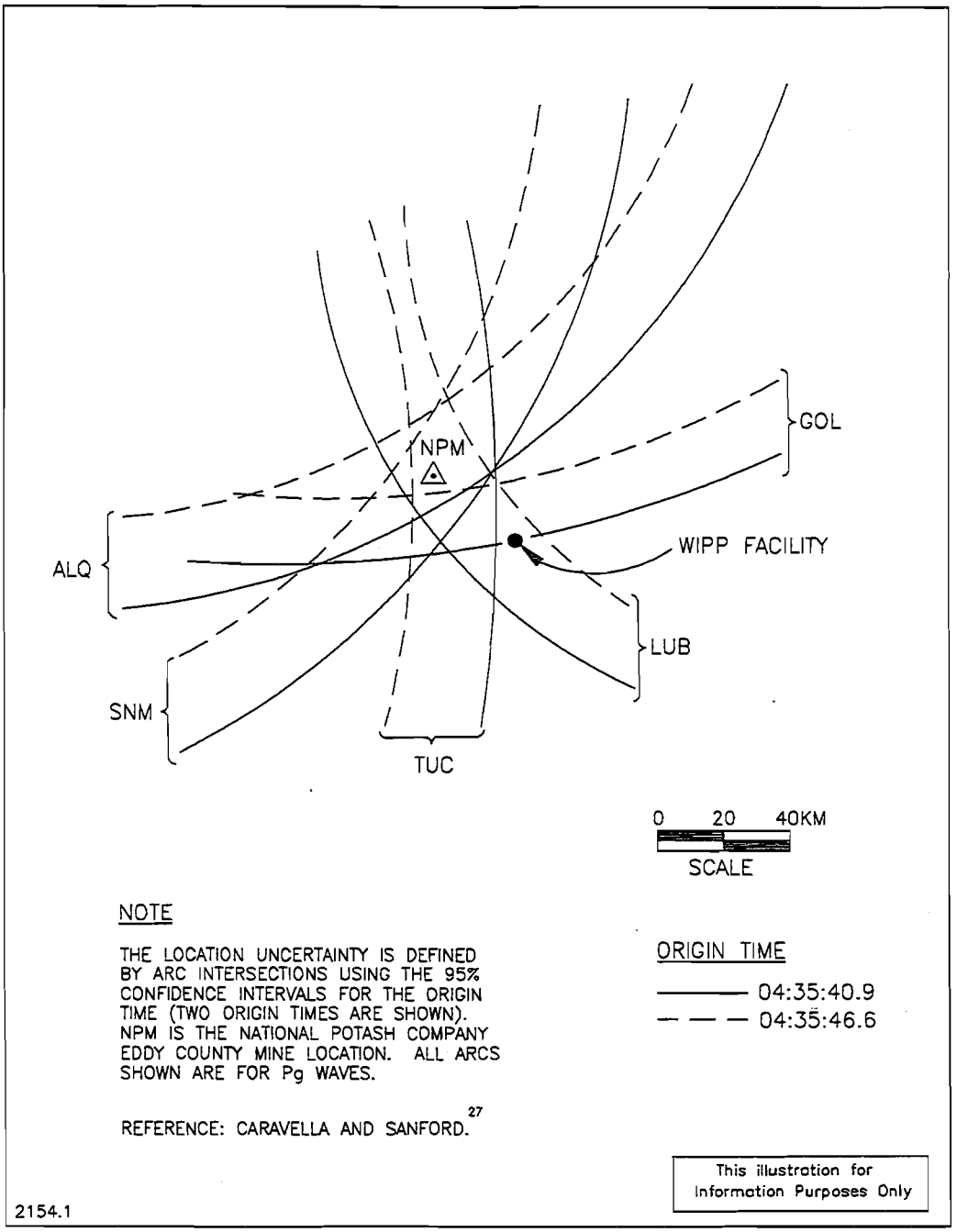


Figure 2.8-19, Location Uncertainty for the July 26, 1972 Event

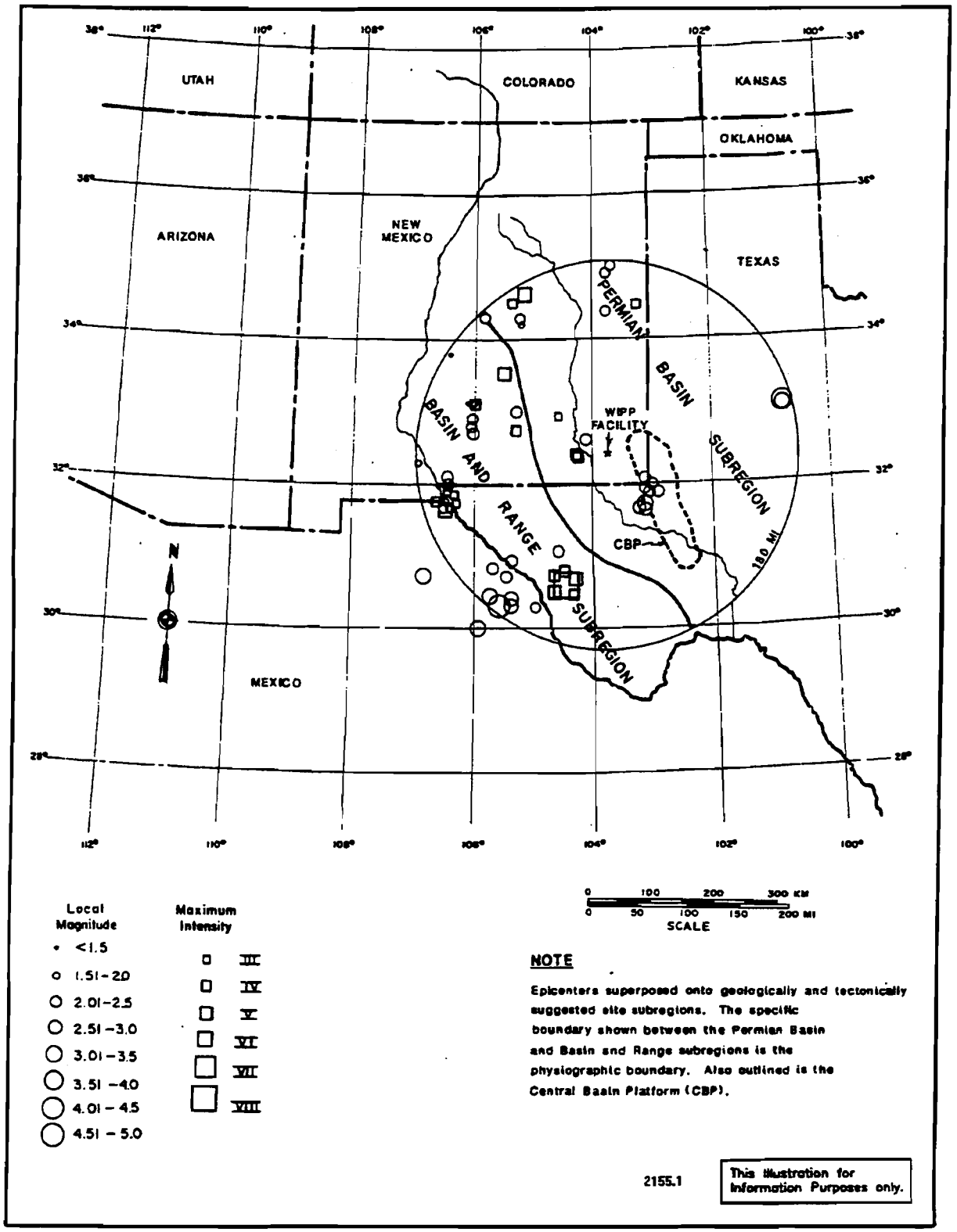


Figure 2.8-20, Earthquakes Located Using Macroseismic or Regional Seismographic Data 1923 - 1977 and Suggested Site Subregions

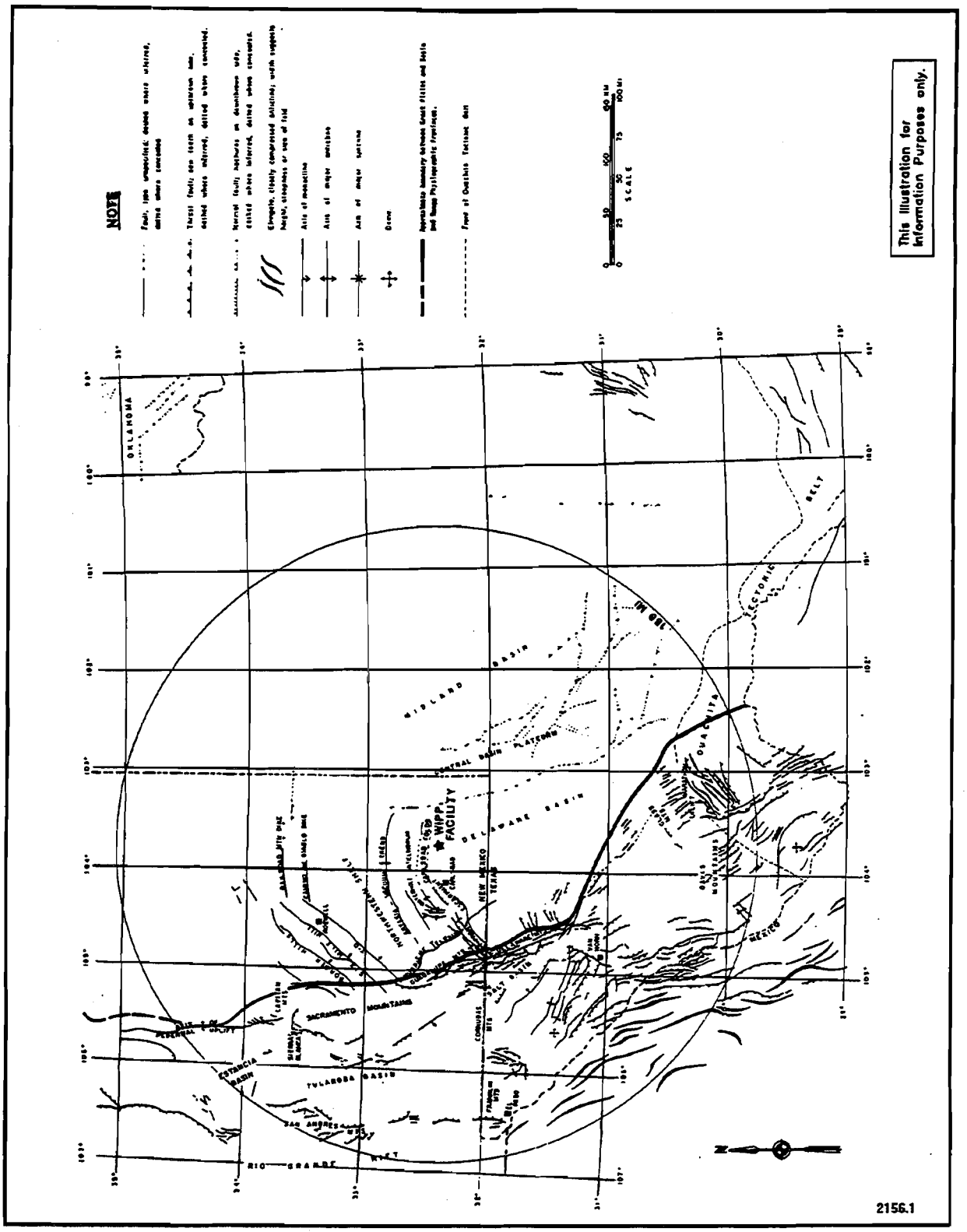
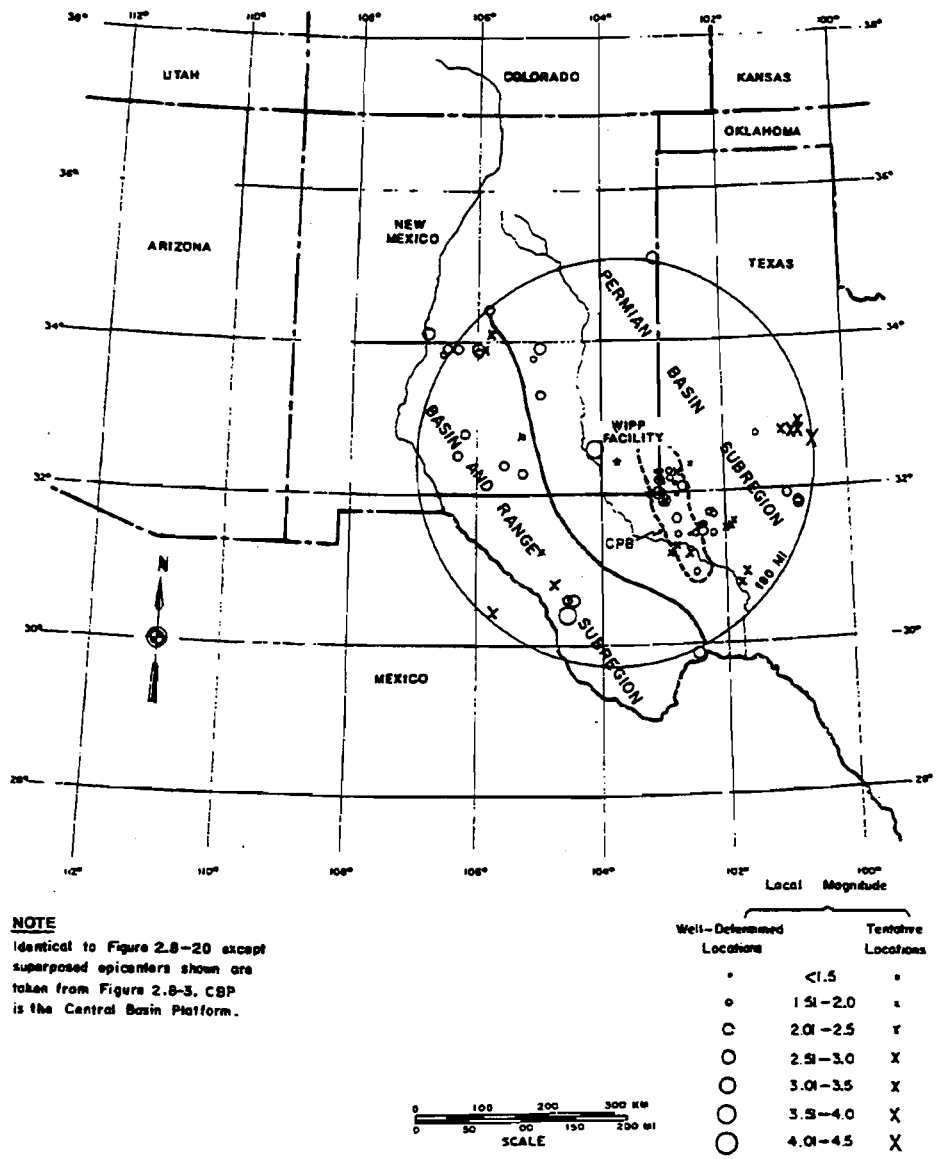


Figure 2.8-21, Site Region Structural Features and the Great Plains-Basin and Range Physiographic Boundary



NOTE
Identical to Figure 2.8-20 except superposed epicenters shown are taken from Figure 2.8-3. CBP is the Central Basin Platform.

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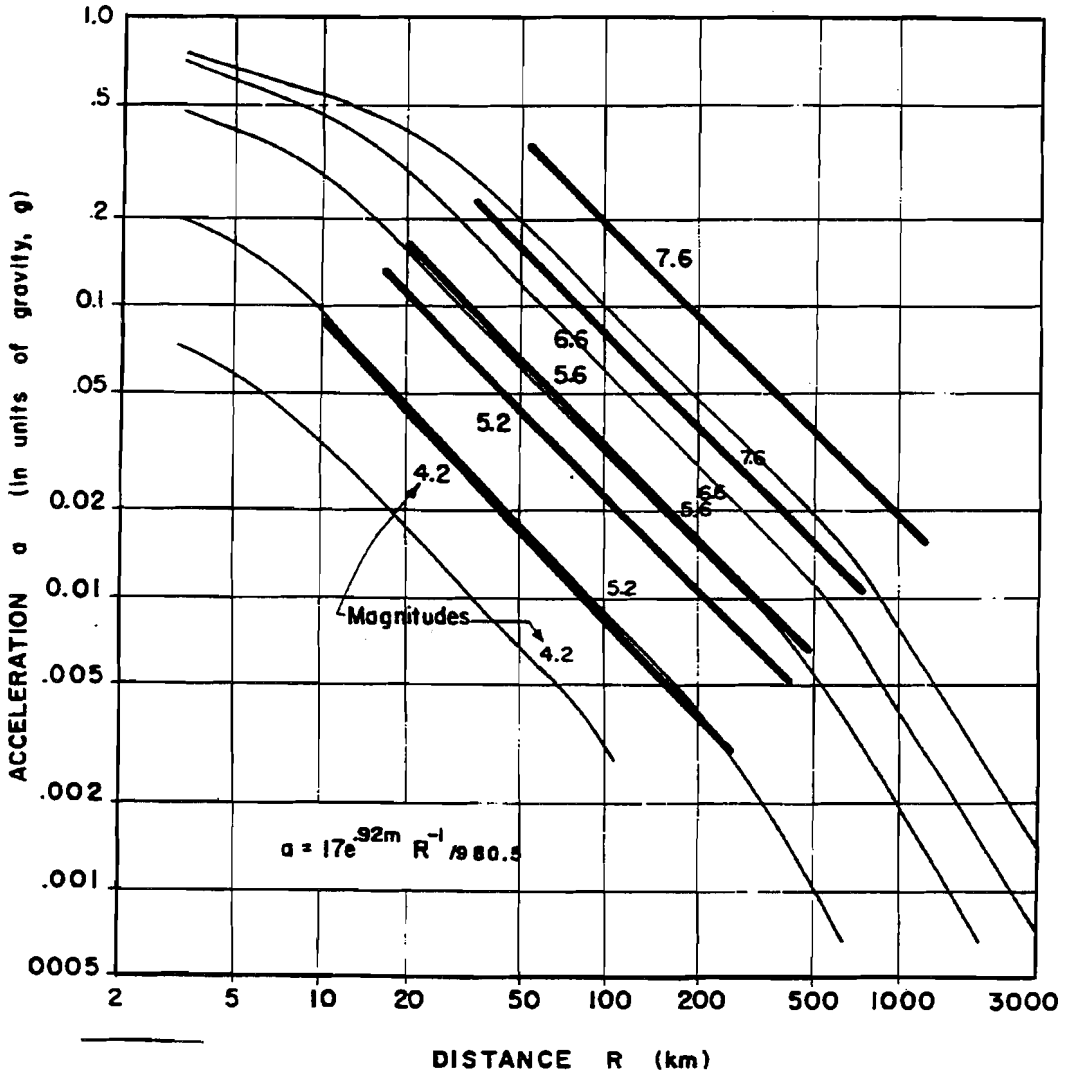
Figure 2.8-22, Earthquakes Located with the Help of Data from Station CLN and Suggested Site Subregions



NOTE

Comparison of acceleration attenuation curves for various magnitudes for areas of the United States east of 105°W longitude after Algermissen and Perkins [32] (light lines) with those used in the site hazard analysis of this report (heavy lines). The equation for the recommended attenuation curves is shown in the inset.

2158.1

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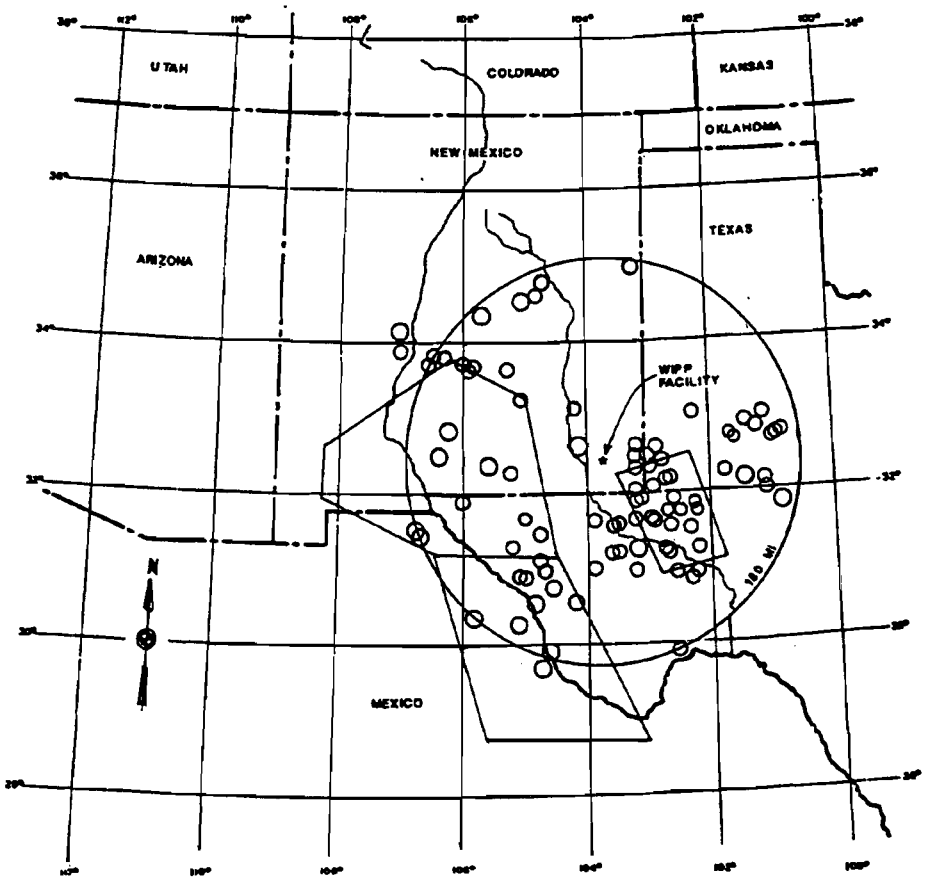
Figure 2.8-23, Recommended Attenuation Curves



NOTE

Seismic source zones as taken from Algermissen and Perkins[82]. The numbering of the three zones shown is in conformity with that study. For purposes of discussion Zones 43 and 45 are the Southern Basin and Range-Rio Grande rift source zones (northern and southern region respectively). Zone 46 is the Central Basin platform source zone. Earthquake epicenters are exactly as shown in Figures 2.8-1 and 2.8-3 of this report. All information concerning them may be found in the explanation for that figure.

Local Magnitude

Well-Determined Locations

- > 3.50
- 2.50 - 3.49
- 1.50 - 2.49
- 0.50 - 1.49

0 100 200 300 KM

0 50 100 150 200 MI

SCALE

2159.1

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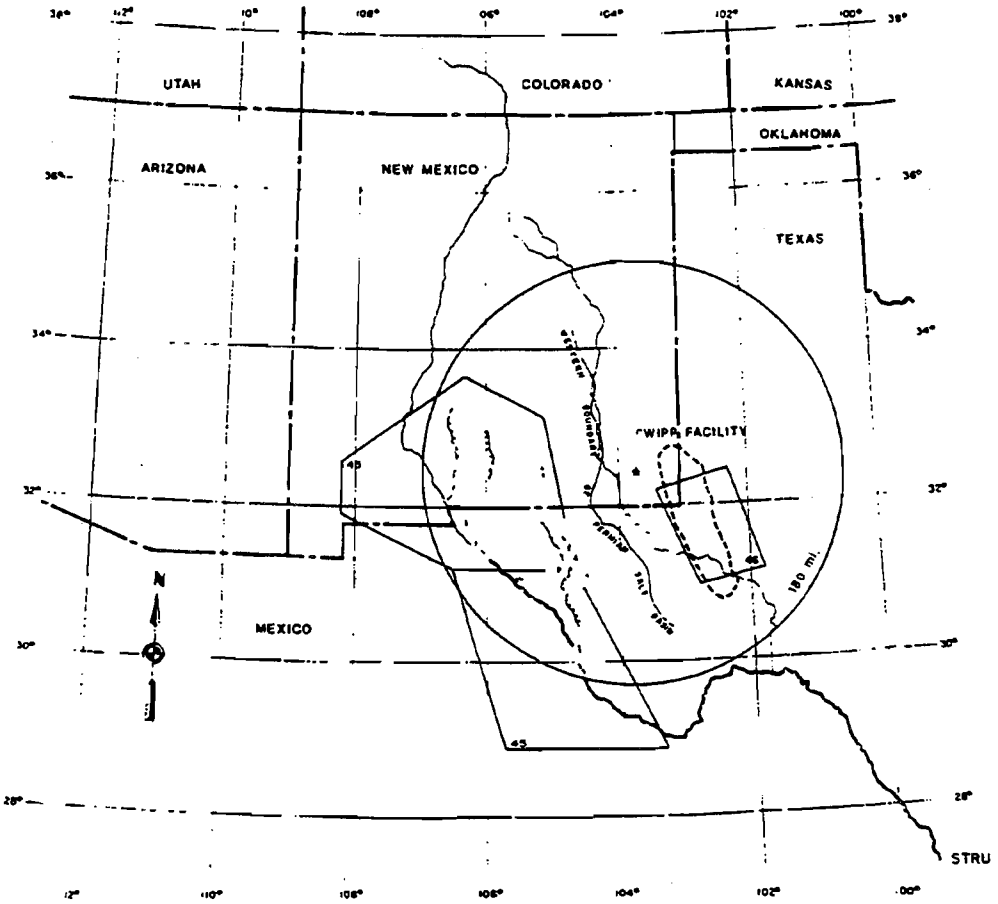
Figure 2.8-24, Algermissen and Perkins Seismic Source Zones



NOTE

Seismic source zones are as shown in Figure 2.8-24. Plotted Quaternary faulting features are taken from Sanford and Toppozada[1] and Muehlberger et al.[46] The western boundary of the Permian Salt Basin as taken from the earlier study is also shown. The outline of the Central Basin Platform (CBP) is taken from Rogers and Malkiel.[23]

SCALE

2160.1

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Figure 2.8-25, Structural Features in the WIPP Site Region

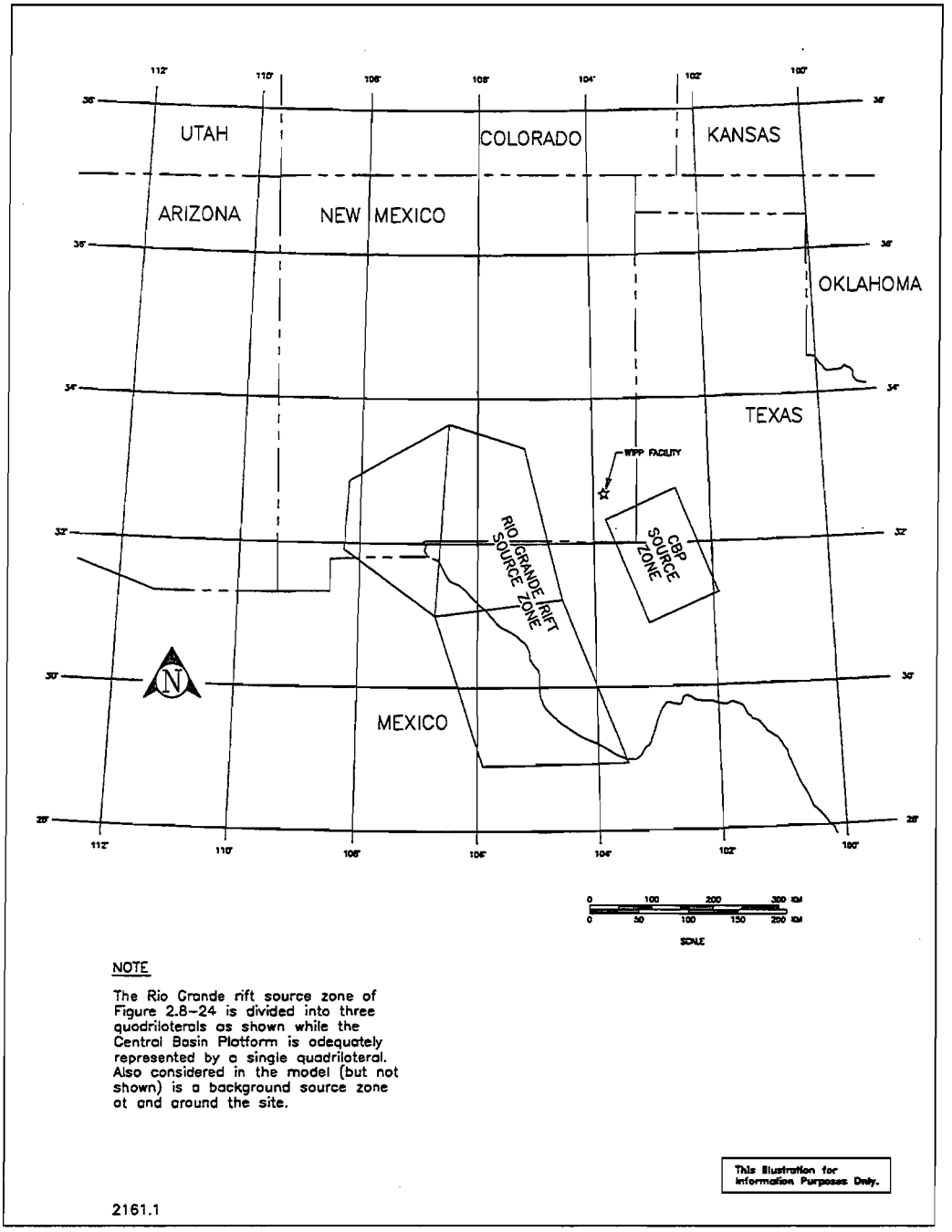

Figure 2.8-26, Quadrilateral Representation of Algermissen and Perkins Source Zones

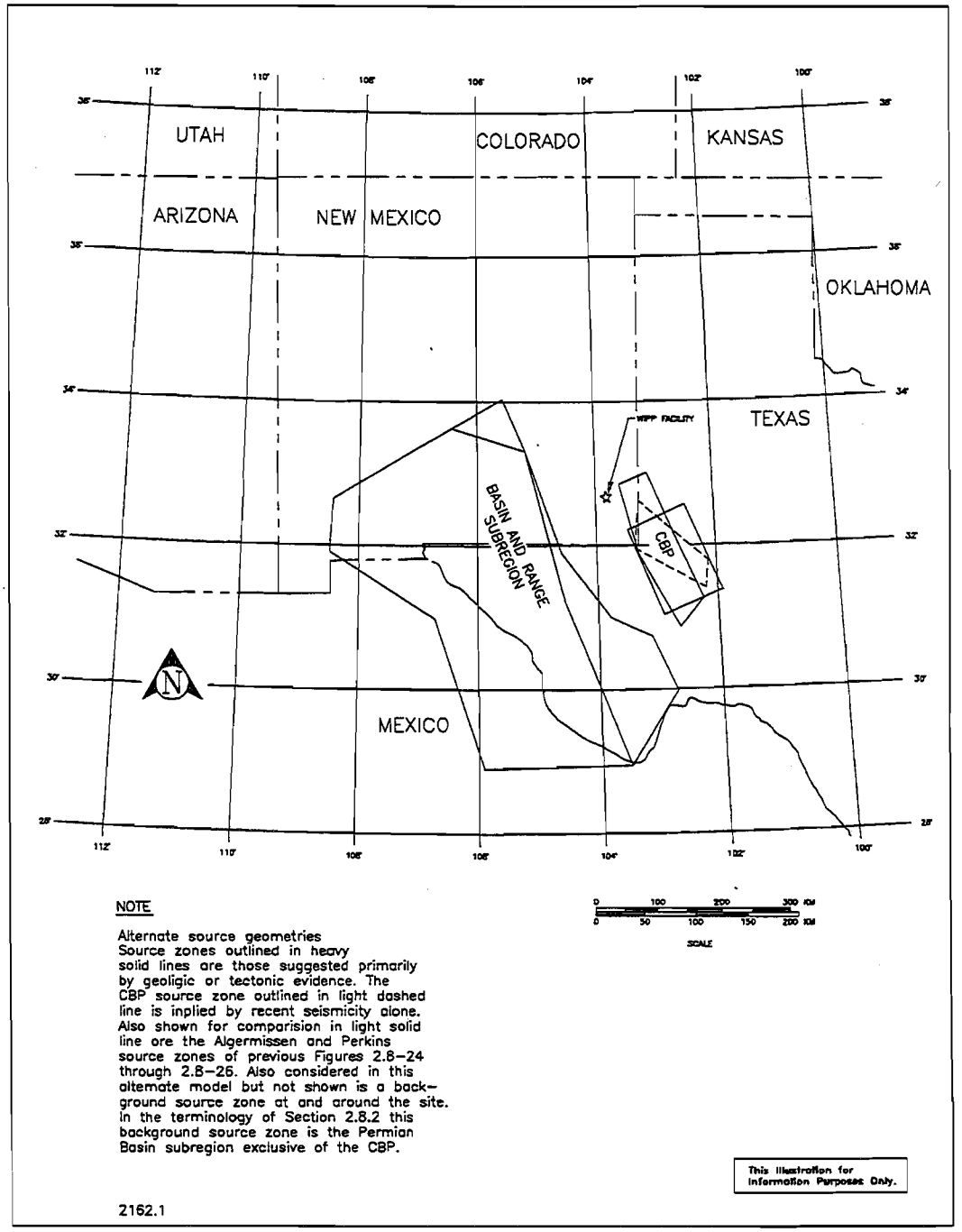

Figure 2.8-27, Alternate Source Geometries

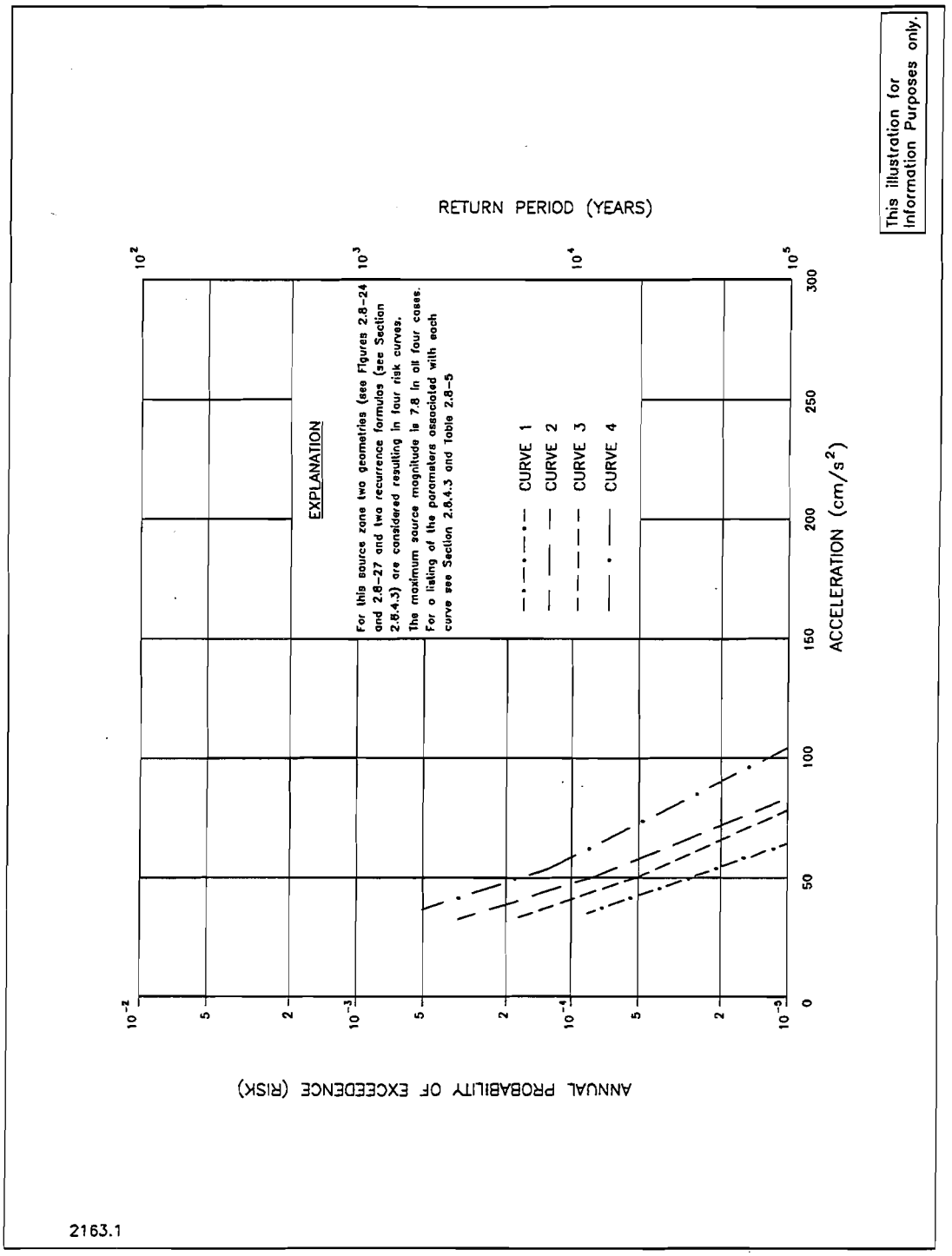

Figure 2.8-28, Risk Curves from Basin and Range or Rio Grande Rift Seismicity

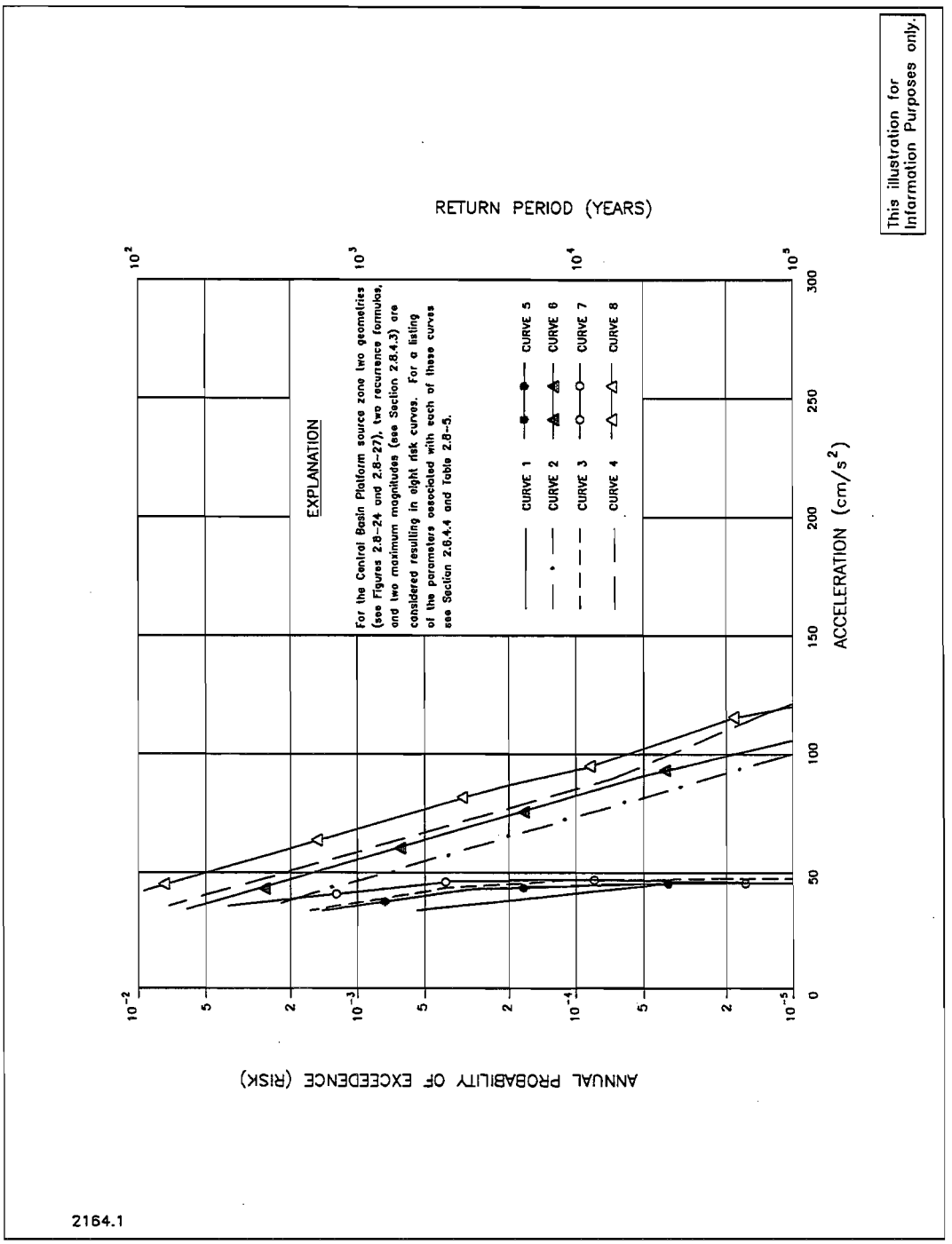

Figure 2.8-29, Risk Curves from Central Basin Platform Seismicity

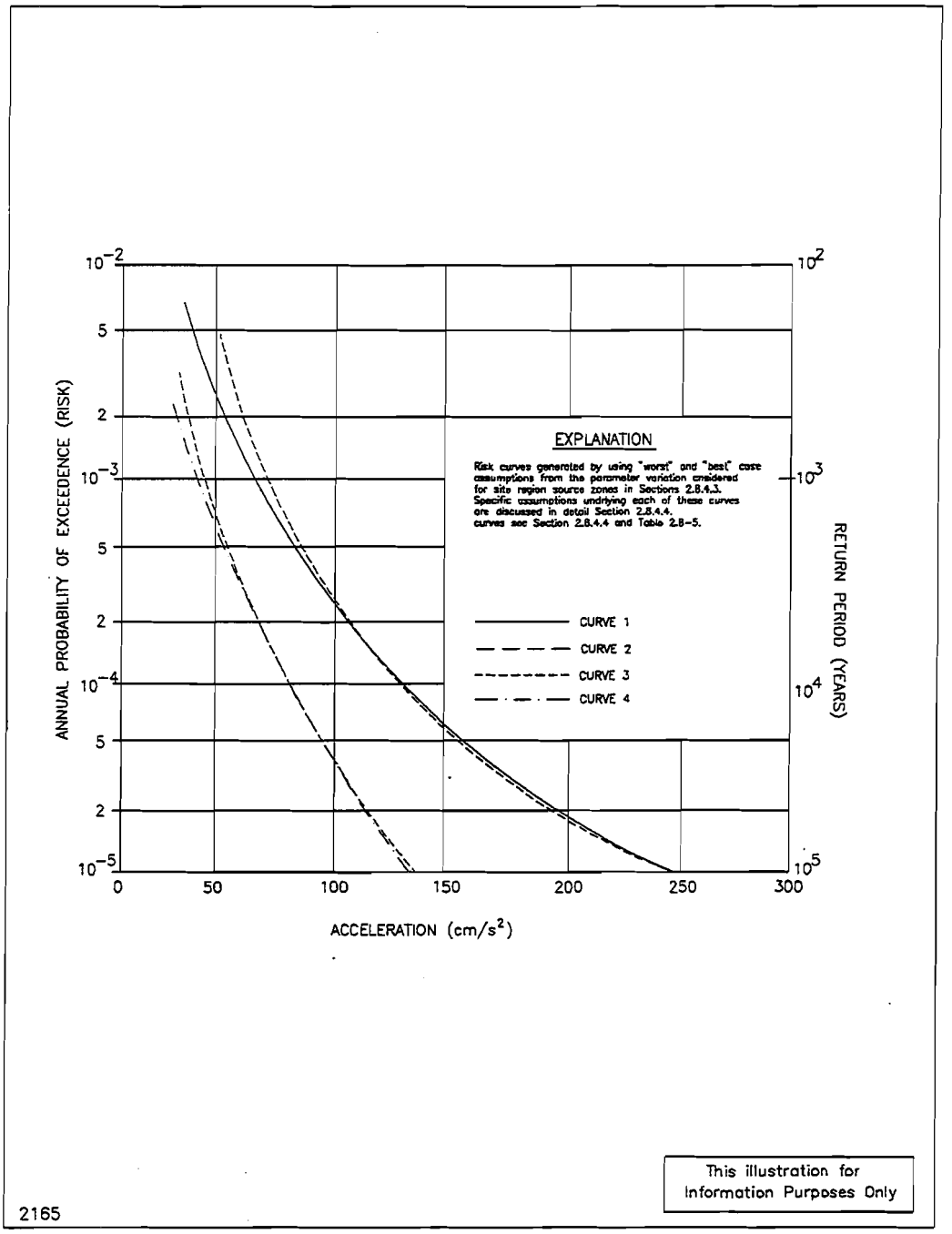

Figure 2.8-30, Risk Curves from WIPP Facility Source Zone Seismicity

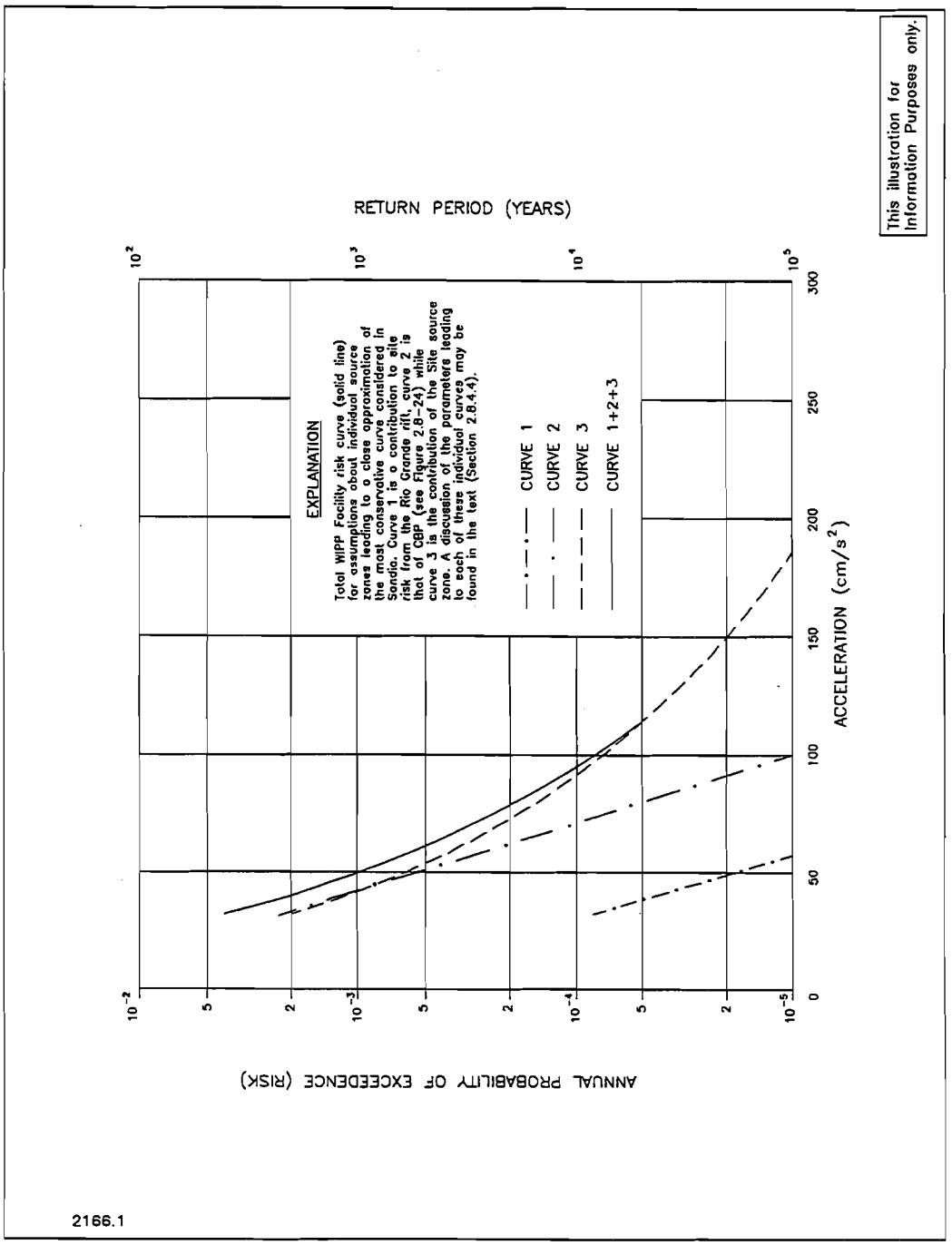

Figure 2.8-31, Generation of Total WIPP Facility Seismic Risk Curve Individual Source Risk Curves

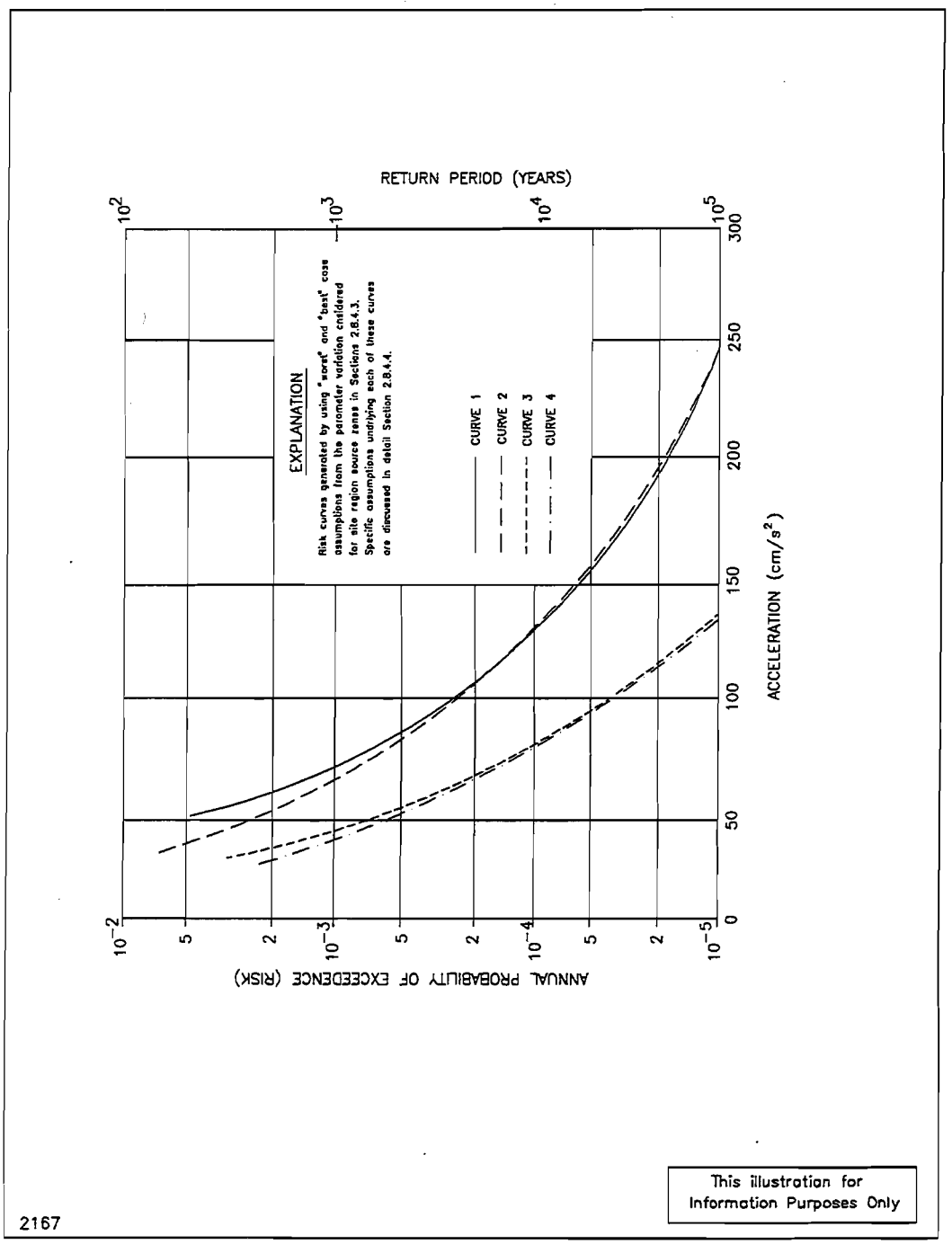

Figure 2.8-32, Total WIPP Facility Risk Curve Extrema

Table 2.8-1, Earthquakes Occurring Before 1962 and Centered Within 300 Km of the WIPP Facility*

Date Yr/Mo/Day	Origin Time, GMT	Location	Intensity	Distance
23/03/07	04:03	El Paso, Tex.	V	260
26/07/17	22:00	Hope and Lake Arthur, N.M.	III	90
30/10/04	03:25	34.5°N 105.4°W	(IV)	280
31/08/16	11:40	Valentine, Tex.	VIII	210
31/08/16	19:33	Valentine, Tex.	(V)	210
31/08/18	19:36	Valentine, Tex.	V	210
31/08/19	01:36	Valentine, Tex.	(V)	210
31/10/02	?	El Paso, Tex.	(III)	260
31/11/03	14:50	29.9°N 104.2°W	(V)	295
35/12/20	05:30	34.4°N 103.2°W	III-IV	230
36/01/08	06:46	Carlsbad, N.M.	(IV)	40
36/08/08	01:40	El Paso, Tex.	(III)	260
36/10/15	18:00	El Paso, Tex.	(III)	260
37/03/31	22:45	El Paso, Tex.	(IV)	260
37/09/30	06:15	Ft. Stanton, N.M.	(V)	200
43/12/27	04:00	Tularosa, N.M.	IV	220
49/02/02	23:00	Carlsbad, N.M.	(IV)	40
49/05/23	07:22	34.6°N 105.2°W	VI	280
52/05/22	04:20	Dog Canyon, N.M.	IV	158
55/01/27	00:37	Valentine, Tex.	IV	210

* A.R. Sandord and T.R. Toppozada, "Seismicity of Proposed Radio- active Waste Isolation Disposal Site in Southeastern New Mexico," New Mexico Bureau of Mines and Mineral Resources, Circ. 143, pp. 1-15 (1974).

Table 2.8-2, Modified Mercalli Intensity Scale of 1931*

(Abridged)

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel scale.)

II. Felt only by a few persons at rest, expecially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale.)

III. Felt quite noticeably indoors, expecially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. (IV to V Rossi-Forel scale.)

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale.)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII Rossi-Forel scale.)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures.

Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars. (VIII+ to IX Rossi-Forel scale.)

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX Rossi-Forel scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel scale.)

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed, broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

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* H.O. Wood and F. Neumann, "Modified Mercalli Intensity Scale of 1931," Seismal. Soc. Am. Bull., 21, pp. 277-283 (1931).

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
62 03 03	18:16:48.1	33.80	106.40	X						1.2
62 03 06	09:59:09.7	31.08	104.55	X						2.9
62 03 22	04:23:53.4	34.25	106.51	X						1.7
62 04 09	23:42:58.0	34.21	106.44	X						1.8
62 09 01	16:15:07.9	34.16	106.66	X						3.0
63 02 22	07:02:08.1	32.42	106.99	X						2.5
63 02 22	08:53:18.1	32.45	106.94	X						1.5
63 03 08	06:16:40.0	32.95	107.08	X						1.6
63 06 02	05:07:34.6	34.23	106.46	X						2.0
63 12 19	16:47:28.4	35.14	104.13	X						2.9
63 12 30	08:48:14.6	34.03	106.54	X						1.7
64 02 11	09:24:31.0	34.35	103.73	X						2.5
64 03 03	01:26:26.6	34.97	103.59	X						2.2
64 06 18	20:20:18.5	33.14	106.10	X						1.2
64 06 19	05:28:38.8	33.09	105.95	X						1.7
64 11 08	09:26:00.5	31.93	102.98	X						2.9
64 11 21	11:21:23.8	31.92	102.98	X						2.6
65 02 03	11:32:34.4	35.10	103.80	X						2.9
65 02 03	19:59:32.4	31.92	102.96	X						3.2
65 05 27	18:50:53.9	33.88	106.73	X						2.0
65 05 27	18:58:40.9	33.90	106.71	X						2.0
65 05 29	13:01:08.2	33.87	106.69	X						2.0
65 07 28	03:52:07.4	33.80	106.70	X						2.6
65 08 30	05:17:29.8	31.92	102.98	X						2.7
66 08 14	15:25:47.1	31.92	102.98	X						3.1
66 08 17	18:47:21.0	30.71	105.98	X						2.9
66 08 19	04:15:44.6	30.30	105.60		X					4.8
66 08 19	08:38:21.9	30.30	105.60		X					3.8
66 09 17	21:30:13.0	34.94	103.71	X						2.2
66 11 26	20:05:41.0	30.86	105.36	X						3.0
66 11 28	02:20:57.3	30.40	105.40		X					3.5
66 12 05	10:10:37.8	30.40	105.40		X					3.5
67 09 29	03:52:48.0	32.27	106.91	X						2.0
68 03 09	21:54:25.7	32.70	106.05	X						2.9
68 03 23	11:53:38.7	32.70	106.05	X						2.2
68 05 02	02:56:43.8	33.02	105.27	X						2.6
68 08 22	02:22:25.5	34.33	105.80	X						2.0
69 05 12	08:26:18.5	31.95	106.44	X						3.2
69 05 12	08:49:16.3	31.96	106.44	X						2.8
69 06 01	17:18:24.2	34.23	105.18	X						2.0
69 06 08	11:36:01.9	34.23	105.18	X						2.4
69 10 19	11:51:34.4	30.80	105.70		X					3.4
71 01 27	07:56:28.3	34.06	106.60	X						2.6
71 03 25	02:43:02.4	34.58	106.03	X						1.7
71 07 30	01:45:50.3	31.74	103.09	X						3.7
71 07 31	14:53:48.0	31.59	103.12	X						3.6
71 09 24	01:01:54.0	31.63	103.18	X						3.0
72 02 27	15:50:03.9	32.89	106.04	X						2.2
72 07 26	04:35:43.9	32.68	103.98	X						2.9

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
72 12 09	05:58:38.9	31.68	106.44	X						2.2
72 12 10	14:37:50.2	31.68	106.41	X						2.2
72 12 10	14:58:02.5	31.65	106.48	X						1.9
74 02 02	20:39:22.6	35.10	103.10	X						2.9
74 07 31	17:34:48.5	33.12	104.18	X						1.8
74 08 17	07:35:17.3	30.30	105.77	X						2.4
74 08 26	07:33:21.5	34.44	105.79	X						2.3
74 09 26	23:44:08.5	32.81	106.16	X						1.9
74 10 02	02:40:20.0	31.98	100.71	X						2.6
74 10 27	16:18:53.9	30.53	104.79	X						2.2
74 11 01	10:45:49.6	33.80	106.60	X						2.0
74 11 12	02:31:59.0	32.06	100.98	X						2.5
74 11 12	02:35:34.2	32.13	102.67	X						1.8
74 11 12	07:14:27.7	31.93	100.72	X						2.2
74 11 21	16:22:58.6	32.53	106.25	X						1.9
74 11 21	18:59:05.8	32.10	102.69	X						2.3
74 11 22	08:54:00.1	32.99	101.14	X						1.9
74 11 22	14:11:13.2	33.81	105.15	X						1.5
74 11 28	03:35:20.5	32.59	104.12	X						3.7
75 01 30	16:00:39.9	31.15	102.85	X						2.1
75 04 08	15:29:42.4	32.18	101.70	X						1.6
75 04 20	16:59:56.4	31.29	102.60	X						2.0
75 07 25	08:11:40.0	29.88	102.54	X						2.8
75 08 01	07:27:41.2	30.65	104.57	X						3.2
75 08 03	03:26:53.1	31.04	103.97	X						1.9
75 10 10	11:16:55.5	33.35	104.99	X						1.9
76 01 10	01:49:58.5	31.74	102.75	X						1.9
76 01 15	20:43:57.6	30.95	102.31	X						1.8
76 01 19	04:03:31.4	31.95	103.10	X						2.4
76 01 21	23:11:17.2	30.90	102.29	X						1.7
76 01 22	07:21:57.7	31.92	103.05	X						2.0
76 01 25	04:48:27.3	31.93	103.09	X						3.1
76 01 28	07:37:54.7	32.29	101.27	X						2.1
76 02 04	16:15:30.0	31.67	103.54	X						1.3
76 02 14	05:35:22.1	31.61	102.47	X						1.6
76 02 19	08:23:58.4	31.60	103.66						X	1.2
76 02 19	08:45:31.5	31.63	103.67						X	1.2
76 02 19	09:23:36.6	31.65	103.66						X	1.0
76 03 05	02:58:18.0	31.92	102.59	X						2.1
76 03 20	12:42:20.4	31.26	104.95	X						1.8
76 03 20	16:15:58.1	32.20	103.10	X						1.7
76 03 27	22:25:21.9	32.21	103.10	X						1.7
76 04 01	14:40:27.7	33.94	105.88	X						1.8
76 04 01	14:46:58.2	33.88	105.98	X						2.2
76 04 01	14:51:16.5	33.94	105.87	X						1.3
76 04 03	20:40:51.4	31.30	103.17	X						2.5
76 04 06	18:09:00.3	33.88	105.93	X						2.6
76 04 12	08:02:34.9	32.25	103.11	X						1.5
76 04 18	03:48:18.5	32.88	105.94	X						1.6

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
76 04 21	08:40:07.5	32.23	103.06	X						1.8
76 04 30	19:28:34.8	31.96	103.20	X						1.5
76 04 30	19:51:12.5	31.91	103.32	X						1.5
76 05 01	11:13:40.1	32.34	103.11	X						2.3
76 05 03	06:52:59.3	32.52	105.52	X						2.0
76 05 03	08:00:38.9	32.03	103.14	X						1.3
76 05 03	11:27:39.3	32.03	103.06	X						1.2
76 05 06	17:18:24.0	31.95	103.20	X						1.8
76 05 06	17:28:45.1	31.90	103.17	X						1.1
76 05 08	11:46:40.8	31.97	103.12	X						1.0
76 05 11	23:04:40.2	32.25	102.96	X						1.9
76 05 21	13:17:27.8	32.41	105.72	X						2.0
76 06 14	23:29:59.5	31.59	102.59	X						1.7
76 06 15	02:19:56.3	31.55	102.29	X						1.7
76 06 15	08:50:20.6	31.56	102.42	X						2.2
76 07 28	12:21:50.6	33.03	102.30	X						1.9
76 08 05	18:53:09.2	31.57	103.02						X	2.2
76 08 06	21:12:38.6	31.78	102.59						X	1.8
76 08 10	09:03:14.3	31.83	102.42	X						1.7
76 08 10	09:12:28.6	31.77	102.61						X	1.3
76 08 10	10:15:18.7	31.79	102.54	X						2.0
76 08 15	19:12:04.3	30.14	105.22	X						2.2
76 08 25	01:21:23.5	31.65	102.88	X						1.1
76 08 25	01:27:47.5	31.57	102.42	X						2.0
76 08 26	15:22:18.1	31.79	102.57	X						1.6
76 08 29	19:49:24.4	30.12	105.23	X						2.1
76 08 30	11:51:24.8	31.57	102.58	X						1.8
76 08 30	13:07:47.5	33.89	106.29	X						1.6
76 08 31	12:46:22.2	31.57	102.81	X						2.0
76 09 03	21:00:24.7	31.55	103.48						X	1.7
76 09 05	10:39:43.4	32.26	102.62	X						1.1
76 09 05	16:10:27.7	31.61	103.31						X	1.4
76 09 10	19:18:43.4	31.91	103.09						X	1.5
76 09 17	02:47:46.5	32.20	103.10	X						2.2
76 09 17	03:56:29.5	31.46	102.52	X						2.3
76 09 19	10:23:23.3	32.14	103.10	X						1.2
76 09 19	10:40:48.0	30.69	104.43	X						2.7
76 10 14	11:02:59.0	32.29	102.98	X						1.2
76 10 22	05:06:11.1	31.57	102.17	X						2.0
76 10 23	12:51:35.8	31.59	102.32	X						1.5
76 10 25	00:27:04.8	31.83	102.65	X						2.1
76 10 25	10:52:27.3	31.85	102.40						X	1.3
76 10 26	10:44:44.1	31.33	103.28						X	2.0
76 11 03	23:24:06.4	30.86	101.88	X						1.8
76 12 12	23:00:14.2	31.52	102.50	X						2.4
76 12 12	23:25:57.6	31.57	102.61	X						1.5
76 12 15	08:51:45.1	31.64	102.75	X						1.1
76 12 18	18:27:45.7	31.62	103.02						X	1.5
76 12 19	21:26:15.8	31.78	102.56	X						1.8

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
76 12 19	23:54:23.3	32.22	103.09	X						1.5
76 12 19	23:56:47.4	32.23	103.10						X	2.1
76 12 23	08:36:58.0	34.68	105.77	X						1.9
77 01 04	18:31:37.6	32.36	106.92		X					2.7
77 01 04	23:41:58.0	34.03	106.00				X			2.4
77 01 05	12:19:02.0	34.05	106.00				X			1.7
77 01 08	20:20:27.2	31.50	102.98						X	1.1
77 01 29	09:40:40.1	30.53	104.84	X						1.9
77 02 04	07:48:16.2	30.67	104.64	X						1.7
77 02 10	01:22:50.8	32.21	103.07	X						1.1
77 02 18	14:10:36.5	32.24	103.07	X						1.2
77 03 01	11:50:45.9	31.25	103.28						X	1.2
77 03 05	22:56:14.6	31.47	102.84	X						1.4
77 03 12	00:05:23.8	31.62	103.29						X	1.1
77 03 14	10:10:25.6	32.97	101.06	X						2.4
77 03 20	07:54:08.4	32.23	103.07	X						1.6
77 03 23	11:02:51.8	31.81	102.51						X	1.1
77 03 29	00:35:34.7	31.60	103.28	X						1.0
77 04 03	12:39:57.4	31.26	103.03						X	1.1
77 04 03	13:48:09.2	31.49	103.17						X	1.6
77 04 03	14:24:07.3	31.45	103.20	X						1.5
77 04 04	00:44:05.3	31.48	103.17						X	1.6
77 04 04	01:47:50.4	31.44	103.18						X	1.3
77 04 04	04:35:56.8	31.50	103.17						X	1.3
77 04 04	04:47:30.4	31.46	103.18	X						1.3
77 04 04	05:01:29.8	31.23	103.01						X	1.3
77 04 07	05:45:40.3	32.23	103.07	X						1.9
77 04 07	18:56:55.1	31.53	103.29	X						1.4
77 04 12	23:18:26.7	31.22	102.58	X						1.7
77 04 16	06:44:22.2	31.61	103.22	X						0.8
77 04 17	21:47:09.9	31.55	102.30	X						1.3
77 04 18	18:08:24.1	31.60	103.28	X						1.4
77 04 22	22:56:34.8	32.21	102.97	X						1.0
77 04 25	10:12:51.4	32.09	102.78	X						1.4
77 04 26	09:03:07.3	31.90	103.03	X						2.1
77 04 28	12:54:38.2	31.81	102.53	X						0.9
77 04 28	12:55:40.1	31.80	102.53	X						2.2
77 04 28	15:22:36.8	31.78	102.53	X						1.3
77 04 29	03:09:41.3	31.81	102.58	X						1.3
77 05 01	21:33:58.7	31.45	103.16						X	1.1
77 06 07	23:01:20.9	32.85	100.90	X						3.2
77 06 08	00:51:26.0	32.70	100.72	X						2.6
77 06 08	13:29:12.0	32.89	100.95	X						3.0
77 06 08	13:39:25.	32.8	100.9	X						2.6
77 06 17	03:37:05.9	32.87	101.04	X						2.7
77 06 28	23:59:46.6	31.54	103.30						X	2.0
77 07 01	01:06:19.2	31.50	103.34						X	1.7
77 07 05	10:40:27.4	31.60	102.10	X						1.7
77 07 11	12:31:55.7	31.79	102.69	X						1.7

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
77 07 11	13:29:49.7	31.77	102.68	X						1.3
77 07 11	17:19:37.6	30.98	104.90					X		1.2
77 07 12	17:06:06.8	31.78	102.72	X						1.5
77 07 18	12:37:31.7	31.77	102.76	X						1.8
77 07 22	04:01:10.6	31.80	102.75	X						1.9
77 07 22	04:18:10.7	31.79	102.71	X						1.5
77 07 22	04:36:50.8	31.77	102.69	X						0.9
77 07 24	09:23:00.7	31.79	102.70	X						1.5
77 07 26	02:01:08.7	31.78	102.68	X						0.7
77 07 28	12:17:17.8	31.10	105.02					X		1.1
77 07 28	23:35:43.1	31.00	104.91					X		1.0
77 08 01	16:44:51.1	30.97	104.92					X		1.0
77 08 06	20:43:59.7	31.04	104.96					X		1.2
77 08 09	16:07:00.5	31.04	104.65					X		1.1
77 08 12	07:49:11.4	31.40	103.45						X	1.2
77 08 20	02:29:22.2	31.60	103.33						X	1.5
77 08 21	03:01:09.7	30.48	104.86	X						2.6
77 10 13	21:36:11.0	32.74	100.75	X						2.2
77 10 17	21:24:43.2	31.57	102.46						X	1.5
77 10 24	22:50:04.6	31.54	102.51						X	1.3
77 10 25	01:02:32.2	31.52	102.51						X	1.0
77 10 29	00:49:11.6	30.50	104.19					X		1.1
77 11 05	12:28:53.7	31.08	104.97					X		1.1
77 11 14	07:26:27.4	31.60	104.90	X						2.2
77 11 27	20:48:18.1	33.03	101.08	X						2.5
77 11 28	01:40:50.3	32.90	101.02	X						3.4
77 12 07	23:14:19.5	31.56	102.51						X	1.2
77 12 16	11:56:41.9	31.57	102.54	X						1.4
77 12 21	01:36:20.9	31.49	102.36	X						1.4
77 12 29	10:50:55.0	31.62	103.26						X	1.2
77 12 31	13:19:04.5	31.60	102.46						X	1.7
78 01 02	10:10:47.1	31.60	102.53						X	1.8
78 01 12	14:55:02.3	31.45	102.18	X						1.9
78 01 15	23:18:08.2	31.66	102.64	X						1.6
78 01 18	08:53:19.5	31.62	103.23	X						1.2
78 01 19	03:42:35.1	32.60	103.58	X						1.8
78 01 21	01:17:02.4	31.50	104.66					X		2.4
78 01 24	14:26:22.4	30.68	104.59					X		1.1
78 02 04	15:35:48.4	31.62	103.26						X	1.0
78 02 05	10:46:25.0	31.63	103.26						X	1.0
78 02 05	14:19:53.0	31.41	104.61	X						1.8
78 02 10	14:02:29.9	31.63	103.26						X	1.2
78 02 18	14:22:37.1	31.35	104.56	X						2.8
78 02 18	14:29:20.3	30.62	105.16					X		1.7
78 02 18	15:29:37.0	30.60	105.18					X		1.1
78 02 18	16:44:04.7	30.61	105.19					X		1.0
78 02 18	17:30:08.5	30.61	105.19					X		2.1
78 02 18	17:54:09.8	30.61	105.19					X		1.5
78 02 18	18:45:16.5	30.62	105.20					X		1.3

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date Yr/Mo/Da	Origin Time GMT	Epicenter Lat. North	Epicenter Long. West	Located By NMT	USGS	LANL	ASL	UTA	UTEP	Mag.
78 02 19	07:05:18.7	30.61	105.18					X		1.1
78 02 19	12:12:00.0	30.61	105.19					X		2.1
78 02 20	02:52:55.4	30.62	105.20					X		1.1
78 03 02	08:57:51.8	32.18	103.07	X						1.2
78 03 02	10:04:50.1	31.52	102.41	X						2.8
78 03 02	11:27:09.4	31.61	102.69						X	1.2
78 03 02	11:55:57.1	31.59	102.61						X	1.8
78 03 19	10:48:49.1	31.50	102.51	X						1.8
78 03 28	05:51:35.4	29.69	104.04					X		1.1
78 04 06	09:13:27.4	30.86	104.86					X		1.2
78 04 07	00:57:41.6	31.94	105.33	X						2.3
78 04 12	23:05:00.0	30.66	104.48					X		1.1
78 05 30	13:19:31.7	30.65	104.56					X		1.4
78 06 03	11:40:18.2	30.40	104.64					X		1.6
78 06 06	20:05:00.1	30.30	104.58					X		1.4
78 06 16	11:46:54.2	33.03	100.77		X					4.4
78 06 16	11:53:33.0	33.10	101.20					X		3.4
78 06 29	20:58:45.1	31.05	101.94	X						3.4
78 07 05	02:45:06.7	31.78	102.55	X						1.2
78 07 05	10:40:28.9	31.60	102.25	X						1.7
78 07 18	12:07:32.8	30.40	104.28	X						1.8
78 07 21	05:02:36.2	34.68	105.04	X						3.1
78 07 21	20:35:41.6	31.24	102.48	X						1.7
78 08 12	12:45:27.7	31.62	103.27	X						0.9
78 08 14	13:29:43.7	31.61	102.56	X						2.2
78 08 19	19:44:36.5	31.57	103.21	X						0.8
78 09 29	17:59:41.4	30.32	104.66				X			1.9
78 09 29	20:07:43.3	31.52	102.51	X						2.3
78 09 30	23:31:47.5	31.66	102.71	X						1.9
78 10 02	09:35:06.9	31.54	102.51	X						1.7
78 10 02	09:58:33.4	31.60	102.55	X						1.7
78 10 02	11:25:09.9	31.51	102.52	X						2.0
78 10 03	06:12:17.2	31.91	102.99	X						1.8
78 10 06	15:23:46.3	31.53	102.34	X						2.2
79 01 19	09:07:55.1	30.50	105.12					X		1.5
79 02 13	19:02:13.4	30.17	104.36					X		1.5
79 02 16	23:50:32.5	31.03	104.90					X		1.7
79 03 28	15:20:02.8	31.10	102.65	X						1.0
79 04 25	00:19:26.0	31.93	101.99	X						1.6
79 04 28	01:01:40.0	30.58	104.69	X						2.1
79 06 09	01:28:59.1	30.65	104.50					X		1.6
79 06 28	19:23:45.4	30.38	105.15					X		1.6
79 07 05	01:05:05.9	32.90	101.31	X						2.7
79 07 17	07:26:14.4	32.52	103.88	X						2.0
79 08 03	05:29:38.3	32.85	100.94	X						2.6
80 02 05	23:56:54.7	29.92	104.44						X	2.9
80 03 21	08:35:23.7	31.56	102.41	X						1.0
81 08 13	23:39:52.4	31.91	102.58	X						2.2
81 09 16	03:08:53.8	33.74	105.24	X						1.8

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
82 01 04	16:56:08.1	31.18	102.49							3.4
82 07 22	14:38:55.6	34.27	105.62	X						0.5
82 08 28	08:04:18.2	32.55	104.52	X						1.1
82 09 22	15:41:52.5	34.10	106.10	X						0.5
82 10 26	00:37:49.8	33.64	103.58	X						1.5
82 11 03	23:23:50.0	32.86	105.99	X						0.6
82 11 25	18:50:08.6	32.90	100.88	X						2.3
82 11 28	02:36:48.0	33.00	100.80					X		3.3
83 01 09	11:49:04.0	30.35	105.76	X						1.9
83 01 12	10:11:12.5	34.33	105.17	X						1.5
83 01 29	11:44:52.2	31.38	102.36	X						2.2
83 03 03	18:13:44.7	29.80	104.29	X						2.8
83 03 31	20:51:21.2	32.36	106.42	X						1.7
83 04 04	09:57:21.0	30.58	105.25	X						1.2
83 04 11	11:19:15.0	31.28	102.48	X						1.2
83 04 17	19:39:02.0	33.43	105.93	X						1.7
83 04 24	05:13:02.0	32.32	103.90	X						-1.5
83 04 30	07:34:18.8	33.30	106.43	X						3.4
83 05 14	01:35:00.0	31.92	106.67	X						0.8
83 05 17	01:40:20.0	31.47	103.57	X						2.0
83 05 20	03:44:29.0	31.50	102.08	X						1.2
83 06 03	20:31:21.0	29.83	103.42	X						1.1
83 06 05	06:17:22.0	32.52	105.35	X						1.3
83 06 18	23:52:22.0	31.05	102.47	X						1.1
83 06 21	23:01:13.0	33.63	103.58	X						1.6
83 07 06	22:17:02.0	30.38	103.28	X						1.2
83 07 09	04:31:19.0	30.33	104.00	X						1.0
83 07 09	17:06:02.0	30.35	104.02	X						0.7
83 07 13	20:38:00.0	32.87	104.17	X						0.2
83 07 21	15:35:26.0	30.95	105.15	X						1.6
83 08 02	08:16:11.0	32.58	103.60	X						0.0
83 08 02	09:23:17.0	32.55	103.67	X						0.0
83 08 04	00:50:31.0	32.60	105.12	X						1.3
83 08 14	13:35:59.0	33.47	105.35	X						1.1
83 08 19	03:17:02.0	31.92	101.92	X						1.5
83 08 19	03:31:07.0	31.58	102.17	X						1.3
83 08 23	15:05:02.0	30.58	105.25	X						1.9
83 08 26	04:56:40.0	31.37	102.28	X						1.9
83 08 30	21:16:01.0	32.35	104.62	X						0.9
83 08 31	11:10:07.0	32.52	103.58	X						0.6
83 08 31	22:25:58.0	31.80	102.45	X						1.9
83 09 06	11:12:48.0	33.75	105.82	X						1.0
83 09 29	07:44:11.0	34.93	104.43	X						2.7
83 09 30	11:42:35.0	30.57	104.00	X						1.6
83 11 09	00:12:49.0	32.67	102.58	X						0.9
83 11 12	03:11:18.0	32.60	102.75	X						1.3
83 11 16	21:01:50.0	32.52	103.47	X						-0.4
83 12 01	10:05:59.0	31.83	102.02	X						1.4
83 12 03	23:46:51.0	30.90	103.33	X						2.1

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
83 12 26	11:05:11.0	31.17	102.33	X						1.5
84 01 02	10:29:36.0	31.70	102.15	X						1.8
84 01 03	09:38:18.0	30.80	103.00	X						1.5
84 01 03	10:20:00.0	30.80	103.00	X						1.5
84 01 03	10:28:33.0	30.80	103.00	X						1.3
84 01 16	08:49:03.0	33.88	103.08	X						0.8
84 01 16	12:09:44.0	33.88	103.08	X						1.1
84 02 23	05:43:30.0	32.65	104.02	X						-0.7
84 03 02	09:08:56.0	30.90	105.10	X						1.4
84 03 12	12:37:10.0	32.62	103.72	X						0.2
84 03 23	01:37:36.0	32.30	100.80	X						1.5
84 03 24	22:58:00.0	34.75	105.30	X						0.5
84 04 17	16:16:46.0	32.43	106.57	X						1.5
84 05 12	17:29:55.0	34.17	105.63	X						1.1
84 05 21	20:25:26.0	32.37	104.03	X						1.2
84 05 26	00:57:16.0	32.60	103.47	X						-0.2
84 06 28	01:58:29.0	34.33	105.98	X						0.1
84 07 17	08:24:06.0	32.77	105.92	X						1.3
84 07 20	21:56:58.0	34.68	105.38	X						0.3
84 08 01	04:04:07.0	32.70	105.90	X						0.4
84 08 14	06:32:22.0	33.50	106.45	X						1.3
84 08 18	12:46:18.0	31.53	103.12	X						1.8
84 08 21	05:39:23.0	33.57	106.57	X						1.4
84 08 25	00:01:32.0	32.92	103.73	X						0.9
84 08 28	12:13:54.0	34.27	105.67	X						1.0
84 08 31	02:49:02.0	34.72	105.30	X						1.3
84 09 11	14:47:34.0	32.00	100.70	X						3.0
84 09 21	01:44:21.0	34.67	105.38	X						1.5
84 09 25	23:23:02.0	32.35	102.58	X						0.8
84 10 03	08:09:56.0	32.80	103.98	X						0.7
84 10 04	05:15:06.0	33.88	103.30	X						1.3
84 11 10	23:10:00.0	34.57	105.37	X						1.1
84 11 27	19:06:03.0	33.62	105.37	X						1.6
84 12 04	20:36:30.0	32.55	103.12	X						2.5
84 12 08	00:37:37.0	34.72	105.28	X						1.4
84 12 12	23:53:40.0	33.33	105.63	X						1.5
85 01 06	14:30:45.0	34.35	104.78	X						2.3
85 01 06	22:49:30.0	33.58	105.42	X						1.1
85 03 09	22:53:28.0	33.93	105.15	X						1.3
85 03 12	04:01:41.0	33.40	106.10	X						1.3
85 03 18	05:37:39.9	32.36	104.72	X						1.6
85 04 16	12:26:02.0	34.03	106.00	X						0.8
85 04 16	12:27:06.0	34.03	106.00	X						0.4
85 05 03	15:28:20.0	31.17	104.68	X						1.9
85 05 04	04:05:50.0	33.35	106.40	X						0.5
85 05 17	03:08:09.0	34.72	105.30	X						1.2
85 05 30	19:54:13.0	32.57	106.93	X						1.0
85 05 30	23:13:12.0	32.55	106.95	X						1.1
85 05 30	23:22:50.0	32.48	106.92	X						1.2

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
85 06 02	13:54:54.0	31.25	102.18	X						1.6
85 06 04	23:06:49.0	34.65	105.33	X						1.4
85 06 05	10:36:01.0	32.57	106.92	X						2.9
85 06 05	11:15:09.0	32.58	106.92	X						1.2
85 06 05	11:47:30.0	32.52	106.80	X						1.1
85 06 10	04:53:03.0	33.83	105.95	X						1.0
85 06 10	21:23:24.0	34.22	105.93	X						2.0
85 06 12	01:58:31.0	34.72	103.82	X						1.8
85 07 28	16:45:53.0	34.07	105.87	X						0.4
85 08 02	01:39:57.0	32.48	104.23	X						1.4
85 08 04	13:57:27.0	33.40	106.30	X						0.9
85 08 12	19:55:12.0	34.30	106.02	X						1.2
85 08 27	04:58:59.0	33.37	106.08	X						1.8
85 09 05	06:56:49.0	33.65	103.75	X						1.8
85 09 05	17:57:52.0	32.55	106.95	X						1.4
85 09 06	05:22:03.0	32.52	106.90	X						0.9
85 09 06	05:22:46.0	32.55	106.93	X						2.6
85 09 09	08:57:58.0	33.95	105.98	X						0.5
85 09 18	14:49:39.0	30.93	103.47	X						2.0
85 09 19	00:37:48.0	32.57	106.90	X						1.0
85 09 22	22:59:30.0	32.57	106.93	X						1.2
85 09 23	01:35:07.0	32.57	106.93	X						1.1
85 09 25	02:13:22.0	33.33	106.47	X						0.8
85 09 25	19:23:22.0	32.52	106.93	X						2.5
85 09 25	20:35:07.0	32.52	106.93	X						0.8
85 09 25	23:01:38.0	32.52	106.93	X						1.1
85 09 26	01:04:23.0	32.52	106.93	X						0.6
85 10 23	02:28:29.0	33.22	106.43	X						0.6
85 11 13	06:17:58.0	32.02	103.12	X						1.8
85 11 13	08:47:19.0	33.67	105.73	X						0.6
85 11 13	23:07:58.0	33.80	106.35	X						0.9
85 11 28	19:39:05.0	31.57	102.02	X						1.8
86 01 15	21:01:41.0	34.50	105.47	X						1.8
86 01 28	03:52:37.0	34.15	105.27	X						1.2
86 01 30	19:07:18.0	33.55	103.98	X						1.9
86 01 30	22:26:37.0	31.17	101.23	X						3.5
86 02 07	12:36:09.0	32.50	105.45	X						1.4
86 03 11	05:57:07.0	32.08	105.07	X						2.0
86 03 21	00:36:13.0	33.40	105.68	X						1.6
86 03 26	05:19:08.0	34.62	105.28	X						1.5
86 04 05	13:41:48.0	34.07	105.75	X						0.9
86 04 17	21:04:30.0	32.58	106.92	X						2.7
86 04 29	23:14:03.0	31.03	102.67	X						1.2
86 04 30	01:28:02.0	31.03	102.67	X						1.1
86 05 11	10:35:44.0	30.60	105.97	X						1.9
86 05 18	14:06:43.0	34.38	105.65	X						0.8
86 05 28	22:15:24.0	31.75	105.12	X						1.6
86 06 07	02:29:50.0	30.17	105.48	X						1.9
86 06 19	05:06:08.0	32.50	106.95	X						1.4

Table 2.8-3, Instrumental Origin Times, Locations and Magnitudes of Earthquakes Within 180 Mi of the WIPP Facility January 1, 1962 Through September 30, 1986*

Date	Origin Time	Epicenter		Located By						Mag.
Yr/Mo/Da	GMT	Lat. North	Long. West	NMT	USGS	LANL	ASL	UTA	UTEP	
86 06 27	09:47:24.0	32.00	102.00	X						2.2
86 07 09	19:51:02.0	31.50	102.48	X						1.6
86 07 20	19:31:26.0	33.47	105.02	X						1.5
86 08 02	17:51:43.0	33.68	103.78	X						1.7
86 08 14	21:26:52.0	32.57	104.68	X						1.3
86 08 15	07:59:20.0	33.02	103.77	X						1.7
86 09 10	16:50:49.0	34.12	105.75	X						0.8

* REFERENCES 1, 2, 3, 29, 30

Table 2.8-4, Risk Curve Parameters

#	Figure	Curve	Source Zone	Recurrence Formual	M_{max}
1	2.8-28	1	Algermissen & Perkins* Rio Grande rift (see Figure 2.8-12)	$\log N = 2.56 - M_L$	7.8
2	2.8-28	2	Algermissen & Perkins* Rio Grande rift (see Figure 2.8-12)	$\log N = 3.06 - M_{CORR}$	7.8
3	2.8-28	3	Basin & Range subregion (Figure 2.8-15)	$\log N = 2.75 - M_L$	7.8
4	2.8-28	4	Basin & Range subregion (Figure 2.8-15)	$\log N = 3.25 - M_{CORR}$	7.8
5	2.8-29	1	Algermissen & Perkins* Cen. Basin Plat. (see Figure 2.8-12)	$\log N = 2.74 - 0.9M_L$	5.0
6	2.8-29	2	Algermissen & Perkins* Cen. Basin Plat. (see Figure 2.8-12)	$\log N = 2.74 - 0.9M_L$	6.0
7	2.8-29	3	Algermissen & Perkins* Cen. Basin Plat. (see Figure 2.8-12)	$\log N = 3.19 - 0.9\ M_{CORR}$	5.0
8	2.8-29	4	Algermissen & Perkins* Cen. Basin Plat. (see Figure 2.8-12)	$\log N = 3.19 - 0.9\ M_{CORR}$	6.0
9	2.8-29	5	Cen. Basin Plat. geometry suggested by geology (see Figure 2.8-15)	$\log N = 2.74 - 0.9\ M_L$	5.0
10	2.8-29	6	Cen. Basin Plat. geometry suggested by geology (see Figure 2.8-15)	$\log N = 2.74 - 0.9\ M_L$	6.0
11	2.8-29	7	Cen. Basin Plat. geometry suggested by geology (see Figure 2.8-15)	$\log N = 3.19 - 0.9\ M_{CORR}$	5.0
12	2.8-29	8	Cen. Basin Plat. geometry suggested by geology (see Figure 2.8-15)	$\log N = 3.19 - 0.9\ M_{CORR}$	6.0
13	2.8-30	1	WIPP Facility	$\log N = 1.93 - M_L$	4.5
14	2.8-30	2	WIPP Facility	$\log N = 1.93 - M_L$	5.5
15	2.8-30	3	WIPP Facility	$\log N = 2.43 - M_{CORR}$	4.5
16	2.8-30	4	WIPP Facility	$\log N = 2.43 - M_{CORR}$	5.5

* S. T. Algermissen and D. M. Perkins, "A Probabilistic Estimate of Maximum Ground Acceleration in the Contiguous United States," U.S. Geol. Surv. open-file Report 76-416, pp. 1-45, (1976).

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PRINCIPAL DESIGN AND SAFETY CRITERIA

This chapter discusses principal design and safety criteria for structures, systems, and components (SSCs) that protect the public, workers, and the environment from hazards posed by Waste Isolation Pilot Plant (WIPP) operations. For the WIPP, SSCs are categorized as Design Class I, II, and III in the WIPP System Design Descriptions (SDDs). Criteria for the selection of Design Class I, II, and III SSCs are identified in the General Plant SDD (GPDD)[1] and are discussed in Section 3.1, General Design Criteria. Design information for WIPP Design Class I, II, and III SSCs is provided in Chapter 4, Facility Design and Operation.

3.1 General Design Criteria

The mission of the WIPP is to demonstrate the technical and operational principles for the permanent isolation of defense generated transuranic waste in salt. The WIPP facility was designed and constructed according to DOE Order 6430, General Design Criteria Manual for Department of Energy Facilities, draft, dated June 10, 1981,[2] and codes and standards applicable at the time of construction. Facility modifications since that time have been designed according to the revision of DOE Order 6430 and codes and standards applicable at the time of modification. All future modifications shall be designed according to DOE Order 6430.1A, General Design Criteria, dated April 1989,[3] or the revision in effect at the time of facility modification, and all applicable codes and standards as described by the GPDD.

The Department of Energy - Carlsbad Area Office (DOE-CAO) has determined that waste emplacement will only follow a decision, by DOE and by appropriate regulatory agencies, that permanent disposal in the WIPP facility protects human health and the environment. When initiated, the placement of waste in the WIPP will be for the purpose of permanent disposal with no intent to retrieve.

3.1.1 TRU Waste Criteria

The acceptance criteria of contact-handled (CH) and remote-handled (RH) transuranic (TRU) waste received and disposed at the WIPP facility is defined in this section. CH waste has a relatively low surface dose rate, lending itself to direct handling while RH waste requires remote handling.

The WIPP shall provide disposal capacity of 6.2 million cubic ft of TRU waste in TRU waste containers for underground disposal over an operating life of 35 years.

The WIPP shall have the capacity to process up to a maximum of 500,000 cubic ft of CH TRU waste per year and 10,000 cubic ft of RH TRU waste per year.

The acceptance criteria for TRU waste to be accepted for disposal at the WIPP facility and the basis for the criteria are presented in the TRU Waste Acceptance Criteria[4] (WAC) for the WIPP.

The WAC[4] incorporates four related sets of criteria: WIPP Operations and Safety Criteria, Transportation Requirements, Resource Conservation and Recovery Act (RCRA) Requirements and Performance Assessment Criteria. Table 3.1-1 provides a summary of those waste acceptance criteria and requirements.

3.1.2 Facility By-Products

3.1.2.1 Nonradioactive By-Products

The major nonradioactive by-product at the WIPP facility is mined salt. The basic design criterion is the mined salt shall be free of radioactive contamination. Other regulated nonradioactive hazardous by-products shall be handled in compliance with applicable codes and standards.

3.1.2.2 Site-Derived Radioactive Waste

Site-derived radioactive waste shall be treated as radioactive mixed waste unless proof is available that wastes are not mixed. The mixed waste shall be handled in accordance with the regulations of the RCRA as implemented by the Environmental Protection Agency (EPA) or the State of New Mexico (whichever is applicable).

3.1.3 Design Classification of Structures, Systems, and Components

The design classification system shall be used for categorizing SSCs of the WIPP facility and to determine the proper level of design and quality assurance requirements specified for each SSC. These requirements shall be used to ensure that each SSC will perform its required design function reliably when subjected to: (1) design basis accidents, (2) operating loads, and (3) environmental operating conditions.

Classification categories shall be identified as Design Class I, II, or III, with Design Class III subdivided into Design Class IIIA and IIIB as defined in Section 3.1.3.1.

Where a single item performs two or more functions and may be assigned to more than one design classification, the more stringent class shall be assigned. Portions of an item performing different functions may be assigned to different classes if the item contains a suitable interface boundary meeting the requirements of Section 3.1.3.2, Design Class Interfaces.

The basic design codes and standards applicable to each class are shown in Table 3.1-2. SSCs are assigned a Design Class on an item-by-item basis in accordance with procedures of the WIPP Engineering Conduct of Operations and Procedures Manual.[5]

3.1.3.1 Design Class Definitions

3.1.3.1.1 Design Class I

Design Class I shall apply to SSCs for the prevention or mitigation of the consequences of an accident or severe natural phenomena that could result in a 50-year dose commitment beyond the WIPP Exclusive Use Area in excess of 25 rem Total Effective Dose Equivalent (TEDE).

3.1.3.1.2 Design Class II

Design Class II shall apply to SSCs that:

- Provide permanent confinement
- Provide permanent shielding

- Monitor variables to:
  - Verify the selected WIPP operational limits are not exceeded
  - Indicate the status of safety system bypasses that are not automatically removed as a part of safety system operation
  - Indicate the status of Design Class I items during all plant conditions
  - Verify that off-normal radiological dose limits are not exceeded following accidental releases of radioactive material

3.1.3.1.3 Design Class III

This classification shall be divided into Design Class IIIA and IIIB as follows:

Design Class IIIA shall be applied to those SSCs not included in Design Class I or Design Class II, requiring a higher level of quality beyond that expected in commercial-industrial practice and includes any of the following functional considerations:

- Airborne radioactivity monitoring following accidental releases of radioactive materials
- Major sustained stoppage of waste handling and disposal operations due to failure
- Design and fabrication complexity or uniqueness
- Potential for contamination due to component failure
- Special considerations are required beyond those contained in nationally recognized codes and standards to ensure the health and safety of operating personnel
- Equipment failure could be of special significance to the health and safety of operating personnel
- Equipment with unique subassemblies, when replaced, shall be identical in terms of function, form, and fit

Design Class IIIB: Class IIIB shall be applied to all other items.

3.1.3.2 Design Class Interfaces

When the failure of less-stringently classified SSCs could prevent more-stringently classified SSCs from accomplishing their required function, then one of the following options shall be followed:

- Change the design to preclude consequential failure of the more-stringently classified item
- Reclassify the less stringently classified item to correspond to that of the more-stringently classified SSC
- Provide an interface barrier to protect the more-stringently classified SSC

Exceptions to these criteria shall be addressed on a case-by-case basis and described in the design documents.

3.1.3.3 Severe Natural Events

3.1.3.3.1 Design Basis Tornado (DBT)

The DBT is the most severe credible tornado that could occur at the WIPP site as described in Chapter 2. DBT SSCs shall be designed to withstand the highest winds generated by this tornado (183 mi/h), based on a 1,000,000-year recurrence period, and retain their safety function.

3.1.3.3.2 Design Basis Earthquake (DBE)

The DBE is the most severe credible earthquake that could occur at the WIPP site as described in Chapter 2. DBE SSCs shall be designed to withstand a free-field horizontal and vertical ground acceleration of 0.1 g, based on a 1,000-year recurrence period, and retain their safety functions.

3.1.4 Decontamination and Decommissioning

Design of equipment and areas of facilities that may become contaminated with radioactive or other hazardous material shall incorporate features to simplify decontamination. Examples of features to be incorporated are identified in DOE Order 6430.1A, Section 1300-11.[3]

The WIPP shall be designed to have the capability of being decommissioned, shall have a documented closure plan and shall provide for the surveillance, maintenance, and decommissioning of the facility as required by DOE Order 5820.2A.[6] The WIPP equipment and facilities in which radioactive or hazardous materials are utilized shall be designed to simplify decommissioning and to increase the potential for reuse of the facilities, equipment, and materials.

References for Section 3.1

1. Waste Isolation Pilot Plant General Plant Design Description (GPDD), Rev. 1, April 1995.

2. DOE Order 6430, General Design Criteria Manual for Department of Energy Facilities, June 10, 1981 draft.

3. DOE Order 6430.1A, General Design Criteria, April 1989.

4. WIPP-DOE-069, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 4, December 1991.

5. WP 09, Engineering Conduct of Operations and Procedures Manual, Rev. 1.

6. DOE Order 5820.2A, Radioactive Waste Management, September 26, 1988.

Table 3.1-1, Summary of Waste Acceptance Criteria and Requirements[1] Page 1 of 3

WASTE PACKAGE REQUIREMENTS/CRITERIA					
WAC Criterion/ Requirement & Section	**CH or RH**	**WIPP Operations and Safety Criteria**	**Transportation: Waste Package Requirements: TRAMPAC/RH-Cask[1]**	**RCRA Requirements**	**Performance Assessment Criteria**
Waste Containers 3.2.1	CH	*Type A, Noncombustible*	*55-gal Drums, SWBs, or SWB Overpack of 55-gal Drums*	No Additional Requirements	Same as Transportation
	RH	*Type A, Noncombustible*	*RH Canister*	No Additional Requirements	None
Waste Package Size 3.2.2	CH	Maximum Dimension Specified	*55-gal Drums in Two Seven Packs, or Two SWBs*	None	Same as Transportation
	RH	*RH Canister*	RH Canister	None	None
Waste Package Handling 3.2.3	CH	Drum and Box Handling Attachments	*Seven Packs, or SWBs*	None	No Additional Requirements
	RH	*Axial Pintle*	Axial Pintle	None	None
Immobilization 3.3.1	CH & RH	*$\leq$ 1% Below 10 microns, $\leq$ 15% Below 200 microns*	None	No Additional Requirements	Same as WIPP Operation
Liquids 3.3.2	CH & RH	*Only Residual Liquids (See Definitions in Section 3.3.2.1 of the WAC)*	< 1 Volume Percent	No Additional Requirements	< 1 Volume Percent
Pyrophoric Materials 3.3.3	CH & RH	$\leq$ 1% Radionuclides, No Non-Radionuclide Pyrophorics	*< 1% Radionuclides, No Non-Radionuclide Pyrophorics*	*See Section 3.3.5.3 of the WAC*	Same as Transportation
Explosives and Compressed Gases 3.3.4	CH & RH	Not Permitted, 49 CFR 173 Subpart C and G	*Explosives and Compressed Gases are Not Permitted*	*See Section 3.3.5.3 of the WAC*	No Additional Requirements
TRU Mixed Waste 3.3.5	CH & RH	*Hazardous Waste must be Reported*	*Corrosives are Not Permitted*	*WIPP RCRA Parts A & B Permit Applications, WAP, NMD*	No Additional Requirements
Specific Activity of Waste 3.3.6	CH	*> 100nCi/g TRU*	Same as WIPP Operations	None	Same as WIPP Operations
	RH	*> 100nCi/g TRU $\leq$ 23 Ci/liter total*	Same as WIPP Operations	None	Same as WIPP Operations

Table 3.1-1, Summary of Waste Acceptance Criteria and Requirements[1] Page 2 of 3

WASTE PACKAGE REQUIREMENTS/CRITERIA					
WAC Criterion/ Requirement & Section	**CH or RH**	**WIPP Operations and Safety Criteria**	**Transportation: Waste Package Requirements: TRAMPAC/RH-Cask[2]**	**RCRA Requirements**	**Performance Assessment Criteria**
Waste Package Weight 3.4.1	CH	< 21,000 lbs	*1000 lbs per Drum, 4000 lbs per SWB, 7265 lbs per TRUPACT-II payload 19,250 lbs per TRUPACT-II, 80,000 lbs GVW (DOT)*	None	None
	RH	*< 8,000 lbs*	RH-Cask TBD	None	None
Nuclear Criticality (Pu-239 FGE) 3.4.2	CH	See List in 3.4.2.1 of the WAC	*< 200 g/Drum, < 325 g/SWB, or < 325 g/TRUPACT-II*	None	Same as Transportation
	RH	≤ 600 g	*< 325 g/cask*	None	Same as Transportation
Pu-239 Equivalent Activity 3.4.3	CH & RH	*≤ 1000 PE-Ci/ package*	*None*	None	None
Surface Dose Rate 3.4.4	CH	*≤ 200 mrem/hr*	*≤ 200 mrem/hr, DOT Package Limits, and Shielded Packages per SARP*	None	Same as WIPP Operations
	RH	*95% ≤ 100 rem/hr. 5% ≤ 1000 rem/hr.*	RH-Cask TBD and DOT Package Limits	None	None
Removable Surface Contamination 3.4.5	CH & RH	*≤ 50 pCi/100 cm² alpha, ≤ 450 pCi/100 cm² beta-gamma*	None	None	Same as WIPP Operations
Thermal Power 3.4.6	CH	No Limit Report it > 0.1 watts/ft³	*Refer to Limits in TRUPACT-II SAR Section 1.2.3.3*	None	Same as Transportation
	RH	*300 watts/canister*	RH-Cask TBD	None	None
Gas Generation 3.4.7	CH	Vented	*TRAMPAC Limits; See Requirements in Section 3.4.7.2 of the WAC, ≤ 500 ppm Flammable VOCs; Chemical Compatibility Study; all Trace Chemicals < 5 weight percent*	NMD Requirements Apply	SNL Test Plan
	RH	Vented	RH-Cask TBD	None	Same as CH
Labeling 3.4.8	CH	*ID Number, DOT*	*ID Number and Waste Shipping Category*	Same as DOT	None
	RH	*ID Number, DOT*	RH-Cask TBD	TBD	None

Table 3.1-1, Summary of Waste Acceptance Criteria and Requirements[1] Page 3 of 3

DATA PACKAGE REQUIREMENTS/CRITERIA					
WAC Criterion/ Requirement & Section	**CH or RH**	**WIPP Operations and Safety Criteria**	**Transportation: Waste Package Requirements: TRAMPAC/RH-Cask[2]**	**RCRA Requirements**	**Performance Assessment Criteria**
Data Package/ Certification 3.5.1	CH	*Certification, WWIS Information, Data Format*	*Tables 13.1 to 13.3 in Appendix 1.3.7 (TRAMPAC)*	*Hazardous Waste Manifest per 40 CFR Part 262 NMD and QAPP Requirements*	*PA Data Package, QAPP Requirements*
	RH	*Certification, WWIS Information, Data Format*	RH-Cask TBD	TBD	None
OTHER REQUIREMENTS/CRITERIA					
WAC Criterion/ Requirement & Section	**CH or RH**	**WIPP Operations and Safety Criteria**	**Transportation: Waste Package Requirements: TRAMPAC/RH-Cask[2]**	**RCRA Requirements**	**Performance Assessment Criteria**
Additional Requirements 3.6.1	CH	None	*One Shipping Category per TRUPACT-II, Authorized TRUCON Content Codes, Waste Aspirated per SARP, Payload Control Procedures*	Regulations or Permit Conditions as Determined by NMED	None
	RH	None	RH-Cask TBD	TBD	None

1 - Limiting parameters are shown in italics.
2 - RH Cask limits have not been finalized.

Table 3.1-2, Basic Design Requirements

Principal Codes and Standards						
	Typical Equipment	Applicable Codes & Standards	Design Class I	Design Class II	Design Class IIIA	Design Class IIIB
Structure/ Supports		DBE, DBT, ACI-318, AISC	X	(1), (2)	(1)	
		UBC, ANSI A58.1		X	X	X
		SITE SPECIFIC	(1)	(1)	(1)	(1)
Liquid and Process Air Handling Processing and Storage Equipment	Vessel	ASME VIII, NFPA (5)	X, (6)	X	(1)	(1)
	Piping and Valves Pumps	ANSI B31.1, NFPA (5)		X	X	(1)
		UPC				X
	Pumps	API-610, NFPA (5)	X	X	(1)	
	Storage & Tanks	API-650 or API-620	X	X		
	Heat Exchangers	ASME VIII, TEMA	X	X	(1)	(1)
	All Other Equip.	MFR's STD			X	X
Air Handling Ducting & Fans		ARI, SMACNA, AMCA	X, (3)	X, (3)	X, (3)	X
HVAC Filters	Pre Filters	ASHRAE 52.68	X, (3), (4)	X, (3)	X, (3)	X
	HEPA Filters	MIL F 51068C, ANSI N 509, ANSI N 510	X, (3)	X, (3)	X, (3)	X
Mechanical Handling Equipment	Crane & Related Equip.	CMAA	X	X	(1)	
		CMAA, AISC, AWS	X	X	(1)	
		MFR's STD			X	X
Instrumentation and Electrical		IEEE-NE	X			
		ANSI STDS or NEC	X	X	X	X
		ISA/MFR'S STD		X	X	X

Table 3.1-2, Basic Design Requirements Page 2 of 3

Principal Codes and Standards						
Quality Assurance Program		ASME NQA-1 & SUPPLEMENTS	X	X	X	
		COMMERCIAL AND INDUSTRY PRACTICES				X

X - Minimum Requirements

NOTES
(1) Requirements shall be determined on case-by-case basis.
(2) Required for structure and supports needed for confinement and control of radioactivity.
(3) Except structures and supports that are designed to withstand DBE/DBT when specified in column 1 of this table. (See Section 3.2 for specific criteria.)
(4) Underwriter's Laboratory (UL) class I listed.
(5) For fire protection systems.
(6) ASME III for other class I vessels.

Definitions

ACI-318	American Concrete Institute. Building Code Requirements for Reinforced Concrete (ACI-318-77)	ASHRAE 52.68	American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. Standard 52.68. Method of Testing Air Cleaning Devices Used in Central Ventilation for Removing Particulate Matter
AISC	Specification for Design Fabrication and Erection of Structural Steel for Buildings	ASME VIII	American Society of Mechanical Engineers. Section VIII Division I Pressure Vessel
AMCA	Air Moving and Conditioning Association Fan Performance and Sound Testing Requirements AMCA 210.67 and 300	AWS	American Welding Society
ANSI B31.1	American National Standards Institute, Power Piping	CMAA	Crane Manufactures Association of America. Specification No. 70 Specification for Electric Overhead
ANSI A58.1	Building Code Requirements for Minimum Design Loads in Building and Other Structures	IEEE	Institute of Electrical and Electronic Engineers
ANSI N 509	Nuclear Power Plant Air Cleaning Units and Components	MFR'S STD.	A Commercial Catalogue Item Built to the Manufacturer's Design Standard
ANSI N 510	Testing of Nuclear Air Cleaning Systems	MIL-F-51068C	Military Specification, Fire Resistant High Efficiency Particulate Air Filters
API-610	American Petroleum Institute. Centrifugal Pumps for General Refinery Services	NFPA	National Fire Protection Association

Table 3.1-2, Basic Design Requirements

Principal Codes and Standards			
Definitions			
API-620	Recommended Rules for Design and Construction of Large, Welded Low and Pressure Storage Tanks	NEC	National Electrical Code
API-650	Welded Steel Tanks for Oil Storage Atmospheric Tanks	SMACNA	Sheet Metal and Air Conditioning Contractors National Association, Inc
ARI	Air Conditioning and Refrigeration Institute	TEMA	Tubular Exchanger Manufacturer's Association
ASME-NQA-1	Quality Assurance Program for Nuclear Power Plant NQA 1 1979	UBC	Uniform Building Code
		UPC	Uniform Plumbing Code. (American Standard National Plumbing Code ANSI A40.8)

3.2 Structural Design Criteria

3.2.1 Wind Loadings

The design wind velocity for Design Class II structures shall be 110 mi/h at 30 ft above ground. The wind velocity selected with a 1,000-year mean recurrence interval is adopted from the results of a site specific wind and tornado study.[1] The design wind velocity exceeds the basic wind velocity specified in American National Standard Institute (ANSI) Standard A58.1[2] for the geographical location of the WIPP facility.

The design wind velocity for Design Class III structures shall be 91 mi/h with a 50-year mean recurrence interval, except for the Support Building and Exhaust Filter Building, which is 99 mi/h with a 100-year mean recurrence interval.

3.2.1.1 Vertical Velocity Distribution and Gust Factors

The vertical velocity distribution used shall be as given in Section 6 of ANSI Standard A58.1[2] using exposure C (flat, open country; flat, open coastal belts; and grassland) for the design wind velocity including the appropriate gust factors. The ANSI standard contains the effective wind velocity pressures for the overall design of structures in Table 5 of the standard. The ANSI standard contains the effective wind velocity pressures for the design of parts and portions of structures in Table 6, and the effective wind velocity pressures for calculating internal pressures in Table 12.

3.2.1.2 Determination of Applied Forces

The procedures used to convert the wind velocity into applied forces on structures shall be as outlined in ANSI Standard A58.1.[2] Velocity pressures shall be determined from the tables using the design wind velocity. The design wind loads shall be obtained by multiplying the effective velocity pressures by the appropriate pressure coefficients in Sections 6.5 through 6.9, in accordance with Section 6.4 of ANSI Standard A58.1.[2] The design wind loads for enclosed structures are shown in Table 3.2-1.

3.2.2 Tornado Loadings

Tornado loadings applicable to certain Design Class II surface facilities are described in the following sections. For purposes of structural design, the effects of a tornado are described in Section 3.0 of Bechtel topical report BC-TOP-3-A.[3]

3.2.3 Applicable Design Parameters

Tornado-resistant structures shall be designed for tornado loadings (not coincident with any accident condition or earthquake) as outlined in Sections 3.3 and 3.4 of BC-TOP-3-A.[3] The parameters used for the DBT are the result of a site-specific wind and tornado study for the WIPP facility[1] and the loadings shall be calculated based on the following tornado characteristics:

Maximum wind speed (Including effects of suction vortices)	183	mi/h
Translational velocity	41	mi/h
Tangential velocity	124	mi/h

Radius of maximum wind	325	ft
Pressure drop	0.5	lb/in^2
Rate of pressure drop	0.09	$lb/in^2/s$

The above tornado parameters are based on a 1,000,000-year recurrence period, and the maximum wind speed shall be the vector sum of all velocity components.

3.2.3.1 Determination of Forces on Structures

The methods used to convert the tornado wind and atmospheric pressure change into forces and the distribution of these forces across the structures shall be as outlined in Section 3.5 of BC-TOP-3-A.[3] Combinations of loadings are discussed in Section 3.2.11 below.

The idealized pressure-time function shown in Figure 3.2-1 shall be used to determine the differential pressure loading resulting from atmospheric change. The atmospheric differential pressure with a maximum value of 0.5 lb/in^2 tends to force external surfaces of enclosed structures outward.

3.2.3.2 Plant Structures not Designed for Tornado Loads

Structures not resistant to tornados whose collapse could result in the loss of required function of tornado-resistant structures or systems that are under tornado loading conditions shall be analyzed for their mode of failure. This is to ensure that such a collapse does not cause any tornado-resistant structure or system to lose its intended function.

3.2.4 Water Level (Surface Flood) Design

Flood elevations for the Pecos River and the vicinity of the WIPP facility are described in Chapter 2. The WIPP facility nominal grade elevation is more than 400 ft above the probable maximum flood (PMF) level of the Pecos River, and the WIPP facility is separated from the river by about 14 mi of gradually rising land. Since there are no perennial or intermittent streams near the WIPP facility that have the potential for sustained flooding of the site, neither buoyancy nor static water forces due to flood elevations shall be considered in the WIPP facility design.

3.2.4.1 Phenomena Considered in Design Load Calculations

Phenomena such as flood currents or wind-induced waves shall not apply because the grades for the WIPP facility structures are more than 400 ft above the PMF level on the Pecos River, and none of the local drainage ways has the potential for sustained flooding of the WIPP facility.

3.2.4.2 Flood Force Application

As stated above, the WIPP facility structures are above the PMF level and are not subjected to flood loadings.

3.2.4.3 Flood Protection

Protection against the PMF level on the Pecos River shall not be required for WIPP facility SSCs. Protection from flooding, caused by locally intense precipitation, is described in Chapter 2.

An accidental rupture of the fire water tanks may result in a local flood around the tanks, and provisions shall be made so that any liquid released does not cause a flood of sufficient depth to endanger equipment or systems. Static and dynamic fluid pressures resulting from a tank rupture shall be considered in the design of the structures where applicable. Water storage tanks shall be located outside of buildings so that the water released from them does not flood Design Class II SSCs, and floor drainage systems shall accommodate any water from other small tanks or piping systems within the buildings.

3.2.5 Groundwater Design

3.2.5.1 Groundwater Forces

Forces exerted by water in the geological formations overlying the salt shall be considered as lateral loads on the shafts caused by the piezometric heads in the water-bearing zones of the Rustler Formation and shall be sealed to prevent seepage into the salt formations.

Surface water shall be prevented from entering the shafts by sloped shaft collars.

3.2.5.2 Design Loads

Groundwater forces shall be combined with other types of loads for structural design, as described in Section 3.2.11, Combined Load Criteria.

3.2.5.3 Groundwater Protection

Shaft linings and structures shall minimize water seepage and shall be designed against hydrostatic pressure since the water-bearing unit above the waste disposal level will not be drained.

Chemical seals shall be constructed, as required, around the shafts under the water-bearing unit area to minimize water migration to lower elevations, and water collection rings shall be provided to collect seepage that might enter through the shaft lining.

Since there are no significant sources of moisture or groundwater in the Salado Formation underground mined area, no additional humidity or moisture controls beyond those described shall be required.

3.2.6 Protection Against Dynamic Effects

To prevent plant equipment failures from generating internal missiles, rotating equipment shall be designed, wherever possible, to preclude that possibility. Equipment identified as potential missile sources shall be arranged and oriented so that any missile generated would impact a structure or barrier capable of withstanding that impact, preventing damage to Design Class II SSCs.

3.2.7 Seismic Design

Design Class II confinement SSCs shall be designed to withstand a DBE. The Design Basis Earthquake (DBE) based on a 1,000-year earthquake has been established through a seismic study of the WIPP facility region, as discussed in Chapter 2. This section summarizes the seismic input from Chapter 2 and describes the methods and procedures of seismic analysis.

3.2.7.1 Input Criteria

The maximum ground acceleration for the DBE is 0.1 g in both horizontal and vertical directions and shall be used in analysis and design of surface facilities and equipment. As described in Chapter 2, several WIPP facility region seismic zone characterizations have been taken into account in establishing the maximum ground motion.

3.2.7.1.1 Design Response Spectra

The design response spectra for horizontal and vertical components of the DBE shown in Figure 3.2-2 and Figure 3.2-3, are based on a statistical analysis of the existing strong ground motion earthquake records of various durations recorded at sites having various geologic conditions and located at various epicentral distances.

3.2.7.1.2 Derivation of Design Response Spectra

Synthetic earthquake time histories shall not be required for seismic design of the WIPP facility since actual response spectra were used.

3.2.7.1.3 Critical Damping Values

The range of damping values (percent of critical) for SSCs shall be as given in Sections 2.2 and 3.2 of BC-TOP-4-A[4] and are shown in Table 3.2-2.

Damping values of soil and foundation materials are determined by laboratory tests.

The formulas used to determine the equivalent foundation damping coefficient shall be as given in Section 3.3 of BC-TOP-4-A.[4] They are used when a lumped parameter approach is appropriate for soil structure interaction considerations.

3.2.7.1.4 Soil Supported Structures

The Design Class II surface structures shall be constructed either directly on caliche or compacted sandstone, or on a sand layer above the caliche. The foundation support materials shall be designed to withstand the pressures imposed by the appropriate loading combinations, with an adequate safety factor.

3.2.7.1.5 Soil-Structure Interaction

Structural systems affected by soil-structure shall be analyzed, as applicable, in accordance with Section 3.3 and Appendix D of BC-TOP-4-A.[4]

3.2.7.2 Seismic System Analysis

The structures and systems shall be designed for either DBE or Uniform Building Code[5] (UBC) earthquake loads, as specified in Section 3.1.3.

3.2.7.2.1 Seismic Analysis Method

Analytical methods used for seismic analysis shall be as described in Sections 1.0 and 3.0 of BC-TOP-4-A.[4]

The structural mode shapes and frequencies shall be calculated for the models for the fixed base cases. Whenever appropriate, foundation structure interaction shall be analyzed in accordance with the methods given in Section 3.3 of BC-TOP-4-A.[4] A response spectrum analysis shall be conducted for the structure using the above calculated parameters. The results of the analysis shall include acceleration, displacements, shears, moments, and other related information necessary for structural design. Design allowables shall be as given in Section 3.2.11 of this document for the various loading combinations including seismic loadings.

The simplified method of analysis shall be used for frame type structures in lieu of the analytical method described above. The simplified method shall be acceptable for verifying the structural integrity of frame structures that can be represented by a simple model. No determination of natural frequencies shall be made, but rather the design acceleration shall be assumed to be 1.5 times the peak of the required response spectrum.

3.2.7.2.2 Methods Used to Couple Soil with Seismic Structures

If a detailed design and soil investigation determines that a structure is founded on a sand layer of a depth comparable to its plane dimension, foundation impedances based on elastic half-space theory shall be developed and used to account for the soil-structure interaction as described in Section 3.3.1, of BC-TOP-4-A.[4]

3.2.7.2.3 Development of Floor Response Spectra

A simplified method shall be used to generate the approximate floor response spectra without the need of performing a time history analysis of structures. The method used shall be as developed by Tsai and Tseng,[6] which derives spectrum peak envelopes from the design response spectra shown in Figure 3.2-2 and Figure 3.2-3. Subsequently, the floor response spectra for equipment design shall be developed using these peak envelopes and the frequencies of the soil-structure systems.

3.2.7.2.4 Effects of Variations on Floor Response Spectra

Section 5.2 of BC-TOP-4-A[4] describes the various considerations that shall be used in the seismic analyses including the effects on floor response spectra of expected variations of structural properties, damping, soil properties, and foundation-structure interaction. These calculations shall include the details of the effects of variations on the floor response spectra.

3.2.7.2.5 Use of Constant Vertical Load Factors

The method of analysis used for both the vertical and horizontal directions shall be the re-spectrum method. The induced forces, moments, and resulting stresses due to motions in the vertical and the two horizontal directions shall be combined by the square root of the sum of the squares (SRSS) technique.

3.2.7.2.6 Method Used to Account for Torsional Effects

Torsional effects, if significant, shall be included in the horizontal models at locations of major mass and/or structural eccentricity. The techniques in Section 3.2 and Appendix C of BC-TOP-4-A[4] shall be used to account for torsional effects.

3.2.7.2.7 Analysis Procedure for Damping

The analysis procedure employed to account for damping in various elements of the model of a coupled system shall be as described in Sections 3.2 and 3.3 of BC-TOP-4-A,[4] including the criteria for evaluating the composite model damping of the system and accounting for the damping of various structural elements and foundations.

3.2.7.3 Seismic Subsystem Analysis

This section covers the seismic analysis of Design Class II equipment and subsystems essential to confinement.

3.2.7.3.1 Determination of the Number of Earthquake Cycles

During the plant life, one DBE shall be assumed to occur. For the DBE, about ten maximum stress cycles shall be assumed to be induced in the SSCs and the SSCs shall be designed on the basis of analytical results. In general, the design of structures and equipment for the WIPP facility shall not be fatigue controlled since most stress and strain changes occur only a small number of times or produce only minor stress-strain fluctuations or both. Earthquake and Design Basis Accident (DBA) full-design strains occur too infrequently and with too few cycles to generally require fatigue design of structures and equipment.

3.2.7.3.2 Basis for the Selection of Forcing Frequencies

Structural fundamental frequencies shall be calculated in accordance with Section 4.2.1 of BC-TOP-4-A.[4]

3.2.7.3.3 Root-Mean Square Basis

The term "root-mean square basis" used for a combination of modal responses shall be the same equation as SRSS given as follows:

$$Q\ max = (Q_1^{\ 2}\ max + Q_2^{\ 2}\ max + \ldots + Q_n^{\ 2}\ max)^{1/2}, \text{ where } Q\ max = SRSS$$

3.2.7.3.4 Procedure for Combining Modal Responses

The procedure for combining modal responses (shear, moments, stresses, and deflections or accelerations or both) when a response spectrum modal analysis is used, shall be as follows:

- The SRSS method of combining modal responses shall be used, if modes are not closely spaced.
- All significant modes up to 33 Hz shall be used in the analysis, however, the lowest three modes shall always be used. Above 33 Hz the element acts as a rigid body and the calculations would be trivial.

- Where closely spaced frequencies of two or more modes occur, these modal responses shall be combined in an absolute sum; the resulting sum is treated as that of a pseudo-mode, then combined with the remaining modes by SRSS.

3.2.7.3.5 Significant Dynamic Response Modes

Seismic designs of subsystems (i.e., floor or wall-mounted components, etc.) shall be based on modal analysis by using the appropriate floor response spectra and the procedures in Section 3.2.7.2.3. The static loads equivalent to the peak of the floor spectrum curve shall be used only for: (1) a subsystem that can be idealized as a single degree-of-freedom system, or (2) a multiple degree-of-freedom system whose fundamental frequency is far from all the other natural frequencies. In such cases, only the fundamental mode shall be considered.

3.2.7.3.6 Basis for Computing Combined Response

The basis for the methods used to determine the possible combined (two-component) horizontal and vertical amplified response loading for seismic design of equipment, including the effect of seismic response of the supports, equipment, and structures and components, shall be as described in BC-TOP-4-A.[4]

3.2.7.3.7 Amplified Seismic Responses

The dynamic analysis method used to analyze subsystems shall be as described in Section 3.2.7.2.1.

3.2.7.3.8 Modal Period Variation

The peaks of floor response spectra shall be widened, by an amount to be determined by the procedure given in Section 5.2 of BC-TOP-4-A,[4] on both sides of the peak to account for modal period variations due to the variation of structural and foundation properties and idealization in mathematical modeling.

3.2.7.3.9 Torsional Effects of Eccentric Masses

The torsional effects of valves and other eccentric masses shall be included.

3.2.7.3.10 Seismic Analysis for Overhead Cranes

All overhead cranes shall have seismic retainer attachments to prevent them from dislodging during a seismic event.

3.2.8 Snow Loadings

Design Class II structures shall be designed for a snow load of 27 lb/ft^2.

The design snow load is derived by using the 100-year recurrence snow load of 10 lb/ft^2 specified in ANSI Standard A58.1[2] and by determining the quantity of standing water from winter precipitation required to arrive at a threshold condition.

Roof snow loads shall be calculated by multiplying the design snow load by the appropriate coefficients (C_s) specified in Figure 5, Figure 6, and Figure 7 of ANSI A58.1.[2]

In the combined loading calculations given in Section 3.2.11, the roof snow loads shall be used in place of the minimum roof live load where such loading is more critical in governing the design.

3.2.9 Equipment and Materials-Derived Loads

Equipment and materials-derived loads in this section are discussed by first defining loading nomenclature, then presenting the loading criteria.

3.2.9.1 Nomenclature

D Dead Load - The dead load shall consist of the weight of the structure, permanent equipment, piping, conduits, cables, and other permanent static loads.

L Live Load - The live load shall consist of uniformly distributed occupancy loads, moving vehicle loads, crane or its related equipment loads, snow and ice loads, and other loads which vary with intensity and occurrence. The minimum uniformly distributed live loads, concentrated loads, and minimum roof live loads shall be those specified in ANSI A58.1,[2] Table 1, Table 2, and Table 3. The live load arrangement design shall use the highest stresses in the supporting members. Structures carrying live loads that can induce dynamic, vibratory, or impact forces shall be designed for those forces, as specified in Section 3.4 of the ANSI A58.1,[2] or as determined by appropriate analysis.

S Snow Load - A snow load shall be used in the design of structures, and shall be applied in accordance with Section 7 of ANSI A58.1.[2] Snow load shall be used instead of roof live load, when such loading is more critical to the design.

W Wind Load - A wind speed of 110 mi/h with a 1,000-year mean recurrence interval shall be used in the design of Design Class II structures. A wind speed of 99 mi/h with a 100-year mean recurrence interval shall be used in the design of the structural portions of the Support Building, Exhaust Filter Building, and Building 412. All other Design Class IIIA and IIIB structures shall be designed for a basic wind speed of 91 mi/h with a 50-year mean recurrence interval. Conversion of wind speed to wind pressure shall be per Sections 6.1 thru 6.11 of ANSI A58.1[2] and the DOE Guide for Calculation of Design Wind Pressures,[7] Sections A and B.

W_t Total Tornado Load - The loads generated by the design basis tornado, W_t, shall include the effect of tornado wind and pressure differential. The most critical case of the following combinations governs the design.

W_t = Tornado Wind Load (W_w)
W_t = Tornado Differential Pressure (W_p)
$W_t = W_w + 0.5\ W_p$

E' Seismic Load - Load generated by the DBE.

F Hydrostatic Load - Vertical liquid pressure shall be considered as dead load with due regard to variation in liquid depth.

H Soil Pressure - Structures or parts of structures which retain fills, excluding shafts, shall be proportioned to withstand the lateral soil pressure as given in the WIPP Soils Design Report - Volume I, DR-22-V-01.[8]

Salt Creep - Provisions shall be made for eliminating or accommodating stresses, deformations, and/or movements in structures, such as brattice walls, bulkheads, etc. adjacent to the salt. An adequate gap shall be provided between the salt and structure to accommodate creep effect. For structures, walls, or bulkheads that require sealing, the gap shall be bridged with a fire-resistant or noncombustible flexible material.

T Thermal Load - Provisions shall be made for stresses, deformations, or movements resulting from variations in temperature. For surface structures, the ambient temperature rise or fall from that at the time of erection, is assumed to be 60°F for metal structures and 40°F for concrete or masonry structures. For underground structures, the ambient temperature rise or fall from that at the time of erection is assumed to be 30°F for metal structures and 20°F for concrete structures.

3.2.10 Thermal Loadings (Salt)

An estimation of the thermal loading effect on the salt formations near the emplaced RH TRU in the underground shall be analyzed using a suitable computer modeling program for creep closure and the general stability of the roofs and pillars.

This model shall account for the various physical properties of the geological materials (i.e., halite, argillaceous halite, anhydrite, and clay seams). Heat flow gradients shall be established, and material physical properties shall be adjusted as affected by thermal change.

A number of assumptions about the site, the waste, and the emplacement methods shall be made in order to use this program. RH TRU waste disposed at the WIPP facility shall be assumed to have an average radioactive half-life of 30 years based on the Sr-90 and Cs-137 components of the waste, and shall be emplaced so that heat generation does not exceed an average of 10 kW/acre. For design purposes, RH TRU waste shall be estimated to generate an average of 60 W of heat per canister.

3.2.11 Combined Load Criteria

Design Class II confinement structures and supports shall be designed for dead, live, thermal, wind, earthquake, tornado, and soil pressure loads.

The Design Class III structures and those Design Class II structures and supports not required for confinement shall be designed in accordance with the UBC.[5]

3.2.11.1 Nomenclature

Nomenclature is defined in Section 3.2.9.1, and additional symbols related to the design of steel and concrete structures shall be defined as follows:

Note: The 33 percent increase in allowable stresses for concrete and steel due to seismic or wind loadings shall not be permitted.

S For steel structures, S shall be the required strength based on the elastic design method and the allowable stresses defined in Part I of the American Institute of Steel Construction (AISC) Specification.[9]

U For concrete structures, U shall be the required strength to resist the design loads. This is based on the strength design method described in America Concrete Institute Standard 318-77.[10]

3.2.11.2 Load Combinations

3.2.11.2.1 Design Requirements

All structures shall be designed to have strengths at all sections at least equal to the structural effects of the design loads as listed in Table 3.2-3 in such combinations as shown below.

Design Class II - Reinforced Concrete Structures

$U = 1.4D + 1.4F + 1.7L + 1.7H$
$U = 1.4D + 1.4F + 1.7L + 1.7H + 1.7W$
$U = 1.05D + 1.05F + 1.3L + 1.3H + 1.3T$
$U = 1.05D + 1.05F + 1.3L + 1.3H + 1.3W + 1.3T$
$U = D + F + L + H + T + E'$
$U = D + F + L + H + T + W_t$

Design Class II - Steel Structures

$S = D + L$
$S = D + L + W$
$1.5S = D + L + T$
$1.5S = D + L + T + W$
$1.6S = D + L + T + E'$
$1.6S = D + L + T + W_t$

Where the structural effects of differential settlement may be significant, it shall be included with the dead load (D) in load combination. An estimation of this effect shall be based on a realistic assessment of such effect occurring in service. When any load reduces the effects of other loads, the corresponding coefficient for that load shall be taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with the other loads, else the coefficient for that load shall be taken as zero.

Design Class IIIA - Reinforced Concrete and Steel Structures

Design Class IIIA structures shall be designed in accordance with the provisions of UBC,[5] except that the design loads shall comply with ANSI A58.1,[2] unless otherwise specified in Table 3.2-3.

Design Class IIIB - Reinforced Concrete, Steel and Masonry Structures

Design Class IIIB structures shall be designed in accordance with the provisions of UBC,[5] except that the design loads shall comply with ANSI A58.1,[2] unless otherwise specified in Table 3.2-3.

Design Class IIIB - Pre-engineered Metal Building Structures

The pre-engineered metal building shall be designed in accordance with the Metal Building Systems Manual of Metal Building Manufacturers Association,[11] except that the design loads shall comply with ANSI A58.1[2] with the following exceptions:

Wind load shall be calculated based on a basic wind speed, V, of 91 mi/h. For building height less than 30 ft, the effective velocity pressures q_F, q_M, and q_P in ANSI A58.1[2] shall be reduced using the following formulas.

$$q_F = 0.00268\ V^2\ (H/30)^{2/7}$$
$$q_M = 0.00246\ V^2\ (H/30)^{2/7}$$
$$q_P = 0.00377\ V^2\ (H/30)^{2/7}$$

Where H = Mean height of the roof or 15 ft whichever is greater.

Seismic load shall be in accordance with the requirements set forth in UBC,[5] Seismic Zone No. 1.

Snow load shall be calculated based on a basic snow load of 10 lb/ft^2.

3.2.11.2.2 Minimum Factors of Safety with Respect to Overturning, Sliding, and Floatation

In addition to the above load combinations, the following combinations and factors of safety shall apply to structures when being checked for overturning, and sliding:

Minimum Factors of Safety

Load Combination	Overturning	Sliding
D + H + W	1.5	1.5
D + H + E′	1.1	1.1
D + H + W_t	1.1	1.1

Where Section 3.2.9.1 describes H, D, E′, W, and W_t except that, for conservatism, only the weight of a structure and the components permanently attached to it shall be accounted for in D. The factor of safety against floatation, defined as the ratio of dead load divided by the hydrostatic uplift, shall be 1.1 minimum.

3.2.12 Soil Erosion Control

The design control measures to minimize soil erosion and to control sediment laden runoff at the WIPP facility shall be in accordance with the amended Water Control Commission regulations, Water Quality Control Commission, State of New Mexico, and applicable federal regulations.

References for Section 3.2

1. The University of Chicago, SMPR Research Paper No. 155, A Site Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico, UN000075, February 1978.

2. ANSI A58.1-1972, American National Standard Building Code Requirements for Minimum Design Loads in Buildings and other Structures.

3. BC-TOP-3-A, Tornado and Extreme Wind Design Criteria for Nuclear Power Plants, August 1974.

4. BC-TOP-4-A, Seismic Analyses of Structures and Equipment for Nuclear Power Plants, November 1974.

5. Uniform Building Code, 1979 edition.

6. Tsai and Tseng, Standardized Seismic Design Spectra for Nuclear Plant Equipment, Nuclear Engineering and Design, Vol. 45, UN000169, 1978.

7. DOE Guide for Calculation of Design Wind Pressures.

8. DR-22-V-01, WIPP Soils Design Report, Volume I, Bechtel, Inc., 1979.

9. American Institute of Steel Construction, Specification for Design, Fabrication, Erection of Structural Steel for Buildings, November 1, 1978.

10. American Concrete Institute Standard 318-77, Building Code Requirement for Reinforced Concrete, December 1977.

11. Metal Building Systems Manual of Metal Building Manufacturers Association, Cleveland, OH.

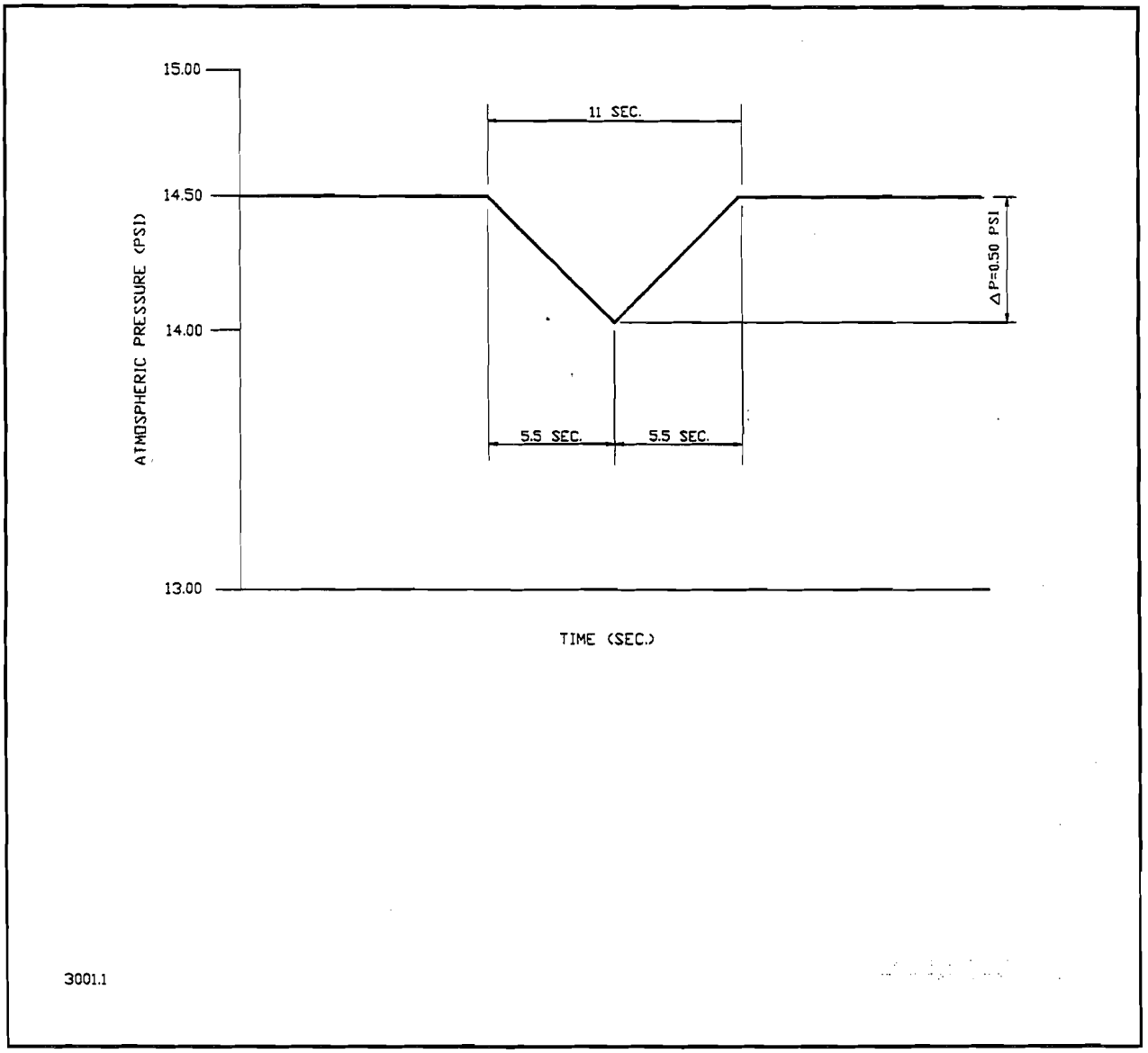

Figure 3.2-1, Idealized Function of Atmospheric Pressure Change vs. Time

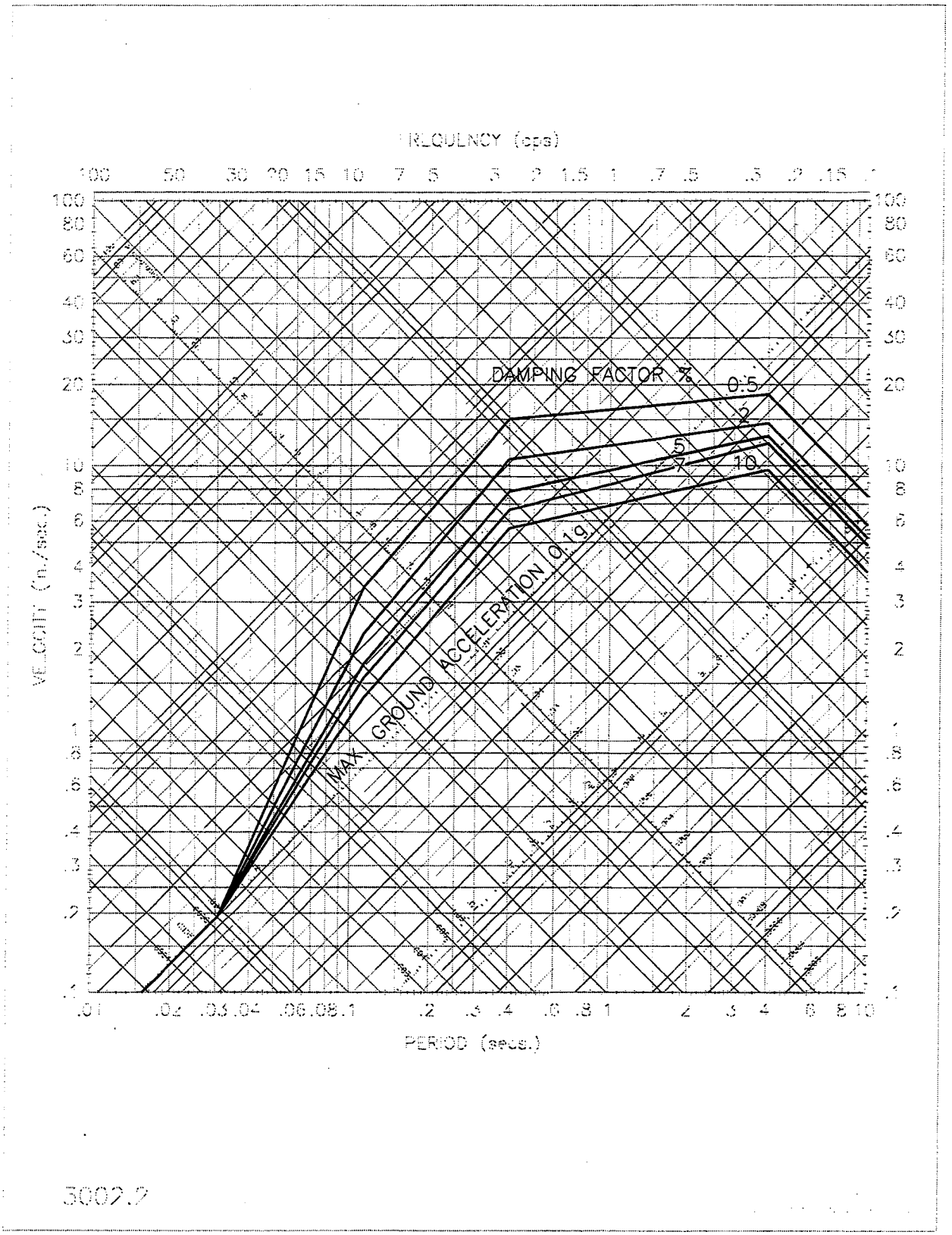

Figure 3.2-2, Horizontal Design Response Spectra

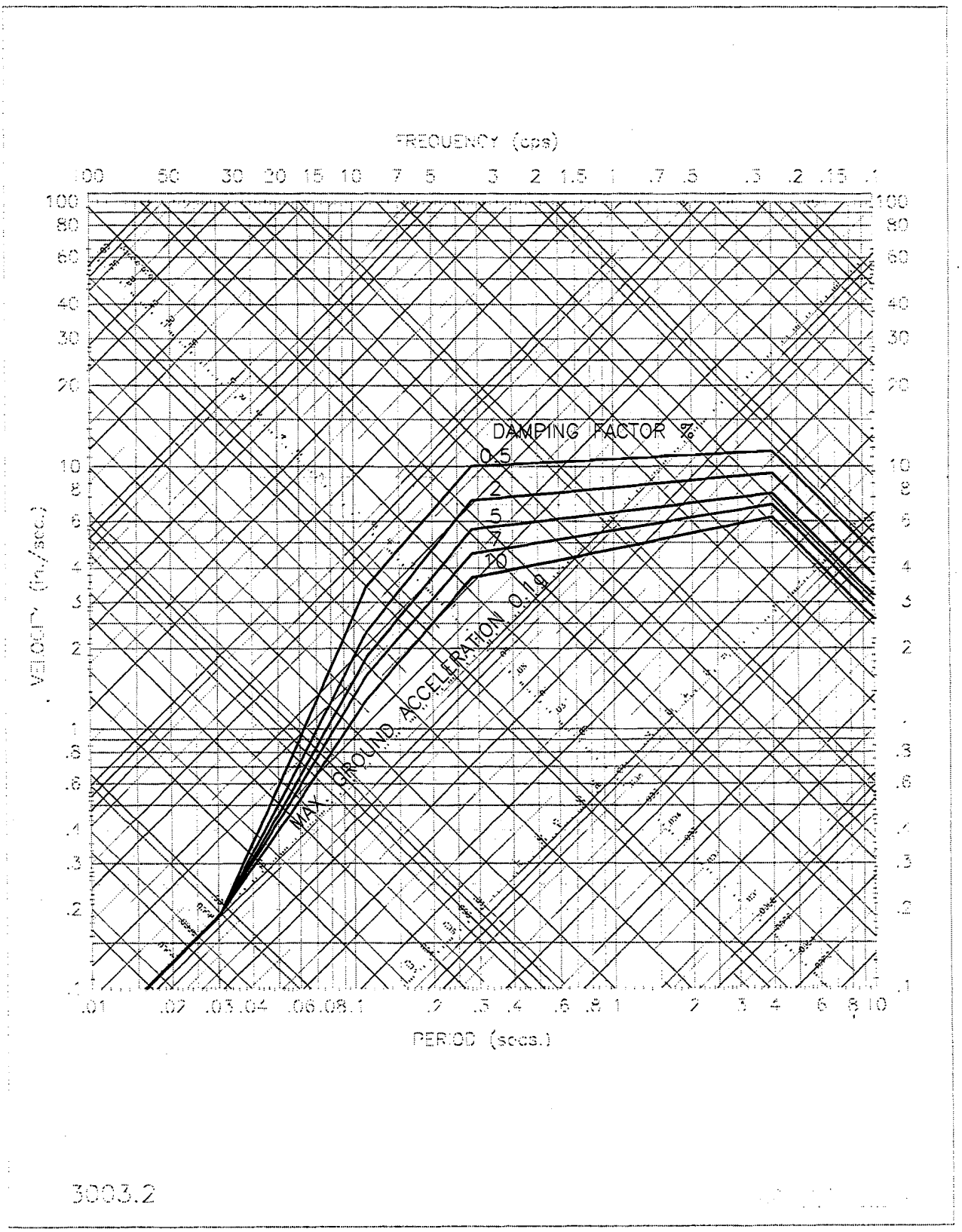

Figure 3.2-3, Vertical Design Response Spectra

Table 3.2-1, Design Wind Load (Enclosed Structures Subjected to 110 mi/h Wind)

	Height, ft	Windward, lb/ft^2	Leeward, lb/ft^2	Roof, lb/ft^2	Sides, lb/ft^2	Limitations
External	0-29	+26	-19	-22	-22	Height/Width < 2.5
	30-40	+35	-26	-25	-25	Height/Length < 2.5
	50-99	+40	-30	-35	-35	
	100-149	+45	-34	-39	-39	
Internal Pressure	0-20	-9	-9	-9	-9	No Openings
	30-49	-10	-10	-10	-10	
	50-99	-12	-12	-12	-12	
	100-149	-14	-14	-14	-14	
Internal Vacuum	0-30	+9	+9	+9	+9	No Openings
	30-50	+10	+10	+10	+10	
	50-100	+12	+12	+12	+12	
	100-150	+14	+14	+14	+14	

Table 3.2-2, Damping Values of SSCs for Design Basis Earthquake

Structure or Component	Damping Value % of Critical Damping
Welded steel structures	4
Bolted steel structures	7
Reinforced concrete structures	7
Equipment and large diameter piping systems, pipe diameter greater than 12 in	3
Small diameter piping systems, diameter equal to or less than 12 in	2
Prestressed concrete structures	5

Table 3.2-3, Design Loads for Surface Structures[1]

DESIGN CLASS	STRUCTURE	SEISMIC DBE	SEISMIC UBC	TORNADO DBT	SNOW lb/ft^2	WIND mi/h
Class II	Waste Handling Building	X[2]		X	27	110
Class II	Station A	X		X	27	110
Class IIIA	Support Building	(3)	X	(3)	10	99
Class IIIA	Exhaust Filter Building		X		10	99
Class IIIA	Building 412	(3) X		(3)	27	110
Class IIIB	Warehouse/Shops Building		X		10	91
Class IIIB	Water Pumphouse		X		10	91
Class IIIB	SH Shaft Hoist House & Electrical Room		X		10	91

Notes:

(1) For definition of various loads, see Section 3.2.9.1.
(2) "X" indicates applicable load.
(3) The main lateral force resisting members of the Support Building and Building 412 shall be designed for DBE and DBT to protect the Waste Handling Building from structural failure.

3.3 Safety Protection Criteria

3.3.1 Confinement Requirements

The regulatory requirements for confinement applicable to the WIPP are defined in DOE Order 6430.1A,[1] Division 13, Special Facilities. Confinement systems for the WIPP shall be designed to the pertinent provisions of DOE Order 6430.1A,[1] Section 1300-7, and shall accomplish the following:

- Minimize the spread of radioactive and other hazardous materials within the unoccupied process areas
- Prevent, if possible, or minimize the spread of radioactive and other hazardous materials to occupied areas
- Minimize the release of radioactive and other hazardous materials in facility effluents during normal operation and anticipated operational occurrences
- Limit the release of radioactive and other hazardous materials resulting from DBAs including severe natural phenomena and man-made events in compliance with the guidelines contained in Section 1300-1.4.2, Accidental Releases

The ventilation system of a confinement system shall maintain airflow into the containment rooms or areas of a building to ensure that the airflow is from non-contaminated areas to potentially contaminated areas, and then to areas potentially at higher levels of contamination.

Confinement systems for the WIPP shall be designed to specific provisions of DOE Order 6430.1A,[1] Section 1324-6, as follows:

- The primary confinement shall consist of the waste containers
- The secondary confinement system shall consist of the buildings/structures and associated ventilation systems that enclose the primary confinement
- The tertiary confinement shall be the natural geologic setting

The secondary confinement shall be designed to ensure that it can withstand the effects of severe natural phenomena and man-made events, including DBAs, and remain functional to the extent that the guidelines in Section 1300-1.4.2, Accidental Releases, are not violated.

3.3.2 Fire Protection

The WIPP fire protection system shall be designed in conformance with the design criteria set forth in DOE Order 6430.1A,[1] DOE Order 5480.7A,[2] and 30 CFR 57.[3]

The fire protection system design shall conform to provision of the following codes and standards as applicable.

- National Fire Codes of the National Fire Protection Association (NFPA)
- Loss prevention data sheets of Factory Mutual Research Corporation
- Uniform Building Code
- DOE/EP-0108, Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems[4]

3.3.3 Radiological Protection

The WIPP facility shall use design considerations that assure and maintain radiation exposures as low as reasonably achievable (ALARA) to the general public and workers. These considerations shall be consistent with the intent of the Radiological Control Manual, DOE/EH-0256T,[5] 10 CFR 835,[6] and recommendations of Nuclear Regulatory Commission (NRC) Regulatory Guides 8.8[7] and 8.10.[8]

3.3.3.1 Controlled Areas

Entrance to and exit from controlled areas within the WIPP facility shall be implemented in accordance with the WIPP Operational Health Physics Procedures Manual.[9]

3.3.3.2 High Radiation Areas

All high radiation areas shall be designed with access control and warning devices in accordance with the requirements set forth in, DOE/EH-0256T[5] and 10 CFR 835.502.[6]

3.3.3.3 Shielding

The shielding design basis shall be to limit the maximum exposure to an individual worker to one fifth of the annual occupational external exposure limits specified in 10 CFR 835.[6] Within the design basis, personnel exposures shall be maintained ALARA. Specifically, the shielding shall be designed to limit the occupational exposure during normal operation to the administratively selected limit of 1 rem/yr TEDE for operating personnel.

The integrity, design, and performance of concrete shielding shall be assured by adherence to the requirements and practices recommended in ANSI N 101.6-1972, Concrete Radiation Shields.[10]

The hot cell shielding shall be designed for an internal gamma surface dose rate of 400,000 rem/hr and for an internal neutron surface dose rate of 45 rem/hr.

3.3.3.4 Nuclear Criticality Safety

Criticality safety requirements shall be considered for the WIPP in accordance with DOE Order 5480.24.[11] The basic elements and control parameters of programs for nuclear criticality invoked by the DOE order are the American Nuclear Society's ANSI/ANS nuclear criticality safety standards listed below:

ANSI/ANS-8.1[12]	Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
ANSI/ANS-8.3[13]	Criticality Accident Alarm System
ANSI/ANS-8.5[14]	Use of Borosilicate-Glass Raschig rings as a Neutron Absorber in Solutions of Fissile Material
ANSI/ANS-8.7[15]	Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
ANSI/ANS-8.15[16]	Nuclear Criticality Control of Special Actinide Elements
ANSI/ANS-8.19[17]	Administrative Practices for Nuclear Criticality Safety

3.3.4 Industrial and Mining Safety

The WIPP surface SSCs shall be designed to comply with the occupational safety and health program requirements of DOE Order 5483.1A[18] and the Occupational Safety and Health Administration requirements of 29 CFR 1910[19] and 29 CFR 1926[20] to minimize the potential for industrial accidents.

The WIPP hoists and underground systems and equipment shall be designed in conformance with the requirements of Mine Safety and Health Administration 30 CFR 57[3] and the New Mexico Mine Safety Code For All Mines.[21]

References for Section 3.3

1. DOE Order 6430.1A, General Design Criteria, Division 13, Special Facilities, April 1989.

2. DOE Order 5480.7A, Fire Protection, February 17, 1993.

3. 30 CFR 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, 1977.

4. DOE/EP-0108, Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems, January 1984.

5. DOE/EH-0256T, Radiological Control Manual, June 1992.

6. 10 CFR 835, Occupational Radiation Protection, December 14, 1993.

7. Nuclear Regulatory Commission Regulatory Guide 8.8, Information Relevant to Ensuring Occupational Radiation Exposure As Low As Is Reasonably Achievable (Nuclear Power Reactors), March 1979.

8. Nuclear Regulatory Commission Regulatory Guide 8.10, Operating Philosophy for Maintaining Occupational Radiation Exposure As Low As Is Reasonably Achievable, September 1975.

9. WP 12-HP, WIPP Operational Health Physics Procedures Manual, May 1995.

10. ANSI N101.6-1972, Concrete Radiation Shields, December 1972.

11. DOE Order 5480.24, Nuclear Criticality Safety, August 12, 1992.

12. ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, 1983.

13. ANSI/ANS-8.3, Criticality Accident Alarm System, 1986.

14. ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material, 1986.

15. ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials, 1975.

16. ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements, 1981.

17. ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety, 1984.

18. DOE Order 5483.1A, Occupational Safety and Health Program for DOE Contractor Employees at Government Owned Contractor Operated Facilities, June 22, 1983.

19. 29 CFR 1910, Occupational Safety and Health Standards, 1970.

20. 29 CFR 1926, Safety and Health Regulations for Construction, 1979.

21. New Mexico Institute of Mining Technology, New Mexico Safety Code for All Mines, 1990.

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FACILITY DESIGN AND OPERATION

This Chapter provides an overview of (1) the design of the WIPP facility and associated principal structures, systems, and components (SSCs), and (2) the waste handling/emplacement process. Sufficient detail is provided to facilitate hazard identification and principal design and safety criteria selection.

As discussed in the General Plant Design Description[1] (GPDD), no Design Class I structure, equipment or system exists at the WIPP. Design information is provided in this chapter only for those SSCs listed in Table 4.1-1 that have been designated as Design Class II, and IIIA in the GPDD. Design Class IIIB SSCs are briefly described only to the extent necessary to complete the overview of the facility design and operation. Detailed design information on each SSC may be found in the respective System Design Description (SDD).

4.1 Summary Description

The WIPP facility is located in Eddy County about 26 miles east of Carlsbad, New Mexico, encompassing 10,240 acres (16 sections) within the site boundary (Figure 4.1-1).

The controlled zones and associated fenced-in areas are described in Chapter 2. The facility is divided into three basic groups: surface structures, shafts, and subsurface structures, shown on Figures 4.1-2a, 4.1-2b, and 4.1-3.

The WIPP facility surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground. The surface structures are located in an area (approximately 35 acres) within a perimeter security fence (Figure 4.1-2a).

The vertical shafts extending from the surface to the underground horizon are the waste shaft, the salt handling (SH) shaft, the exhaust shaft, and the air intake shaft (AIS). These shafts are lined from the shaft collar to the top of the salt formation (about 850 ft below the surface), and are unlined through the salt formation. The shaft lining is designed to withstand the full piezometric water pressure associated with any water-bearing formation encountered.

The subsurface structures consist of the waste disposal area, the support area, and the experimental area (Figure 4.1-3).

References for Section 4.1

1. U.S. Department of Energy, Waste Isolation Pilot Plant, General Plant System Design Description (GPDD), Revision 0, September 1993.

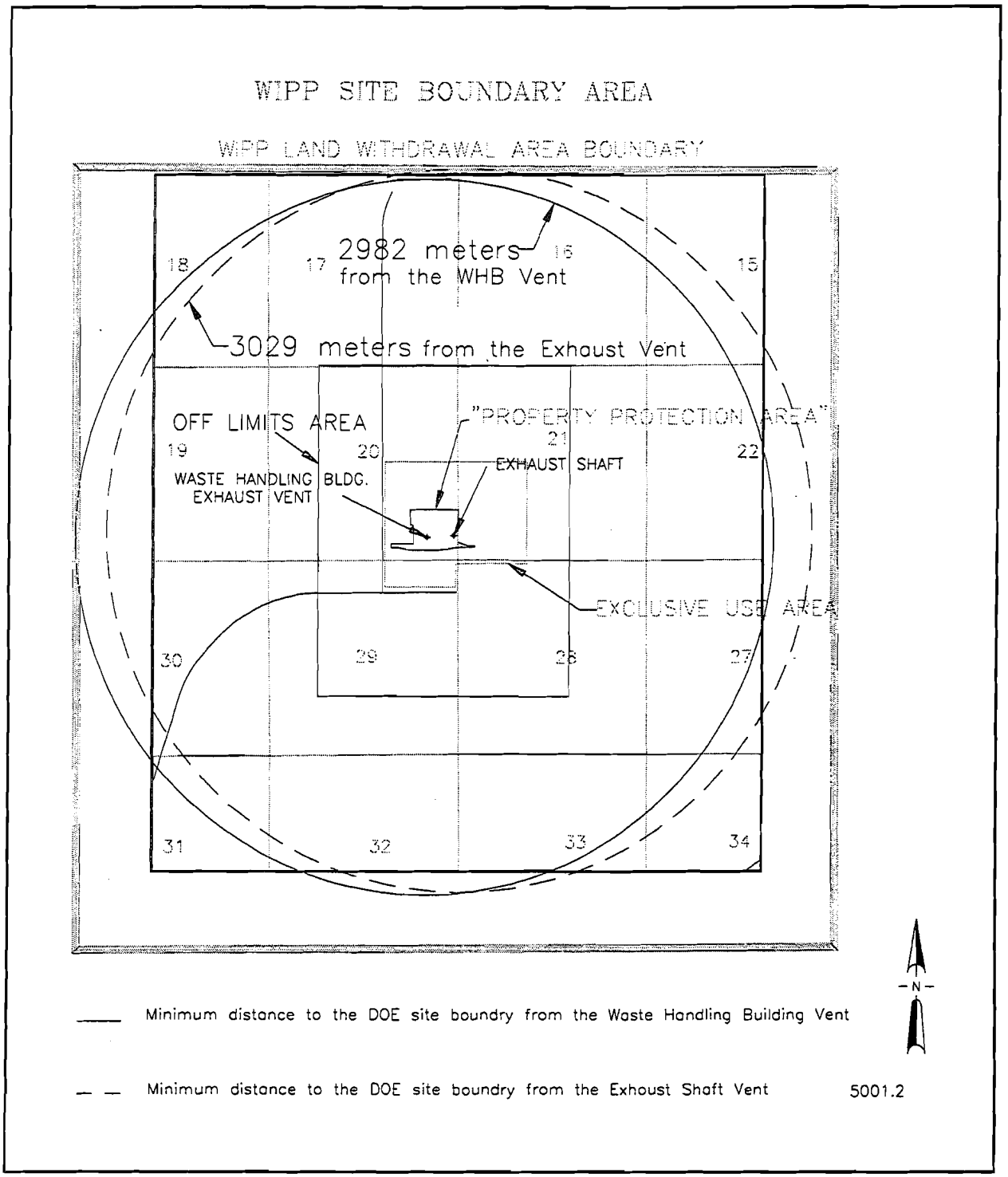

Figure 4.1-1, WIPP Site Boundary and Subdivisions

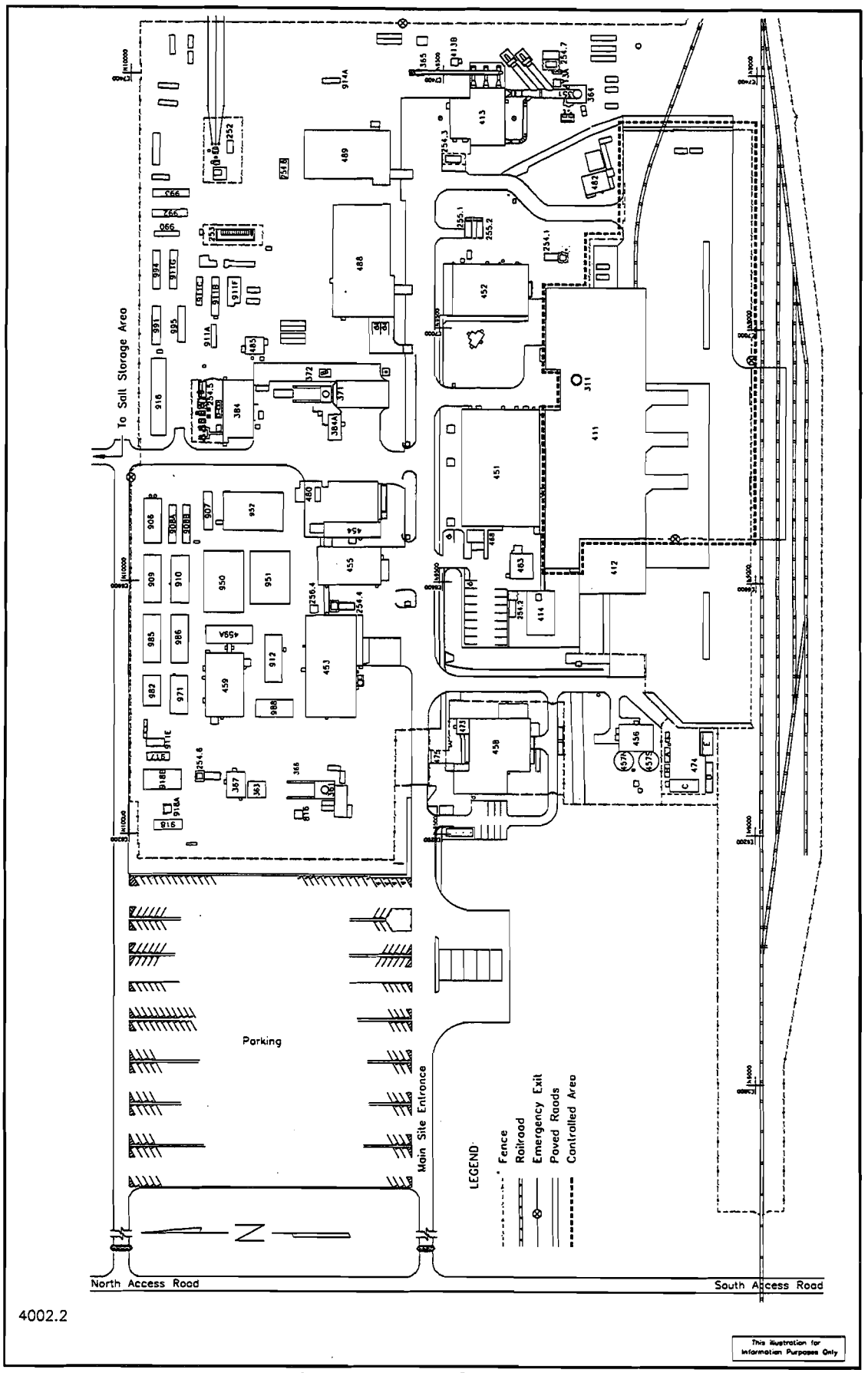

Figure 4.1-2a, WIPP Surface Structures

4003.3

BLDG./ FAC. #	DESCRIPTION
252	SPS UTILITY SUBSTATION
253	13.8 KV SWITCHGEAR 25P-SWG15/1
254.1	AREA SUBSTATION NO.1 25P-SW15.1
254.2	AREA SUBSTATION NO.2 25P-SW15.2
254.3	AREA SUBSTATION NO.3 25P-SW15.3
254.4	AREA SUBSTATION NO.4 25P-SW15.4
254.5	AREA SUBSTATION NO.5 25P-SW15.5
254.6	AREA SUBSTATION NO.6 25P-SW15.6
254.7	AREA SUBSTATION NO.7 25P-SW15.7
254.8	AREA SUBSTATION NO.8 25P-SW15.8
255.1	EMERGENCY GENERATOR #1 25-PE 503
255.2	EMERGENCY GENERATOR #2 25-PE 504
311	WASTE SHAFT
351	EXHAUST SHAFT
361	AIR INTAKE SHAFT
362	AIR INTAKE SHAFT/HOIST HOUSE
363	AIR INTAKE SHAFT/WINCH HOUSE
364	EFFLUENT MONITORING INSTRUMENT SHED A
365	EFFLUENT MONITORING INSTRUMENT SHED B
366	AIR INTAKE SHAFT HEADFRAME
371	SALT HANDLING SHAFT
372	SALT HANDLING SHAFT HEADFRAME
384	SALT HANDLING SHAFT HOISTHOUSE
384A	SALT HOIST OPERATIONS
411	WASTE HANDLING BUILDING
412	TRUPACT MAINTENANCE BUILDING
413	EXHAUST FILTER BUILDING
413A	EFFLUENT MONITORING ROOM A
413B	EFFLUENT MONITORING ROOM B
414	WATER CHILLER FACILITY & BLDG
451	SUPPORT BUILDING
452	SAFETY & EMERGENCY SERVICES FACILITY
453	WAREHOUSE/SHOPS BUILDING
454	VEHICLE SERVICE BUILDING
455	AUXILLIARY WAREHOUSE BUILDING

BLDG./ FAC. #	DESCRIPTION
456	WATER PUMPHOUSE
457N	WATER TANK 25-D-001A
457S	WATER TANK 25-D-001B
458	GUARD AND SECURITY BUILDING
459	CORE STORAGE BUILDING
459A	SANDIA ANNEX
463	COMPRESSOR BUILDING
465	AUXILIARY AIR INTAKE
468	TELEPHONE HUT
473	ARMORY BUILDING
474	HAZARDOUS WASTE STORAGE FACILITY
474A	HAZARDOUS WASTE STORAGE BUILDING
474B	HAZARDOUS WASTE STORAGE BUILDING
474C	OIL & GREASE STORAGE BUILDING
474D	GAS BOTTLE STORAGE BUILDING
474E	HAZARD MATERIAL STORAGE BUILDING
474F	WASTE OIL RETAINER
475	GATEHOUSE
480	VEHICLE FUEL STATION
482	EXHAUST SHAFT HOIST EQUIP. WAREHOUSE
485	SULLAIR COMPRESSOR BUILDING
486	ENGINEERING BUILDING
489	TRAINING BUILDING
816	SANDIA TEST WELL (NOT IDENTIFIED)
906	UNDERGROUND OPERATIONS TRAILER
907	TRANS. & HAZ. MATERIAL HANDLING TRAILER
908A	ENVIRONMENTAL MONITORING LAB TRAILER
908B	UNIVERSITY CONSORTIUM TRAILER
909	PROJECT CONTROL TRAILER
910	ENVIRONMENTAL MONITORING TRAILER
911A	SITE LOCKSMITH TRAILER
911B	SANDIA M101 TRAILER
911C	SANDIA OFFICES TRAILER
911E	SANDIA TRAILER
911F	SANDIA B49 AND B49 ANNEX

BLDG./ FAC. #	DESCRIPTION
911G	SANDIA LABS TRAILER
912	TRAINING TRAILER
914A	TRAINING TRAILER
915	NEW MEXICO ENVIR. DEPT. TRAILER
916	SANDIA OFFICES TRAILER
917	AIS MONITORING
918	VOC TRAILER
918A	VOC AIR MONITORING STATION
918B	VOC LAB TRAILER
950	WORK CONTROL TRAILER
951	PROCUREMENT / PURCHASING
952	TRAILER (7-PLEX)
971	HUMAN RESOURCES TRAILER
982	MAINTENANCE TRAILER
985	QA TRAILER
986	PUBLICATIONS & PROCEDURES TRAILER
988	TRAINING TRAILER
991	SANDIA OFFICES TRAILER
992	SANDIA CALIBRATION LAB TRAILER
993	SANDIA OFFICES TRAILER
994	SANDIA LAB TRAILER
995	SANDIA QA RECORDS TRAILER
SWR NO.1	SWITCHRACK NO. 1
SWR NO.2	SWITCHRACK NO. 2
SWR NO.3	SWITCHRACK NO. 3
SWR NO.4	SWITCHRACK NO. 4
SWR NO.6	SWITCHRACK NO. 6
SWR NO.7,7A,7B	SWITCHRACK NO. 7, 7A, 7B
SWR NO.7C	SWITCHRACK NO. 7C
SWR NO.8	SWITCHRACK NO. 8
SWR NO.9	SWITCHRACK NO. 9
SWR NO.10	SWITCHRACK NO. 10
SWR NO.11	SWITCHRACK NO. 11
--	SANDIA GENERATOR NO.1
--	SANDIA GENERATOR NO.2

Figure 4.1-2b, Legend for Figure 4.1-2a

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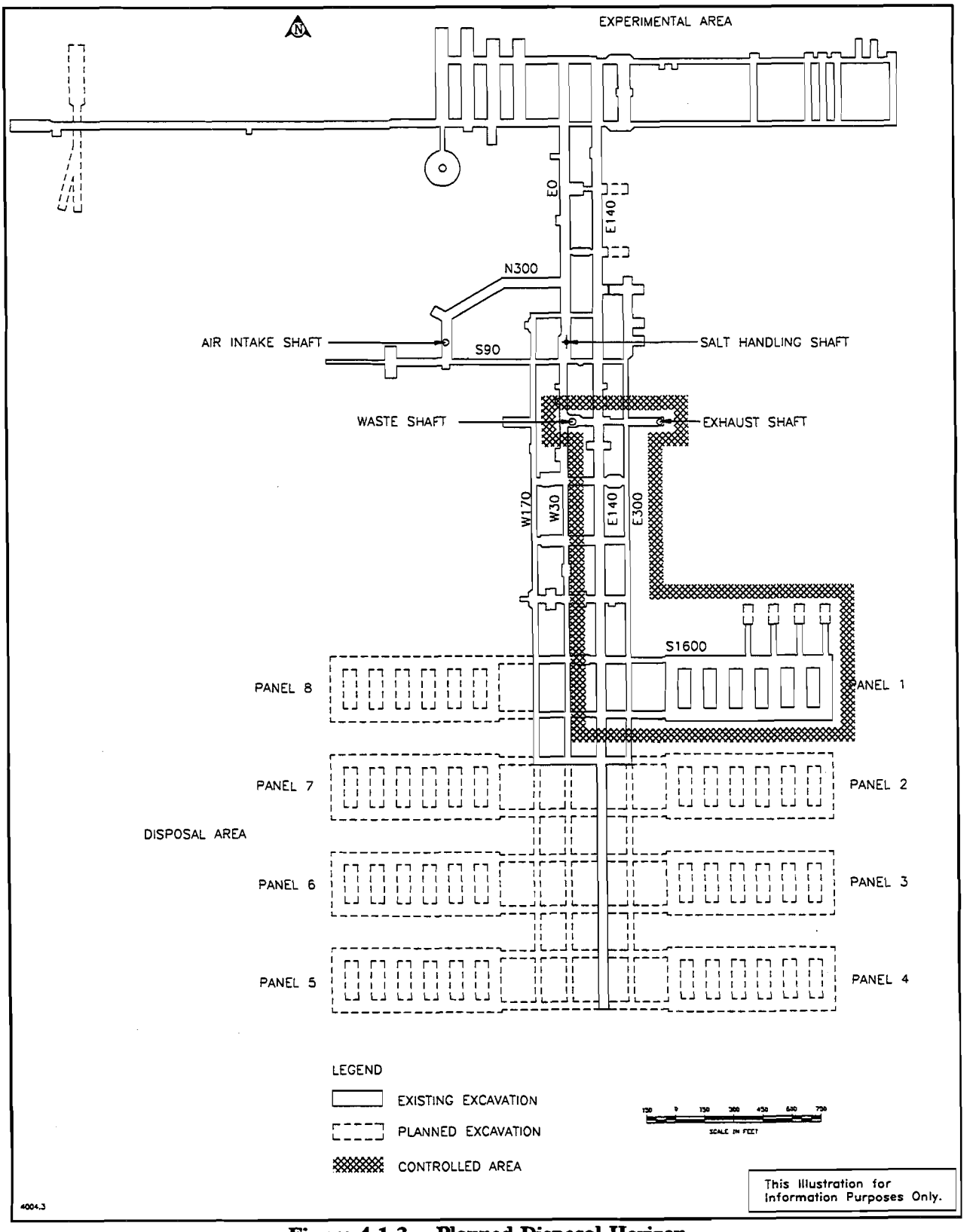

Figure 4.1-3, Planned Disposal Horizon

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
COMPRESSED AIR SYSTEM (SDD-CAOO)			
High Efficiency Particulate Air (HEPA) filters for Support Building compressors	II		Control of radioactive effluent
PLANT BUILDINGS, FACILITIES, AND MISCELLANEOUS EQUIPMENT (SDD-CFOO)			
Waste Handling Building structure and structural components including tornado doors (Bldg. 411)	II	Design Basis Earthquake (DBE), Design Basis Tornado (DBT)	Provide physical confinement
Station A Effluent Monitoring Instrument Shed (Bldg 364)	II	DBE, DBT	Design Class Interface. (Houses Station A)
Effluent Monitoring Rooms A and B (Building 413A and 413B)	II	DBE, DBT	Design Class Interface. (Houses Local Processing Units (LPU)s collecting data from Stations A and B)
Station B Effluent Monitoring Instrument Shed (Bldg 365)	IIIA	Uniform Building Code (UBC)	Design Class Interface. (Houses monitoring equipment for Exhaust Filter Building duct)
Support Building (Bldg 451)	IIIA	UBC (Note 2)	Design Class Interface. (Houses Central Monitoring Room (CMR))

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
Water Pump House (Bldg 456)	IIIA	UBC	Design Class Interface. (Houses Fire Pumps)
Exhaust Filter Building (Bldg 413)	IIIA	UBC	Design Class Interface. (Houses Exhaust Filtration System)
EFB HEPA Filter Units & Isolation Dampers	II		
EFB Exhaust System	IIIA		
Building 412 (Originally TRUPACT Maintenance Facility)	IIIA	UBC (Note 2)	Design Class Interface. (Structural interface with WHB)
PLANT MONITORING AND COMMUNICATION SYSTEM (SDD-CMOO) HEPA Filters & Isolation Dampers	II		
Central Monitoring System	IIIA		Monitors important facility parameters
Exhaust System Instruments and Hardware	IIIA		
ELECTRICAL SYSTEM (SDD-EDOO {Surface and Underground})			
Diesel Generator and associated equipment	IIIA		Provides backup power to Design Class II and IIIA items
Central Monitoring Uninterruptible Power Supply	IIIA		Provide backup power to CMR
ENVIRONMENTAL MONITORING SYSTEM (SDD-EM00)			
Volatile Organic Compound (VOC) Monitoring Equipment and sub-systems	IIIA		Monitors release of VOCs

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
FIRE PROTECTION SYSTEM (SDD-FP00)			
Fire Pumps and Structural Supports	IIIA		Design complexity
HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEM (SDD-HV00)			
Exhaust Filtration System	II		Design Class Interface. (Control of radioactive effluent)
HEPA Filters	II		Control of radioactive effluent
Tornado Dampers	II	DBE, DBT	Control of radioactive effluent
Exhaust Systems HV01 (Bldg 411, CH HVAC), HV02, (Bldg 411, RH HVAC), and HV04 (Bldg 413, Exhaust Filter Building HVAC)	IIIA		Design Class Interface. (Provide filtration and maintain differential pressure)
HVAC for the CMR	IIIA		Design Class Interface. (Maintains acceptable CMR environment)
RADIATION MONITORING SYSTEM (SDD-RM00)			
Station A Units A1 and A2 The remainder of the RMS SSCs are Design Class IIIA	II	DBE, DBT	Monitors radioactive effluents

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
UNDERGROUND HOIST SYSTEM (SDD-UH00)			
Waste Hoist and Equipment	IIIA	(Note 3)	Failure could cause radioactive material release
UNDERGROUND VENTILATION SYSTEM (SDD-VU00)			
Exhaust duct elbow at the top of the Exhaust Shaft	II	DBE, DBT	Design Class Interface. (Channels exhaust air to the EFB)
HEPA Filters and Isolation Dampers	II		Control of radioactive effluent
Exhaust Fans for the filtration mode	II		Design Class Interface. (Channels exhaust air through the EFB)
Exhaust System Instruments and Hardware	IIIA		
WASTE HANDLING EQUIPMENT (SDD-WH00)			
Facility Cask	II	(Note 4)	Provides permanent shielding
Telescoping Port Shield	II	UBC (Note 5)	Provides permanent shielding
Shield Bell	II	(Note 5)	Provides permanent shielding
Shield Valve	II	(Note 5)	Provides permanent shielding
Hot Cell Viewing Windows	II	(Note 5)	Provides permanent shielding
Transfer Drawer	II	UBC (Note 5)	Design Class Interface. (Provides permanent shielding)
Leak check tools for TRUPACT-II	IIIA	(Note 6)	Failure could cause radioactive materials release
5-ton TRUDOCK cranes	IIIA	DBE	Failure could cause radioactive materials release
Adjustable Center-of-Gravity Lift Fixtures (ACGLF's)	IIIA		Failure could cause radioactive materials release
TRUPACT-II tools	IIIA	(Note 6)	Failure could cause radioactive materials release

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
Strongback Lifting Fixture (CH)	IIIA		Failure could cause radioactive materials release
140/25 ton crane	IIIA	UBC (Note 7)	Failure could cause radioactive materials release
Cask Lifting Yoke	IIIA		Failure could cause radioactive materials release
Facility cask loading room Hoist	IIIA		Failure could cause radioactive materials release
Canister Grapple	IIIA		Failure could cause radioactive materials release
The Horizontal Emplacement and Retrieval Equipment (HERE)	IIIA		Failure could cause radioactive materials release
Hot Cell 15-ton Bridge Crane	IIIA	(Note 7)	Failure could cause radioactive materials release
Bridge and Trolley	IIIA	(Note 8)	Failure could cause radioactive materials release
Bridge Mounted Manipulator	IIIA		Failure could cause radioactive materials release
Master-Slave Manipulator	IIIA		Failure could cause radioactive materials release
Overpack Welder Equipment	IIIA		Failure could cause radioactive materials release
Grapple Rotating Block	IIIA		Failure could cause radioactive materials release
Grapples	IIIA		Failure could cause radioactive materials release
Canister Shuttle Car	IIIA		Failure could cause radioactive materials release

Table 4.1-1, Design Classes of Structures, Systems, and Components at the WIPP Facility

System/Component	Design Class (Note 1)	Seismic/Tornado Design Requirements	Design Class Function
SWB Lift Fixture Adapter	IIIA		Failure could cause radioactive materials release
Radiation Assessment Filters	IIIA		Prevents contamination release
All other Systems, Structures, and Components	IIIB		

Notes

Note 1 See Table 3.1-2 for Basic Design Requirement and Table 3.2-3 for the Design Loads.
Note 2 The main lateral force resisting members of the Support Building and Building 412 are designed for DBE and DBT to protect the Waste Handling Building from their structural failure.
Note 3 Design loads and requirements dictated by Mine Safety and Health Administration (MSHA).
Note 4 Cask certification requirements exceed DBT/DBE.
Note 5 System completely within a Class II confinement - DBE/DBT not required.
Note 6 TRUPACT-II Design included in Safety Analysis Report for Packaging (SARP).
Note 7 Designed to hold load in place in the event of a DBE.
Note 8 Supports designed to prevent manipulator from falling during DBE.

4.2 Facility Design

4.2.1 Surface Facilities

The WIPP facilities provide for the handling and subsequent underground emplacement of TRU waste. Surface waste handling operations are conducted within a controlled area (CA). The maximum extent of the CA for simultaneous CH and RH waste handling activities is depicted in Figure 4.1-2a. Operational Health Physics (OHP) will determine specific boundary locations and posting requirements for CAs and/or Radiological Buffer Areas (RBA) as required by scheduled waste handling activities and radiological conditions inside the Waste Handling Building (WHB). The CA external to the WHB provides for the receipt, in-process storage, and dispatch of rail- or truck-transported radioactive waste shipping containers. OHP will determine specific boundary locations and posting requirements for the external CA consistent with scheduled activities.

The TRUPACT II contact handled (CH) TRU shipping containers are removed from their transporters outside of the WHB prior to transfer into the WHB. Remote handled (RH) waste shipments, including the transporter trailer and shielded road cask shipping containers, are transferred into the WHB for subsequent operations.

The land areas around the surface buildings are designed to minimize erosion. Runoff water is diverted as necessary from the buildings, tracks, or roads and returned to the natural drainage path.

4.2.1.1 Waste Handling Building

The WHB and its associated systems provide a facility to unload TRU waste from the incoming shipping containers and to transfer the TRU waste to the underground disposal area via the waste shaft. The WHB is divided into the following functional areas: the CH TRU waste handling area, the RH waste handling area, the WHB support area, Building 412, and the WHB mechanical equipment room. The general layout of the building is shown in Figure 4.2-1a and Figure 4.2-1b, with sectional views shown in Figure 4.2-2. Details of the hot cell area are given in Figure 4.2-3a, Figure 4.2-3b, and Figure 4.2-3c.

The WHB is a steel frame structure with insulated steel siding, and includes portions of the building, such as the hot cell complex that are constructed of concrete for shielding and structural purposes. The WHB acts as a confinement barrier to control the potential for release of radioactive material and is classified as Design Class II. The WHB is designed for Design Class II loads, including the Design Basis Earthquake (DBE) and Design Basis Tornado (DBT). Waste handling areas subject to potential for contamination are provided with protective coatings.

4.2.1.1.1 CH TRU Waste Handling Area

The CH TRU side of the WHB has space and equipment for the unloading of TRUPACT II shipping containers and enables the transfer of facility pallets and waste containers to the waste hoist for transfer underground. This area has air locks, CH Bay, an overpack and repair room (OP&RR), and CH TRU support facilities, as shown in Figure 4.2-1a.

Entrance Air Locks

TRUPACT II shipping containers are unloaded from the transport trailers in the CA external to the WHB and are transferred into the CH Bay area through the three air locks that provide access to the CH TRU side of the WHB. To assist the HVAC in maintaining the building at a negative pressure, the doors at each end of the air lock are interlocked to prevent inadvertent opening of both doors at the same time.

CH Bay

The CH Bay on the CH TRU side of the WHB is used for surface CH TRU waste handling operations. To accommodate the TRUPACT II shipping containers, the WHB is equipped with two TRUDOCKS and two overhead cranes for opening and unloading the TRUPACT II shipping containers (Figure 4.2-4). The TRUDOCKS provide for convenient access to the shipping container for opening and unloading operations.

Each TRUDOCK is serviced by a 5 ton overhead crane that is used to transfer the TRUPACT-II OCV and ICV lids to their individual support stands and the payload waste containers to the facility pallet. The cranes are Design Class IIIA and are identical having a single girder, underhung bridge, trolley, and wire rope hoist.

Each crane is controlled by its individual pendant control. The TRUDOCK crane is designed to hold its load in place in the event of a Design Basis Earthquake (DBE). Overhead cranes used in waste handling operations are certified to lift their rated capacity, and load tested to 125 percent of maximum rated lift.

There are two heavy duty industrial 13 ton forklift trucks. These forklift trucks are used to unload the TRUPACT-IIs from their transportation trailers (or rail cars), move them through the WHB airlocks to support stands located in the pockets of the TRUDOCKS in the CH bay of the WHB, and, if required, transfer shipping containers from the CH bay to the overpack and repair room. They are also used to move and transfer facility pallets with or without a load of waste containers between the CH bay and the conveyance loading car. Each of the 13 ton forklift trucks have a maximum lift height of 96 in. The forklift trucks' drive units use dc motors which are battery powered. The forklift trucks can operate for eight hours before the batteries have to be recharged. Each forklift truck has a high volume pump unit that supplies the fluid power for lift, tilt and sideshift of the forks. A separate hydraulic power unit supplies fluid power for braking and steering.

There is one 6 ton forklift truck in the CH bay of the WHB. It has a hydraulically operated side-shift positioner for shifting the load to the right or left. Either standard type forks or specially designed fixtures can be attached to the positioner for lifting different loads. The forklift truck is essentially a standard battery powered forklift truck with a maximum lift height of 118 in.

The 6 ton forklift truck can operate for one shift before requiring a recharge of the batteries. It can be operated with different attachments as listed below:

- A BRUDI push/pull rack fixture with a drum handler to lift and move seven-packs of waste containers (drums).
- An SWB forklift fixture to lift and move individual SWBs.
- Two forks for lifting loads

One SWB forklift fixture, Design Class IIIA, is provided in the CH bay area of the WHB to lift and move SWBs with a 6 ton battery powered forklift truck. The SWB forklift fixture is basically a welded steel frame designed to be mounted and supported on the front side of a 6 ton forklift truck carriage on which the lifting forks have been removed. The fixture is a lifting accessory with a rated load lifting capacity of 4000 lbs designed specifically for lifting SWBs.

The CH Bay also provides space for transferring loaded facility pallets to the waste hoist via forklifts, an access route to the OP&RR, a shielded holding area, a waste handling equipment battery recharge area, and an office space for waste handling operations personnel.

Storage locations are provided within the CH Bay for equipment, facility pallets, and TRUPACT II drum pallets. The shielded holding area provides for surface in-process holding of CH TRU waste containers during operational interruptions when surface dose rates exceed 100 mrem/h, limiting the dose rates within the CH Bay. The shielded holding area can accommodate seven-packs of drums as well as standard waste boxes (SWBs).

Overpack and Repair Room

OP&RR provides space and facilities for opening and unloading TRUPACT II shipping containers discovered with internal contamination during the unloading operations. Radiological conditions will dictate whether the shipping container will be transferred from the TRUDOCK unloading area or to the OP&RR for subsequent operations.

OP&RR access is via an air lock large enough to accommodate the TRUPACT II shipping container. To reduce the potential for contamination to spread, the HVAC system maintains the OP&RR at a negative pressure relative to the CH Bay and the exterior of the WHB. The air lock assists the HVAC system in providing control of air flow within the building.

A separate HEPA filtered TRUPACT II disassembly enclosure is available within the OP&RR in order to provide an additional measure of protection. The function of this structure is to enhance the aspects of unloading, overpacking, and decontamination operations to maintain radiation exposures As Low As Reasonably Achievable (ALARA).

The CH overpacking enclosure 5 ton overhead "A" frame gantry crane is used for disassembly and unloading of a TRUPACT-II during decontamination or overpacking operations. The gantry crane is a two-legged tubular steel weldment frame structure with steel wheels that roll in steel channels fastened to the floor of the overpacking enclosure. The crane supports an I-beam approximately 18 feet above the floor and has a 16 feet span. Each leg of the crane has two stabilizing jacks which can be lowered and locked into position for load stabilization. The gantry crane has a motor driven trolley with a speed of 10 fpm. The hoist, which is also electrically driven, has a mechanical brake to limit the speed of descent. The crane has a maximum height lifting capability of 15 ft. and is designed to operate at either 6 or 18 fpm. A pendant control provides operator controls for the hoist (up and down) and the trolley (east and west). There are two pneumatic cable cylinders which, when pneumatically actuated, move the 5 ton gantry crane in the north-south direction to provide the bridge motion. The cable cylinders are 236 inches long and have a stroke of 216 inches. The cylinders are pneumatically actuated by a control lever located in the south-west corner of the enclosure. Actuation of the cylinder drives the plastic coated 1/4 inch diameter wire cable that is attached to the base of the gantry crane. The two cylinders each have cable tensioning devices with a 1 in stroke and are actuated by separate pneumatic lines. The pneumatic cable cylinders require a compressed air supply of 100 to 125 psi.

CH TRU Support Facilities

Facilities supporting CH TRU operations include a small equipment decontamination room, a personnel change room, and the site-derived waste room. Final packaging of solid site-derived radioactive waste will be accomplished in the site-derived waste room. The site-derived waste room connects to the CH Bay and the OP&RR via air locks. Access to the personnel change room and small equipment decontamination room is from the air lock, separating the site-derived waste room from the OP&RR.

4.2.1.1.2 RH TRU Waste Handling Area

The RH side of the WHB includes structures and equipment for the unloading of shielded road cask shipping containers containing an RH TRU waste canister and transferring the canisters of RH TRU waste from the shielded road cask to a shielded facility cask via the hot cell. The major areas within the RH waste handling area are shown in Figure 4.2-1a and Figure 4.2-1b.

RH Bay

The RH Bay on the RH side of the WHB provides a cask receiving area, preparation area, maintenance station and handling equipment for RH TRU waste shielded road cask shipping containers. A 140-ton bridge crane with a 25-ton auxiliary hoist is also provided in this area for lifting the shielded road cask and is designed to stay on its rails retaining control of the load during a DBE.

Shielded Road Cask Receiving Area

The road cask receiving area provides space to unload shielded RH road casks from incoming truck or rail transporters, and to load empty shielded road casks on outgoing transporters. The overhead bridge crane is designed to lift a shielded road cask from the transporter and to position the shielded road cask on the road cask transfer car located at the road cask preparation station. The road cask receiving area also provides laydown space for road cask tie-downs, impact limiters, and other components that must be removed as part of the road cask unloading operation.

Road Cask Preparation Area

The road cask preparation area provides a tracked transfer car that travels between the road cask preparation area and the road cask unloading room portion of the hot cell complex. The transfer car supports the shielded road cask and incorporates an integral work platform providing personnel access to the head area of the shielded road cask. Road cask preparatory operations provided for in this area include: radiological surveys, controlled venting of the shielded road cask cavities, removing the outer closure, unbolting of the inner closure, and installing a road cask seal collar mating with the seal ring in the road cask unloading room. The road cask transfer car is designed for a road cask weight of up to 50,000 lbs.

Road Cask Maintenance Station

The road cask maintenance station, located adjacent to the road cask preparation area, provides space and equipment for periodic shielded road cask maintenance, and this area lies within the operating envelope of the overhead bridge crane. If required, this area could be used for shielded road cask decontamination activities.

Hot Cell Complex

The hot cell complex provides the required facilities and equipment necessary to transfer canisters of RH TRU waste from the shielded road cask to the shielded facility cask and to transfer the canister to the underground disposal area. Facilities included within the hot cell complex are: the road cask unloading room, the hot cell, the canister transfer cell, and the facility cask loading room. The hot cell complex is designed for a 45 rem/h neutron surface dose rate and a gamma surface dose rate of 400,000 rem/h. Viewing windows, equivalent to hot cell wall shielding, provide for near 100 percent visual observation of all areas within the hot cell. Supporting facilities include an operating gallery, a hot cell HEPA filter gallery, a crane maintenance room, and a manipulator repair room. Details of the hot cell complex are shown in Figure 4.2-3a, Figure 4.2-3b and Figure 4.2-3c.

Road Cask Unloading Room

The road cask unloading room is a floor-level concrete-shielded room where the road cask is transferred to by the road cask transfer car. A 140-ton concrete-filled shield door at the entrance to the road cask unloading room provides radiation protection for personnel outside the room during shielded road cask unloading operations. The shield door is supported by air bearings for ease of movement and interfaces with an inflatable seal.

Access to the hot cell above the road cask unloading room is through shielded floor plugs in the hot cell. These plugs must be in place when the shielded road cask enters the cask unloading room. An interlock is provided between the road cask unloading room shield door and the hot cell grapple requiring the door closed in order to operate the grapple or to handle a waste canister. The unloading room ceiling incorporates a seal ring and road cask seal collar, with an inflatable seal, that mates with the upper surface of the road cask. When the shield door is closed and sealed, and the road casks are mated with the seal collar, the road cask unloading room functions as an air lock between the hot cell (including the road cavity) and the RH Bay. The hot cell is maintained at the lowest negative pressure and air leakage, if any, would be from the RH Bay through the road cask unloading room to the hot cell itself.

Hot Cell

The hot cell is a concrete-shielded room where RH waste canisters are handled following removal from the shielded road cask. The hot cell is a shielded cell and has provisions for maintenance of installed equipment. Air locks are provided for personnel access to the hot cell, and access is permitted only when RH canisters are not present.

Two ports are located in the floor of the hot cell: (1) an 8 ft 8 in diameter port which also contains a concentric 2 ft 8¼ in diameter port and which connects with the road cask unloading room, and (2) a 5 ft square port which connects with the canister transfer cell. When closed, these ports provide shielding corresponding to the level of radiation protection required by the road cask unloading room and the facility cask loading room. Position switches are used to ensure the proper closure of the canister transfer cell port. The port connecting to the road cask unloading room also allows the transfer of road cask heads into the hot cell.

The hot cell contains two primary workstations: an inspection station and a welding station. Inspection of the RH canisters, including visual inspection, verification of canister identification, and contamination checks are accomplished at the inspection station. If the results of this inspection show that overpacking of the canister is required, this will be accomplished at the welding station. At the welding station, the canister is inserted into an overpack body and the closure is welded using remotely operated welding equipment.

The hot cell is equipped with a remote-operated 15-ton bridge crane, master/slave manipulators, a bridge mounted power manipulator, a portable overpack welder, a closed-circuit television system, a shielded pass through drawer, and various storage locations supporting hot cell operations.

The overhead bridge crane, equipped with a rotating block and grapple, is used for all heavy lifting operations within the hot cell, including handling of the hot cell shield plug(s), road cask inner closures, RH canisters, and canister overpack components. This crane is designed to stay on its tracks and to maintain control of its load in the event of a DBE or electrical failure.

The master/slave manipulators are used to conduct detailed handling operations, including contamination checks at the inspection station and support functions at the welding station. A shielded transfer drawer is used to introduce small items into the hot cell and to allow swipe materials to be checked. The bridge-mounted manipulator is provided to accomplish those specific operations that lie between the capability of the bridge crane and the master/slave manipulators. Various storage locations are provided within the hot cell, from change-out stations for the bridge mounted power manipulator tools, to overpack canister components.

Canister Transfer Cell

The canister transfer cell is located beneath the hot cell and transfers canisters from the hot cell to the facility cask loading room via a seven position shuttle car. The cell includes provisions for a manual override tool to be used in the event of a grapple failure or to release the grapple from an RH canister, and is operated from an area shielded from the canister transfer cell. Canisters are lowered into the shuttle car by the hot cell bridge crane through a shielded valve in the floor of the hot cell. A ceiling-mounted hoist, located in the facility cask loading room, is used to remove canisters from the shuttle car through a shield valve in the floor of the facility cask loading room.

The shuttle car has chain drives, is equipped with retainers to ensure that the car stays on its tracks, and is designed to resist a DBE. Drive components are located outside of the canister transfer cell providing for easy access for maintenance.

Facility Cask Loading Room

The facility cask loading room is the final element of the RH hot cell complex and provides for transfer of the RH canister to the facility cask which is subsequently transferred to the waste hoist and to the underground. This is accomplished by lifting the canister from the shuttle car through a shield valve and into a vertically oriented facility cask positioned in the facility cask loading room. The shield bell, located above the facility cask and the telescoping port shield valve mating with the underside of the facility cask ensure shielding integrity. In addition, when the operating console is used during this operational sequence, it is located behind a shield. When loaded, the facility cask is rotated to the horizontal position, supported by the tracked facility cask transfer car, and is ready for transfer on the waste hoist. To control potential for contamination spread, the facility cask loading room functions as an air lock between the shaft and the hot cell.

RH Support Facilities

Facilities supporting RH operations are the hot cell operating gallery, the crane maintenance room, the manipulator repair room, and the hot cell filter gallery. The operating gallery provides the space for hot cell operating personnel to monitor and control all operations within the hot cell (Figure 4.2-3a, Figure 4.2-3b, and Figure 4.2-3c). The master/slave manipulators are operated from this area, and are moved from this area to the manipulator repair room for maintenance and repair.

The manipulator repair room is located adjacent to the operating gallery and provides space for repairing the hot cell master/slave manipulators.

The hot cell filter gallery provides space for hot cell HEPA filters and personnel access for maintenance. The filters are normally changed manually and, in the event it becomes necessary, space is provided for remote filter removal (i.e., provision of oversized filter housings). Bag out provisions are incorporated in the design of the HEPA filter system.

The crane maintenance room provides space and facilities for maintenance of the hot cell bridge crane. With the hot cell bridge crane moved into the crane maintenance room and the shield door closed, maintenance personnel may safely enter the room even with a RH canister in the hot cell.

4.2.1.1.3 Building 412

Building 412 (designed as the TRUPACT maintenance facility) is Design Class IIIA; however, the structural portions of the building are Design Class II because of its interface with the WHB. Building 412 provides space and equipment for minor scheduled and unscheduled maintenance activities and includes a 25-ton overhead crane.

4.2.1.1.4 WHB Support Areas

WHB support areas, common to both the CH TRU and RH TRU areas of the WHB, include the waste hoist support areas and the main mechanical equipment room containing the HVAC equipment.

Air locks are located on both the CH TRU and RH TRU sides of the waste hoist including the conveyance loading room on the CH TRU side of the waste hoist and the facility cask loading room on the RH TRU side of the waste hoist. Access doors to the hoist are interlocked controlling air flow and air flow is towards the hoist from the CH TRU loading room or from the RH TRU facility cask loading room.

The hoist control room provides space and equipment for operation of the waste hoist and controls available for operation in manual or automatic.

The main mechanical equipment room of the WHB houses the exhaust fans, HEPA filters (except for the hot cell HEPA filters, which are located adjacent to the hot cell) and the associated ducting that controls ventilation flow within the WHB.

4.2.1.1.5 Waste Handling Building Effluent Monitoring System

The WHB exhaust system is Design Class IIIA; the supply system is Design Class IIIB, and the HEPA filters and isolation dampers are Design Class II. The WHB ventilation system has a single discharge point with all of the air coming from the WHB being processed through a prefilter and two stages of HEPA filters prior to its release to the environment. Station C is located downstream of the HEPA filters and continuously monitors for both alpha and beta-gamma airborne contamination. In addition to continuous monitoring of the air, fixed air sampling is used to quantify the total amount, if any, of radioactivity released to the environment.

4.2.1.2 Exhaust Filter Building

The Exhaust Filter Building, containing the filtration equipment associated with the underground ventilation system, is located adjacent to the exhaust shaft. During normal operations, two exhaust fans draw air from underground areas, up the exhaust shaft, and discharge it to the environment without the HEPA filtration units in service. In the event of an underground radiological event, airflow from the underground is reduced to approximately one-seventh of normal flow and is diverted through the HEPA filtration units located in this building to remove airborne radioactive particulates from the air stream. The underground ventilation system is discussed in Section 4.4.2, and the Exhaust Filter Building layout is shown in Figure 4.2-5.

The Exhaust Filter Building structure is classified as Design Class IIIA and the HEPA filters and isolation dampers are Design Class II. The major areas within the Exhaust Filter Building are the filter room and support area. The filter room houses the HEPA filtration units. The support area includes two mechanical equipment rooms housing the building filtration units, the exhaust fans, the supply-air handling units, the instrument air compressor, the motor control centers, and the air lock.

The effluent monitoring system at the Exhaust Filter Building is composed of two separate stations. Station A is located within the exhaust shaft, and will obtain its sample 21 ft below ground level in this shaft. Station B is positioned downstream from the HEPA filtration system that is located in the Exhaust Filter Building. Both Stations A and B contain continuous air monitors (CAMs) for the detection of airborne alpha or beta-gamma contamination. Each station contains fixed air samplers operated by the WIPP, one each for WID, the state of New Mexico Environment Department, and the Environmental Evaluation Group, quantifying the total amount of radioactivity released to the environment.

The underground ventilation exhaust fans are located outside and move air up the exhaust shaft. The elbow at the top of the exhaust shaft and effluent monitoring systems are designed to withstand the WIPP facility DBE/DBT.

4.2.1.3 Water Pumphouse

The Water Pumphouse, located adjacent to the two water storage tanks (Figure 4.1-2a and 4.1-2b), contains two fire water pumps (one electric and one diesel), three electric domestic water pumps, and space for water chlorination equipment and chemical storage.

The Water Pumphouse is an above ground steel frame and siding building classified as Design Class IIIA. The building contains a wet pipe sprinkler system, portable fire extinguishers, and hose reels.

4.2.1.4 Support Building

The Support Building located adjacent to the WHB, houses general support services for activities at the WIPP facility. The Support Building is constructed of steel framing and sandwich panel siding and is classified as Design Class IIIA. The main lateral force resisting members of the Support Building and Building 412 are designed for DBE and DBT to protect the WHB from their structural failure.

4.2.1.5 Support Structures

The following support structures are designed to the Uniform Building Code (UBC) and are classified as Design Class IIIB support structures.

- Salt Handling Shaft Headframe and Hoist House
- Air Intake Shaft Headframe and Hoist House
- Main Warehouse Building
- Guard and Security Building
- Main Gatehouse
- Safety and Emergency Services Building
- Compressor Building
- Engineering Building
- Training Building

4.2.2 Shaft and Hoist Facilities

4.2.2.1 Shaft and Hoist General Descriptions

The WIPP facility utilizes four shafts:

- Waste Shaft
- Salt Handling (SH) Shaft
- Exhaust Shaft
- Air Intake Shaft (AIS)

These shafts are vertical openings extending from the surface to the underground disposal level as shown on Figure 4.1-2a, which shows the location of the shafts relative to surface features. All shaft construction and mining operations are in accordance with 30 CFR 57.[1]

The waste hoist system is designated as a Design Class IIIA and the SH shaft, the exhaust shaft, and the AIS hoist system are designated as Design Class IIIB. The waste shaft, SH shaft and AIS shaft are designed to resist the dynamic forces of the hoisting system. Shaft linings are designed based on expected hydrostatic heads in the Rustler Formation as described in Chapter 2.

4.2.2.2 Shaft and Hoist General Features

The principal components of each shaft are the shaft collar (extending from above the ground surface to the top of the bedrock), the shaft lining (extending from the bottom of the collar to the top of the salt formation at about 850 ft below the surface), and the key section that terminates the lining in the salt formation with the remainder of each shaft being unlined.

The shaft collars are situated about 400 ft above the historic flood plain of the Pecos River and the collar slab around the shaft is at a higher elevation than the surrounding ground.

The waste shaft, the SH shaft, and the AIS are equipped with conveyances and all hoist towers are made of structural steel. The conveyances in the waste shaft and AIS are guided by steel cables (guide ropes), and the conveyance in the SH shaft is guided by fixed wooden guides and is equipped with safety dogs. The waste shaft is equipped with catch sprags in the hoist tower to prevent the conveyance or counterweight from falling into the shaft if the conveyance overtraveled against the upper crash beam and the hoist ropes failed.

The waste hoist and SH hoist redundantly installed brake systems are designed for either set of brakes stopping the fully-loaded conveyance under all conditions. In the event of a power failure, the brakes will set automatically. The AIS hoist is also equipped with two sets of brakes.

The control system for each hoist detects malfunctions or abnormal operations, such as overtravel, overspeed, power loss, circuitry failure, or starting in a wrong location, and triggers an alarm which automatically shuts down the hoist.

4.2.2.3 Shaft and Hoist Specific Features

The Waste Hoist system exists for the main purpose of moving radioactive waste from the surface to the underground. The system can be used to remove radioactive waste from the storage area if required. It is also used to transport personnel, material and equipment. The system supports maintenance in the Waste shaft. The equipment that is part of this system is the Waste Hoist equipment installed in the Waste Handling building, the headframe, shaft switches, and the conveyance. The waste shaft and hoist arrangement is shown on Figure 4.2-6.

The inside diameter of the unreinforced concrete lined upper portion of this shaft is 19 ft. The waste hoist conveyance (outside dimensions) is approximately 30 ft high by 11 ft wide by 15 ft deep and carries a maximum payload of 45 tons. The conveyance contains an upper and lower deck. During loading and unloading operations, the conveyance is steadied by fixed guides. At the station underground, rope stretch is removed by a chairing device that supports the weight of the conveyance and payload.

The Waste Hoist itself is an electric driven friction hoist. The Hoist Motor is a 600 HP DC machine, designed for a maximum operating speed of 13.5 RPM. The hoists maximum rope speed is 500 ft/min. The field is formed by wound poles and is supplied with a constant DC current obtained from rectifying a 480 volt three phase supply. The DC voltage magnitude and direction controls the speed and direction of the hoist. There is one silicon controlled rectifier (SCR) power supply to power the hoist. The brake system can safely stop and hold the conveyance without the drive motor. Automatic control circuitry will sense electrical problems with the drive motor and stop the Hoist.

There are two brakes, mounted approximately 180 degrees apart on each braking flange of the Hoist Wheel. These disc brakes (four total) are spring set, and are released by hydraulic pressure. Brake switches indicate brake set, release, and wear. A redundant hydraulic power supply exists to supply hydraulic pressure to release the brakes. Each pressure unit has its own motor, pump, and oil reservoir. There is an automatic switch over from the primary system to the standby system if the hydraulic pressure decreases below the set point. There is no automatic switchover from the standby system to the primary system. A timed back up pressure relief path exists to set the brakes if for any reason the brake the pressure is not release within a few seconds after the application of the brake set signal.

Hoisting, Tail and Guide Ropes are provided for the safe operation of the conveyance and the counterweight. The hoisting ropes are 1 - 3/8" diameter, full locked coil bright steel ropes suitable for use with a friction hoist. The tail ropes are 2 - 1/4" diameter, nonrotating bright steel with a synthetic fiber core. The three tail ropes approximately balance the weight of the six hoisting ropes. The guide ropes are 1 - 3/4" diameter, half-lock bright steel with internal and external lubrication and are designed to operate with minimal field lubrication only. There are four guide ropes for the conveyance and two guide ropes for the counter weight. Tension in these ropes is maintained by weights on the bottom of the ropes. The size of the weights are different to prevent harmonic vibrations during operation of the hoist.

Four timbers are provided at the tower and the sump regions for both the conveyance and the counterweight to assist in absorbing energy to stop an over traveling conveyance or counterweight. Retarding frames rest in notches either at the top of the wood arresters, (Sump Area) or at the bottom of the wood arresters (Tower area). The retarding frames have knives that cut into the timbers if driven by the conveyance or the counterweight.

A conveyance and counterweight overtravel arrestor system exists to stop them if the normal control system has failed. Between the crash beam and the top of the conveyance, hydraulic shock absorbers exist to reduce the speed at which the conveyance impacts the crash beam. Safety lugs on the conveyance mate with pivoting dogs on the headframe to prevent the conveyance from falling if the ropes break. The counterweight overtravel system functions in a similar fashion to stop the counterweight in the upward direction. Lever arms exist to raise the pivoting dogs if they are not supporting any weight. On the bottom of the shaft is a similar system to stop the conveyance or the counterweight in the downward direction. The arresting system on the shaft bottom only contains the knives and timbers.

Emergency stop buttons are provided at the Master Control Station (MCS) and all the control stations to effect an emergency stop of the hoist. These buttons are operable in all modes of hoist operation. These buttons will open the control power loop and set the hoist brakes. These buttons provide the most rapid means of bringing the hoist to a stop. A controlled stop button that will decelerate the conveyance before setting the brakes is located on the "Series Six" panel, to the left of the MCS. This is a slower and softer stopping action than the emergency stop.

Twelve signals, two analog and ten contact, from the Waste Hoist Operation are transmitted to the CMR for remote monitoring. The analog signals are the hoist motor volts and amps. The contact signals are "Hoist Operation, Manual", "Hoist Operation, Semi-Auto", "Hoist, Abnormal Condition", "Emergency Stop", "Men Working in Shaft", "Waste on Hoist", "Personnel on Hoist", "Hoist, Up", and "Hoist, Down".

The Waste Hoist Signaling System consists of bells and lights activated by the operators at the MCS and the operating stations.

The SH shaft is used to transport mined salt to the surface and to provide personnel transportation between the surface and the underground horizon. It also acts as a duct for supplying air to the underground mining and disposal areas, and it is one route for the power, control, and communications cables. The hoist's maximum rope speed is 1800 ft/min. The inside diameter is 10 ft for the steel lined portion and 11 ft 10 inches for the unlined portion.

The exhaust shaft is used as the opening to exhaust air from the underground disposal areas to the surface. The inside diameter of the lined portion of this shaft is 14 ft. The shaft lining is unreinforced concrete. The shaft key incorporates polymeric chemical water seal rings. The exhaust shaft collar does not utilize a building or headframe and is sealed at the top by a 14 ft diameter elbow that diverts exhaust air into the exhaust ventilation system.

The AIS is used primarily to supply the fresh air to the underground areas and is also used for backup egress of personnel between the surface and the underground horizon. The hoist's maximum rope speed is 830 ft/min. The inside diameter of the unreinforced concrete lined upper portion of this shaft is 16 ft.

4.2.3 Subsurface Facilities

4.2.3.1 General Design

The subsurface structures in the underground are located at 2,150 ft below the surface and include the waste disposal, experimental, and support areas. The underground support areas provide the facilities to service and maintain all underground equipment for mining and disposal operations, monitor for radioactive contamination, and allow limited decontamination of personnel and equipment. The mining and waste disposal areas are isolated from each other by air locks and bulkheads. Transporation of waste packages from the waste hoist to the disposal panel(s) takes place within the CA shown on Figure 4.1-3.

The underground support facilities and their ventilation flows in the shaft pillar area are shown on Figure 4.2-7.

The support facilities on the disposal side provide for a maintenance area, a vehicle parking area with plug-in battery charging, and a waste transfer station.

The support facilities on the mining side consist of a vehicle parking area, an electrical substation, a mechanical shop, a welding shop, a warehouse, offices, materials storage area, emergency vehicle parking alcoves, and a fueling station for diesel equipment.

An experimental area is separate from the other areas of the underground repository and contained separate areas for evaluating the interaction of simulated waste and thermal sources on bedded salt under closely monitored, controlled conditions. The experimental area is not active at this time.

Underground mining procedures and cavity dimensions incorporate the results of the salt creep analysis in Chapter 2.

The mining area fuel dispensing room is in an alcove off the mining exhaust entry. This fuel dispensing room provides a location and pumping facilities for a portable fuel tank. The portable diesel tank hoisting and lowering is done through the waste shaft, or the SH shaft as required. A dry chemical fire suppression system connected to a manually-activated reserve supply is provided in the fueling area. Fire-generated smoke and fumes would be exhausted directly to the exhaust ventilation system.

There are two underground transporters. The transporter is a diesel-powered tractor trailer with an articulating frame steering system. The transporter has two sections, a front section consisting of the tractor cab and diesel engine and the rear section consisting of a flat bed trailer with a ball screw driven pallet transfer system mounted in the middle of the bed. The pallet transfer system is designed to handle a load of 28,000 lbs. The tractor has a fully hydraulic power type of steering system with a direct drive hydraulic pump, an orbital valve operated by the steering wheel, and two steering cylinders located at the articulated joint. The axle brakes are air over hydraulic disc brakes with a dual master cylinder and separate circuits for the front and rear brakes. There is also a drive line disc brake which is used as a parking brake. This brake is automatically applied when air pressure falls from the normal 100 psi level to below 45 psi. The brake can also be set manually from the tractor cab. The flat bed trailer pallet mover system is powered by a ball screw drive mechanism. The roller guided pallet mover with hook is screw driven by a full length ball drive. After the hook is engaged to the facility pallet pin, operation of the ball screw is controlled from a switch in the tractor cab to rotate the ball screw. This advances the ball nut and hook to the front of the trailer sliding the facility pallet from the waste shaft conveyance on to the transporter trailer. The underground transporter is then ready to move the facility pallet to an underground storage room or the facility pallet platform.

There is one 6 ton forklift truck in the underground. This forklift truck is a standard battery powered forklift truck which is identical to the 6 ton forklift truck used in the CH bay of the WHB described in section 4.2.1.1.1.

There are three sets of BRUDI attachments. The BRUDI attachment is used with a 6 ton forklift truck with the forks removed to handle 7-drum packs on slip sheets. The BRUDI attachment is connected to the forklift truck front carriage. The BRUDI has a gripper which grips the edge of the slip sheet on which the 7-drum packs sit and a linkage assembly to pull or push the 7-drum packs onto or off the platen. After the 6 ton forklift truck moves the 7-drum packs to the emplacement or storage location, the BRUDI pushes the 7-drum packs into position after the forklift truck has raised or lowered the BRUDI platen to the proper height.

There is one SWB forklift fixture in the underground. This fixture is identical and used to perform the same function as the SWB forklift fixture described in section 4.2.1.1.1.

4.2.3.2 TRU Waste Disposal Area

The disposal area provides space for 6.2 x 10^6 ft^3 of TRU waste material in TRU waste containers. This area also includes the four main entries and the cross-cuts that provide access and ventilation.

The main entries link the shaft pillar/service area with the disposal area and are separated by pillars. Normal entries are 12 ft in height and the width is 25 ft for one entrance and three are 14 ft wide. Within a panel, the disposal rooms are a minimum of 13 ft high by 33 ft wide and 300 ft long and are separated by 100 ft wide pillars.

CH TRU waste received at the WIPP facility in seven-pack configuration or in SWBs will be stacked three high across the room width.

The ribs (pillars or walls) of the disposal rooms and entries are used for storing RH TRU waste canisters. RH TRU waste will be disposed in the same rooms as CH TRU waste.

The amount of TRU waste in each panel/room is limited by thermal, structural, and physical considerations and emplacement is designed not to exceed 10kW/acre. Based on current design and thermal constraints, a spacing of approximately 8 ft between centers for RH TRU waste canisters has been specified and a shield plug provides shielding between the canister and the room.

Entries, rooms, and panels are mined as needed during the plant life in order to maintain a reserve of disposal rooms while maintaining ventilation for waste handling and mining operations.

References for Section 4.2

1. Safety and Health Standards - Underground Metal and Nonmetal Mines, 8th edition, 1994. Title 30, Code of Federal Regulations, Part 57.

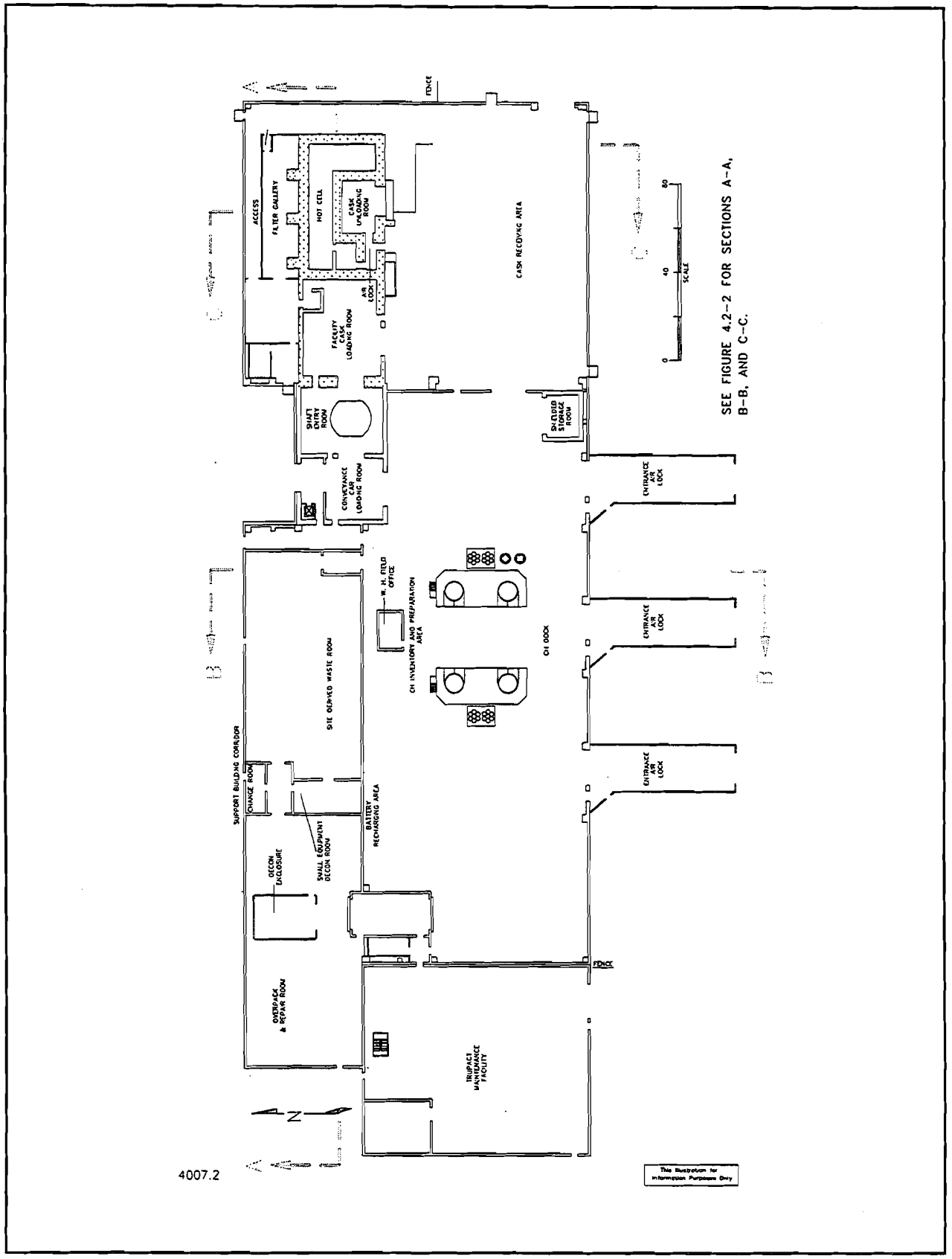

Figure 4.2-1a, WHB Plan (Ground Floor)

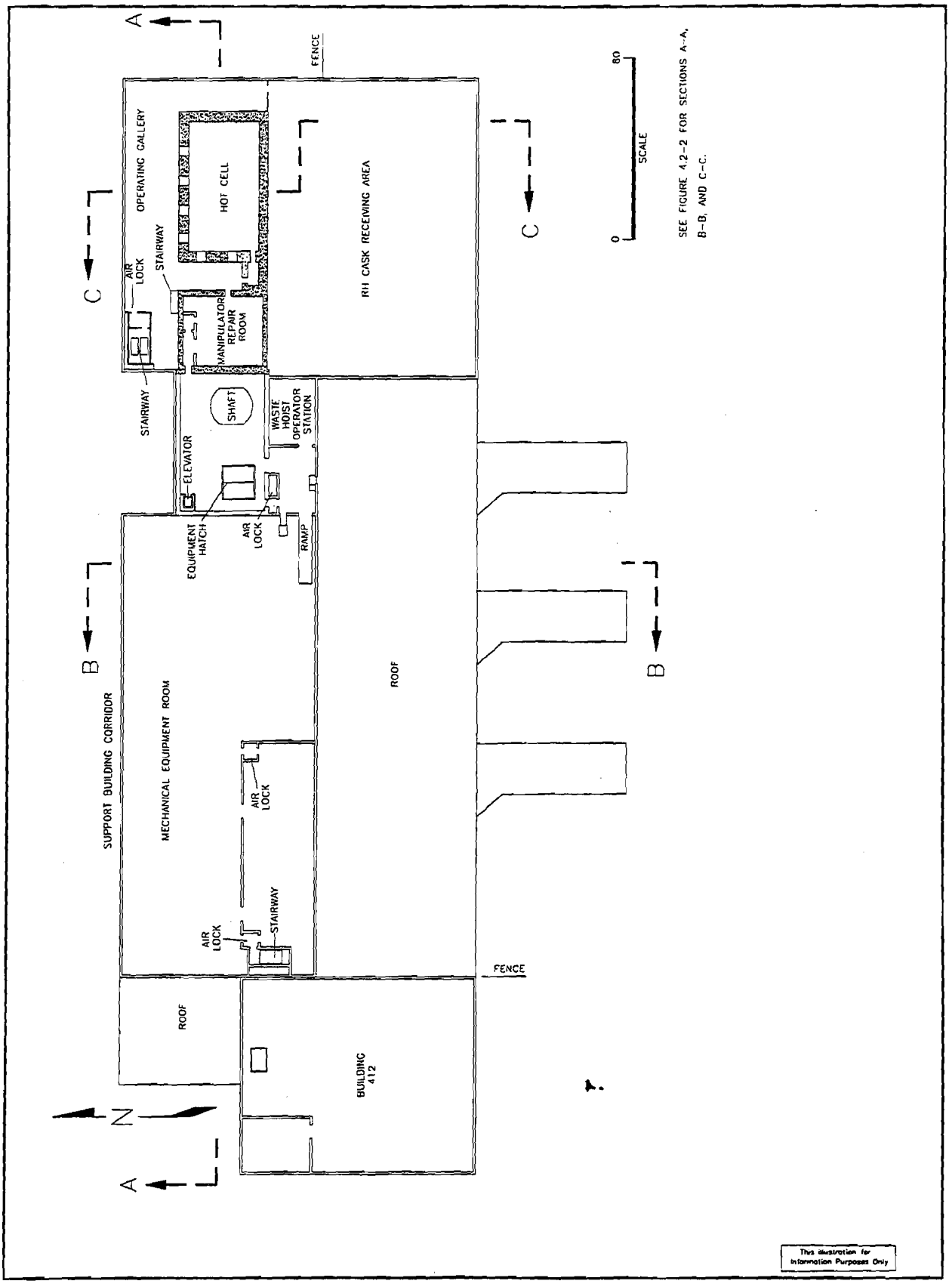

Figure 4.2-1b, Waste Handling Building Plan (Upper Floor)

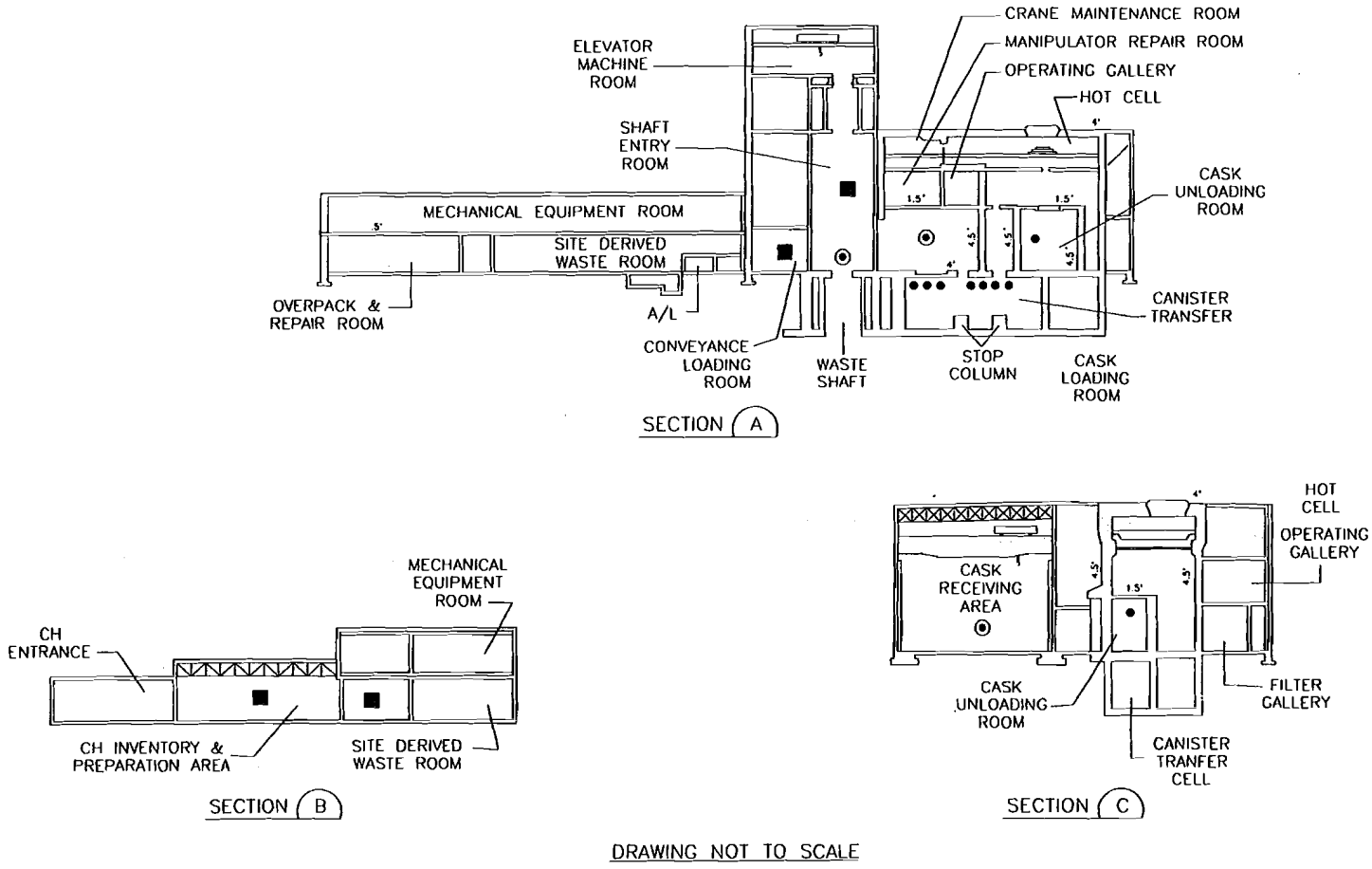

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Figure 4.2-2, Waste Handling Building (Sections)

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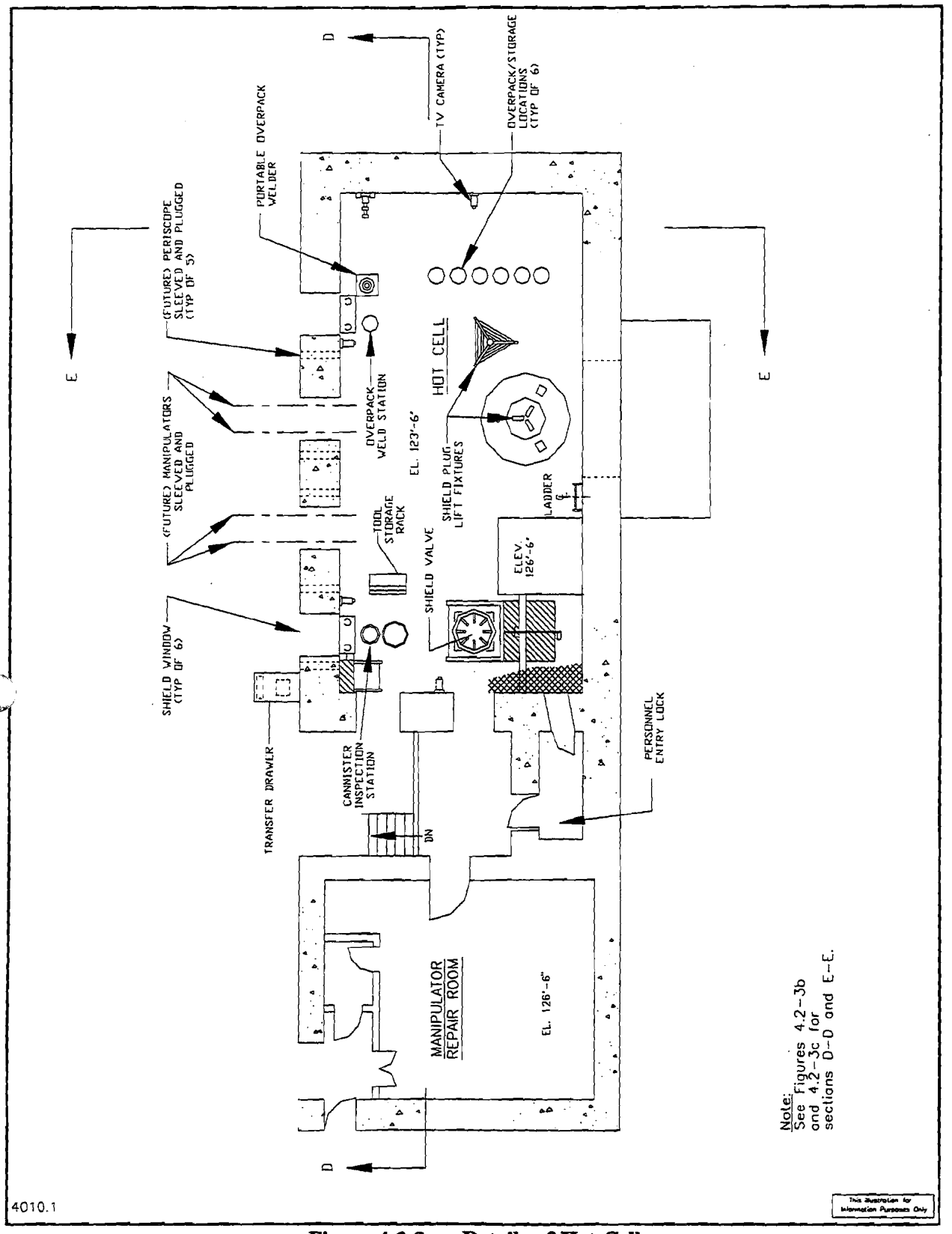

Figure 4.2-3a, Details of Hot Cell

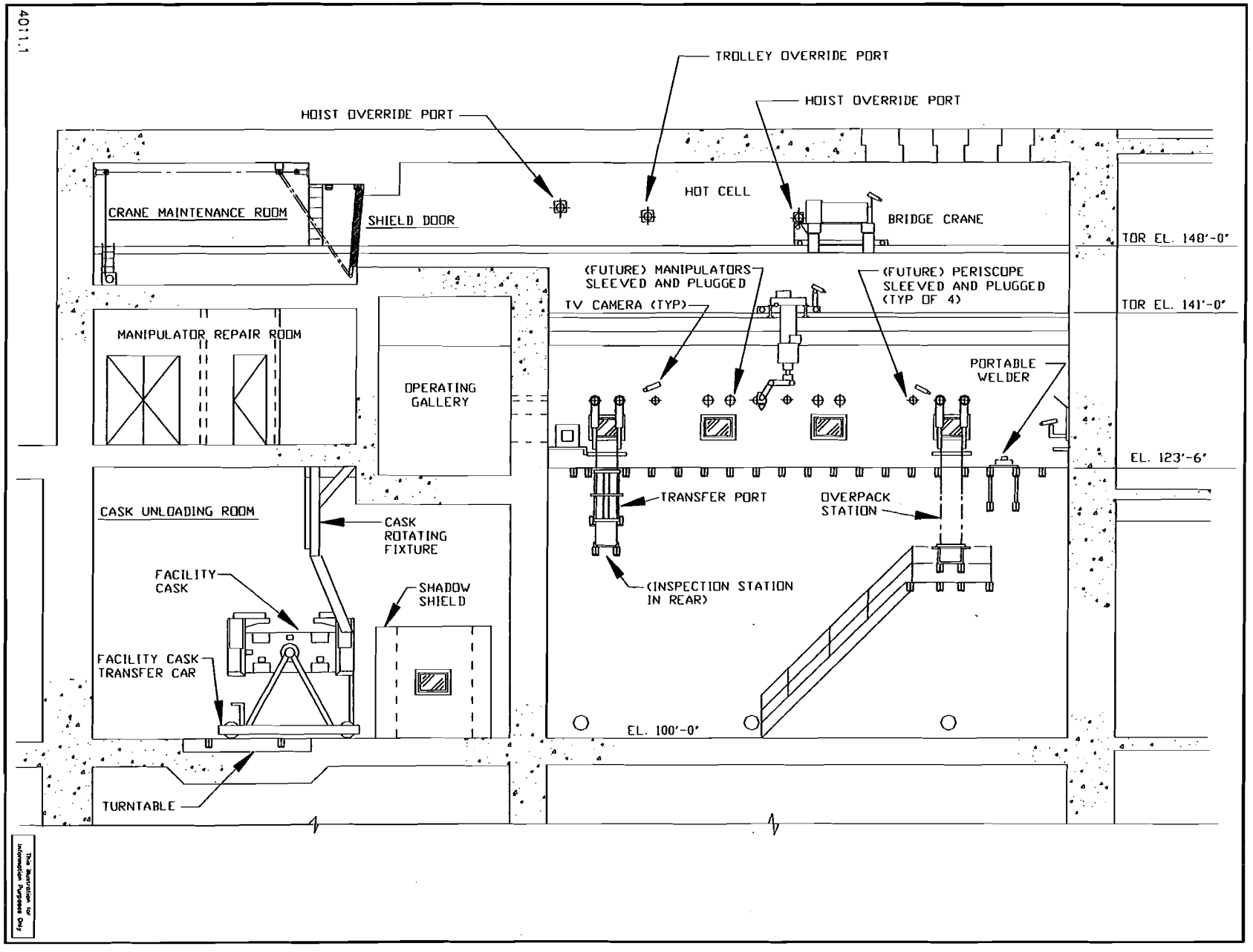

Figure 4.2-3b, Details of Hot Cell Cross Section at D-D

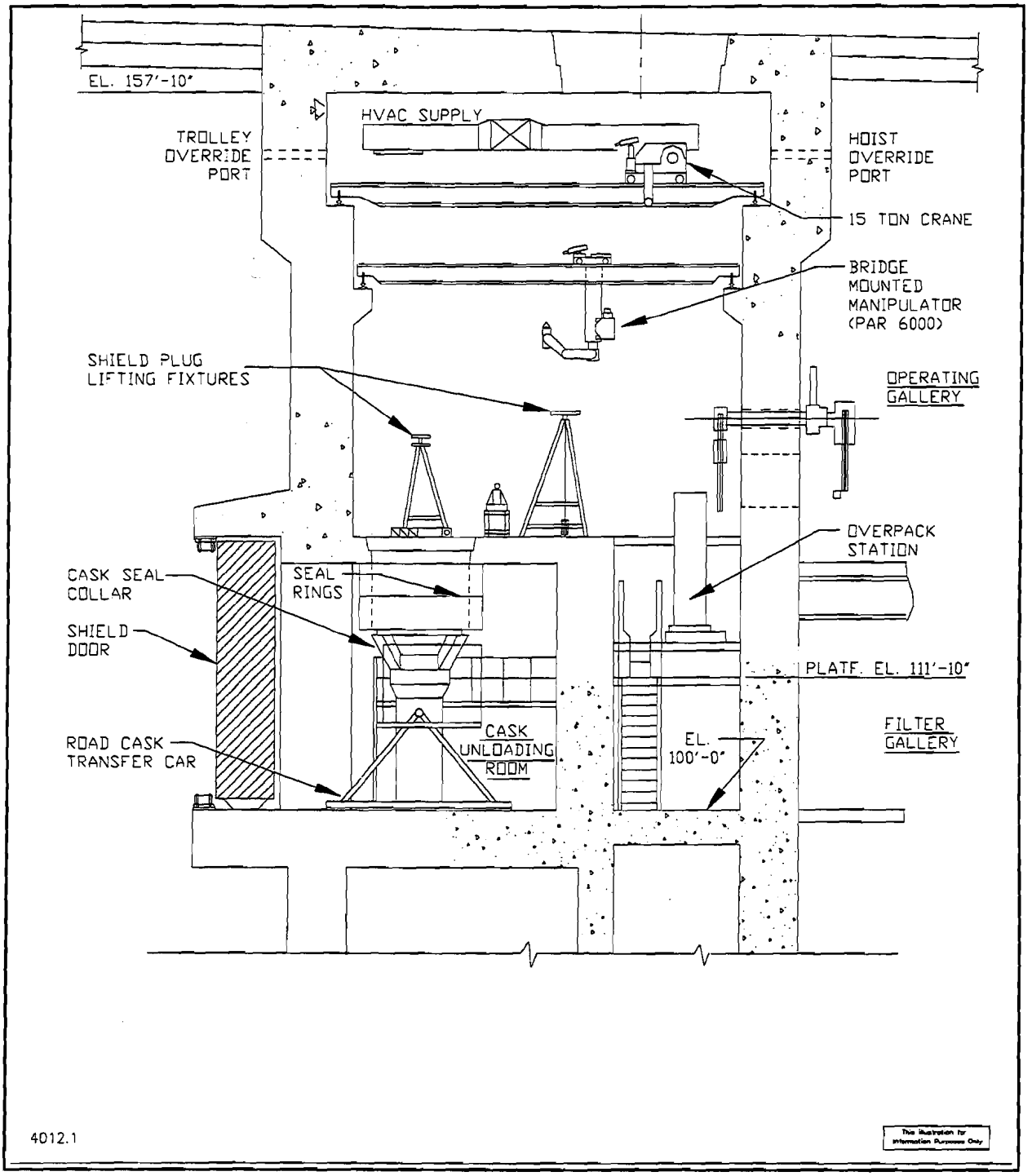

Figure 4.2-3c, Details of Hot Cell Cross Section at E-E

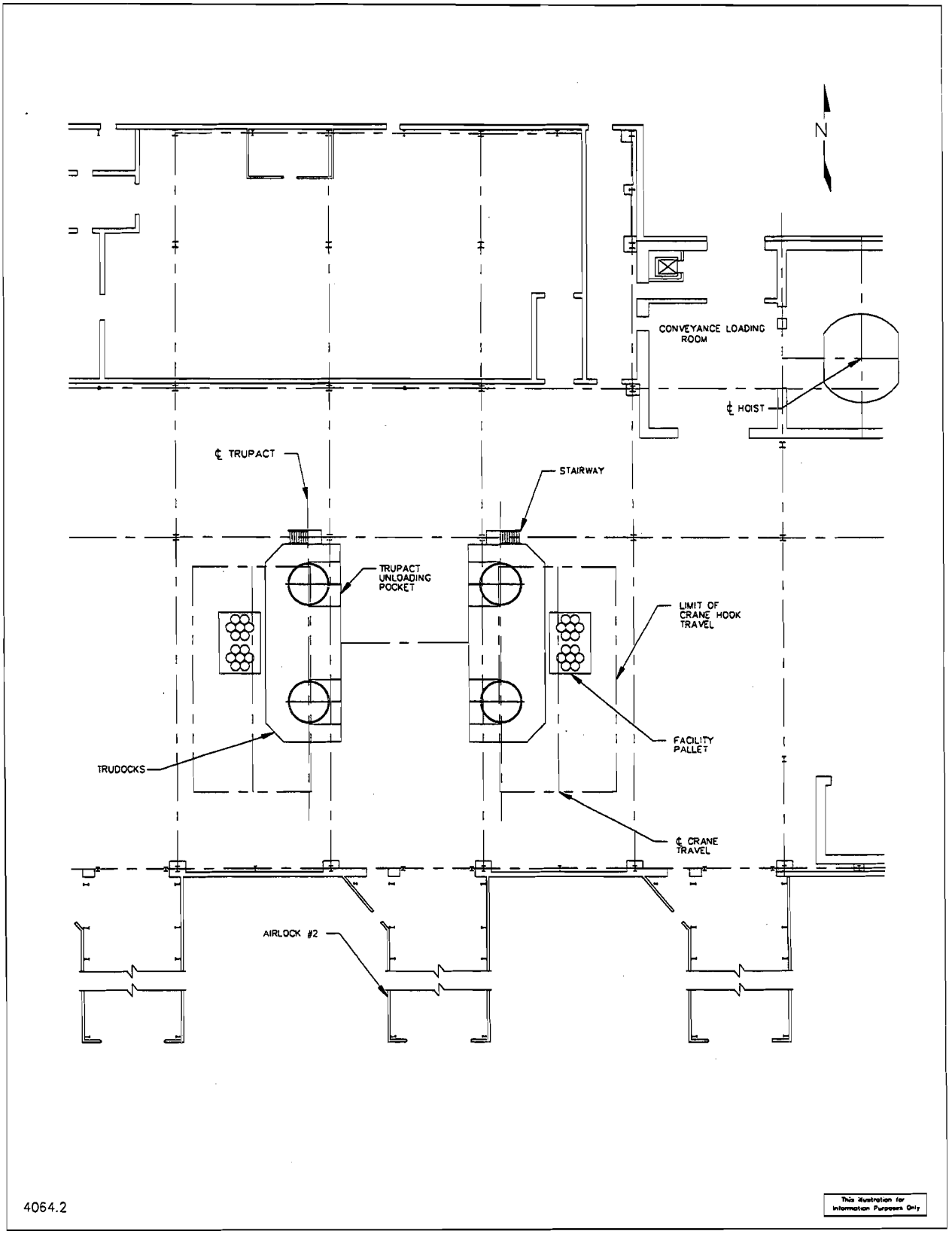

Figure 4.2-4, Configuration of CH TRU Waste Unloading TRUDOCKS in the WHB

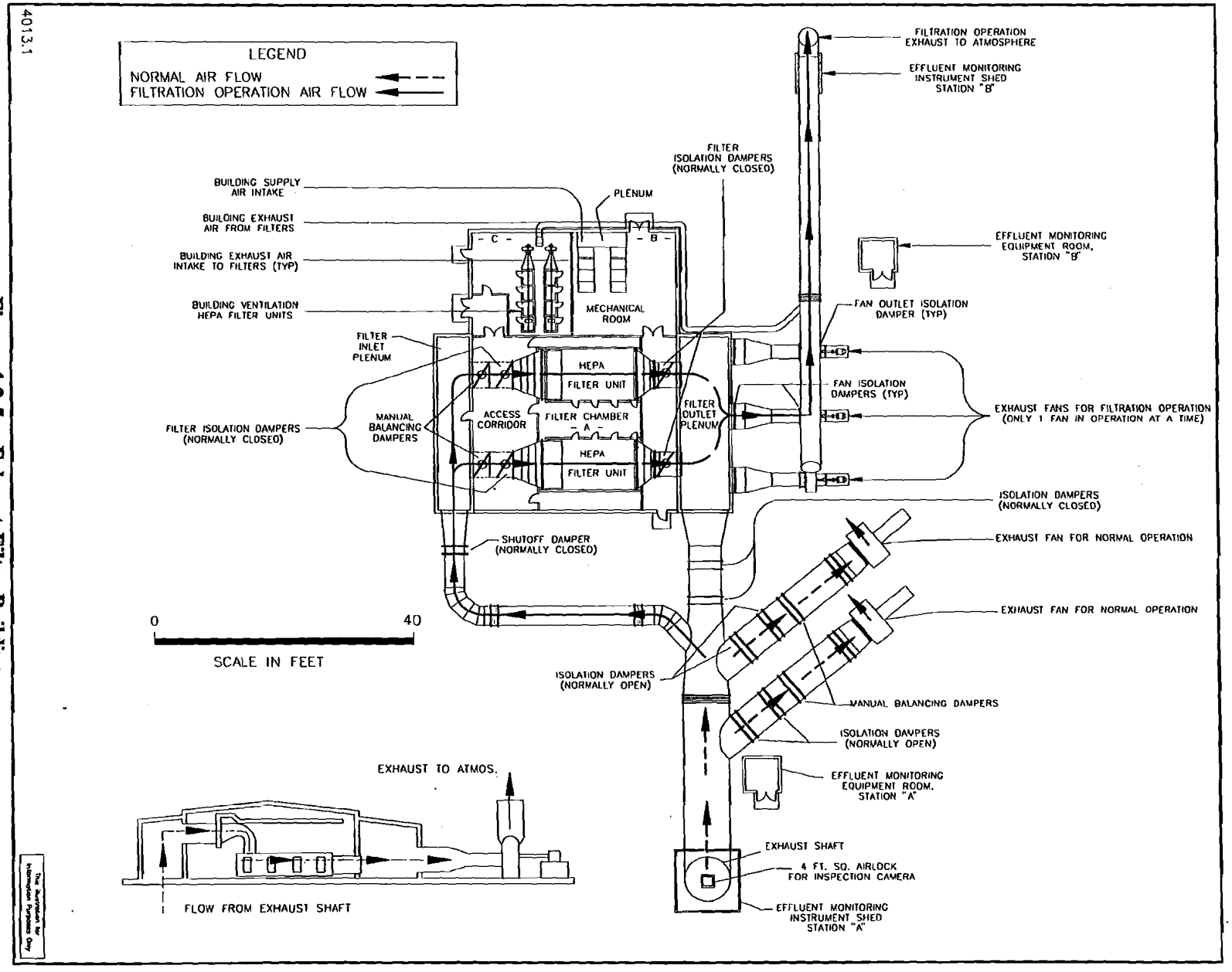

Figure 4.2-5, Exhaust Filter Building

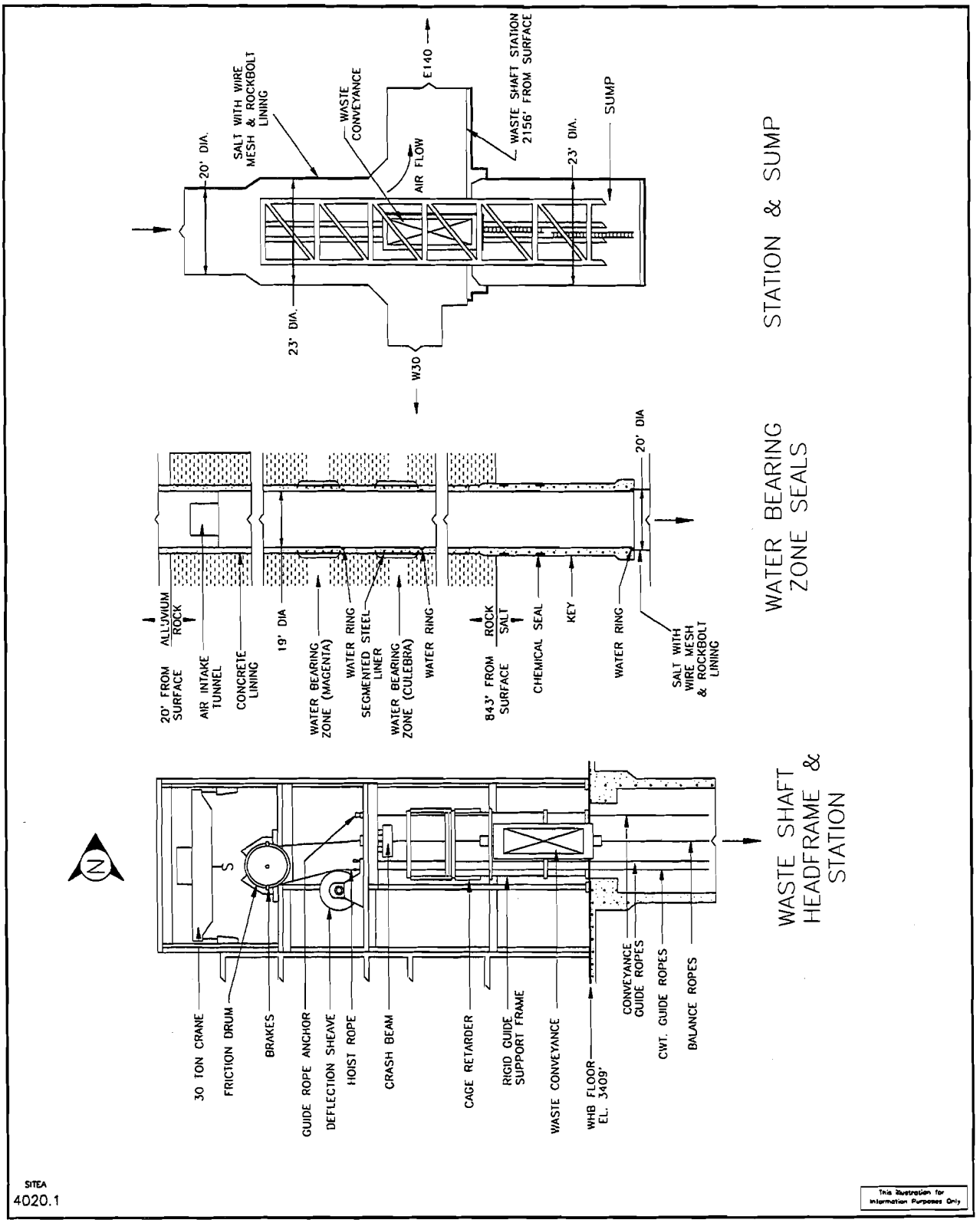

Figure 4.2-6, Waste Shaft and Hoist Arrangement

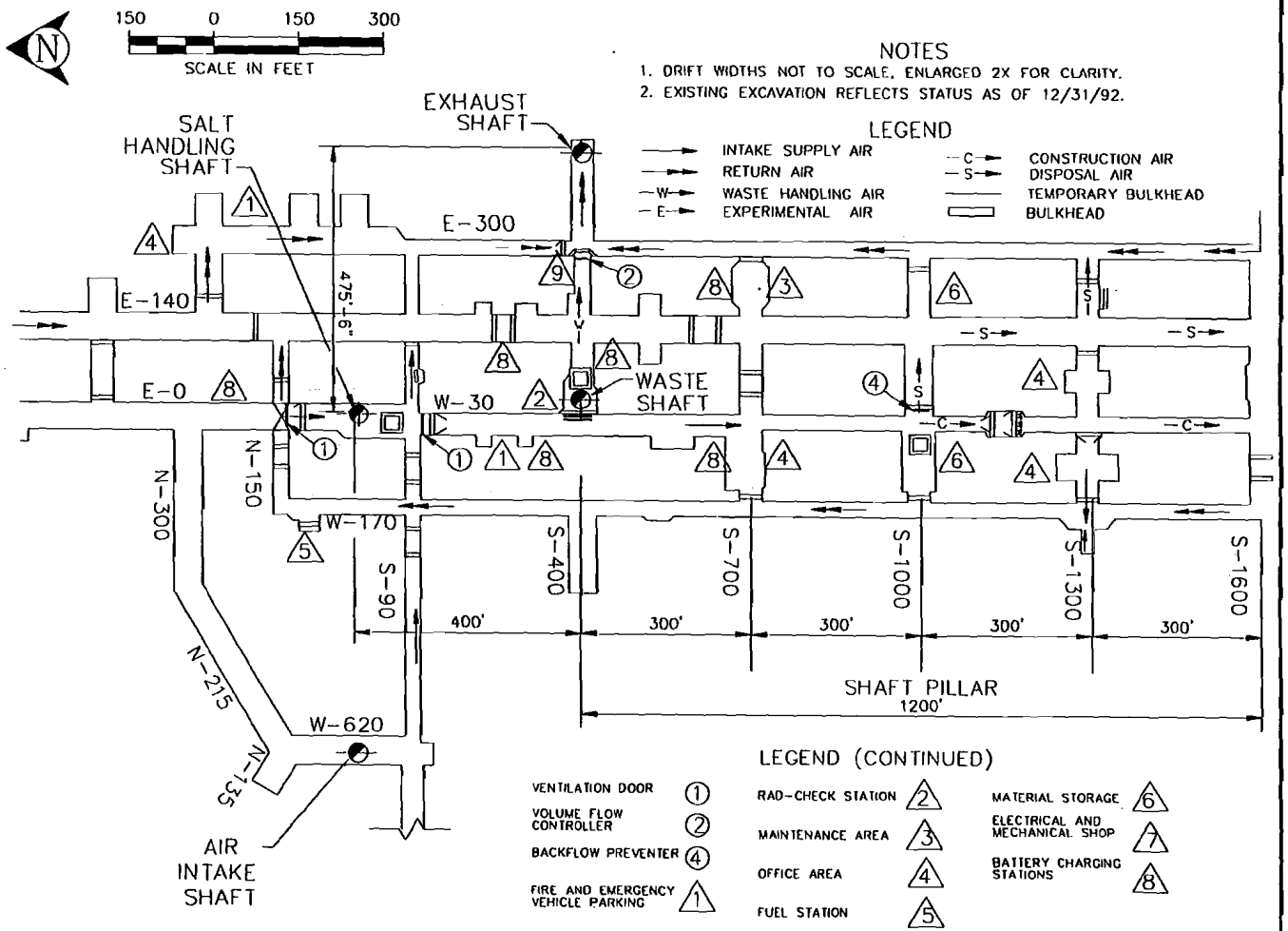

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Figure 4.2-7, Shaft Pillar Area Layout and Ventilation Flows

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4.3 Process Description

This section describes the processes and systems in place for handling CH and RH TRU waste at the WIPP facility. Process descriptions begin at the gate of the WIPP facility where CH TRU and RH TRU waste will arrive by truck. Rail shipments are not addressed at this time since they are not a current shipping mode. Descriptions of the transportation system are beyond the scope of the SAR.

This chapter addresses WIPP facility operation relative to design bases (e.g., 25-year operational life, design disposal capacity and throughput, etc). Process descriptions in this chapter are independent of the actual quantity of waste handled.

4.3.1 CH TRU Waste Handling System

The function of the CH TRU waste handling system is to receive the TRUPACT II shipping containers, bring them into the WHB, remove and inspect the waste packages, and move the packages to the underground disposal area. Damaged or contaminated packages are overpacked or decontaminated as appropriate. A schematic flow diagram of the operations sequence is shown in Figure 4.3-1. The CH TRU loading/unloading dock area, accessed by any of three air locks, consists of two TRUDOCKS, each capable of storing two TRUPACT IIs, for unloading.

The design basis for the CH TRU handling system is that the waste will be packed in 55-gallon drums in seven-pack configurations or in box-like structures referred to as standard waste boxes (SWBs). The standard 55-gallon metal drum (Figure 4.3-2) is a Department of Transportation (DOT) Type A steel fabricated drum with a maximum gross weight of 1,000 lbs, and is constructed with a lap welded bottom and a lid with two possible configurations. One lid configuration is a standard lid with no bungs and the other has a 3/4 in Reike bung fitting, and both require a minimum of one filter. The SWB (see Figure 4.3-3) is a DOT Type A steel fabricated box with a lap welded bottom and an internally flanged bolted closure lid. The weight of an empty SWB is approximately 680 lb and the maximum gross weight of a loaded SWB is 4,000 lb. Four threaded couplings (two on each side of the SWB with the lifting clips) are installed in the flange for inserting a filter to provide protection from particulate leakage during shipment or build-up of internal pressure.

The anticipated mix of waste packages is 60 percent (by volume) in drums and 40 percent SWBs.[1] The TRUPACT II shipping containers are DOT Type B containers certified by the Nuclear Regulatory Commission (NRC). The TRUPACT II is a double contained cylindrical shipping container (measuring 8 ft in diameter by 10 ft high) holding two seven-packs of CH TRU waste drums or two SWBs (Figure 4.3-4). It has a gross loaded weight of about 19,250 lbs, including a payload of approximately 7,265. The payload consists of two layers of SWBs or two layers of seven-packs of 55-gallon waste drums. The two layers of seven-packs of drums rest on a TRUPACT II pallet used for loading and unloading the TRUPACT II shipping container, and the SWBs are unloaded from the TRUPACT II using a SWB lifting fixture. The TRUPACT IIs arrive by truck, with a maximum of three shipping containers on each trailer (Figure 4.3-5). The dimensions and weights of the TRUPACT II are given in Table 4.3-1. Each container and assembly has a permanent identification number.

The average CH TRU waste throughput shown in Table 4.3-2, is based on handling only drums.

CH TRU process procedures are included in the Waste Handling Operations Manual.[2]

4.3.1.1 CH TRU Waste Receiving

Each shipment is inspected and includes verifying the shipment documentation, performing a security check, and conducting an initial radiological survey of the shipment as it arrives on the site. If any levels of radiation, contamination, or significant damage in excess of acceptance criteria are found, actions will be taken in accordance with the waste handling operations procedures.

Following turnover of the shipping documentation, the driver transports and parks the trailer, unhooks the transporter outside the CA in the security yard receiving area, and the driver is subsequently released. The disconnected trailer is attached to a yard tractor and brought into the CA by operations personnel for placement to be unloaded. Final external contamination surveys are performed in the CA. After unloading, empty TRUPACT IIs are loaded on the trailer and returned to the security yard receiving area following radiological surveys and release.

The TRUPACT IIs are unloaded from trailers outdoors in the CA using 13-ton electric forklifts, transported through the air lock, and placed in a vacant TRUDOCK. Electric forklifts are used to minimize the impact of diesel exhaust particulates on the WHB HEPA filters. The physical arrangement and location of the air locks and TRUDOCKS are described in Section 4.2, and each air lock is sized to accommodate a TRUPACT II on a 13-ton electric forklift.

4.3.1.1.1 CH Bay

After entry into the WHB, the TRUPACT II is placed in a TRUDOCK, the container opened, and the waste packages removed (Figure 4.3-6). Before the packages are removed from the TRUPACT II, radiological surveys are conducted on all accessible surfaces. As the packages are removed, further radiological surveys are conducted. If contaminated or damaged packages are found, the radiological conditions are reviewed and a decision is made to decontaminate at the TRUDOCK location or to close the TRUPACT II and transfer it to the overpack and repair room for unloading under more controlled conditions in accordance with procedures in the WIPP Waste Handling Normal Operations Procedures Manual.[2] The decision depends upon the magnitude and nature of the contamination found. If no contamination levels above the limits of the Manual[2] are noted, the unloading sequence continues.

The TRUDOCK provides a 360-degree access work platform for personnel access to the closure mechanism on the TRUPACT II.

The outer lid tamper seal is first removed and recorded. A vacuum is applied to the outer lid vent port to pull the lid down enabling the locking ring to rotate, unlocking the lid. During this process, the atmosphere between the inner lid and outer lid is vented through HEPA grade roughing filters. The outer lid is removed and placed in an adjacent lay down area with the aid of a five-ton overhead bridge crane and specially designed lifting fixture. The vacuum pull process is repeated for the inner lid. The only difference is that a radiological assessment filter is attached to the vent port tool, upstream of the HEPA grade roughing filters. The inner cavity atmosphere is vented first through the radiological assessment filter and then the HEPA grade roughing filters. The radiological assessment filter is subsequently checked for contamination. If no contamination is detected, the closure mechanism is released, the vent hood attached to the inner containment vessel (ICV) lid, and the lid raised. The air from the vent hood is monitored by an alpha CAM prior to passing through an in-line HEPA filter system. The air is then released to the WHB return air ducts.

Prior to moving the lid aside, contamination surveys under the vent hood are performed on the inner lid and accessible waste package surfaces. If no contamination is detected, the vent hood is removed and the ICV lid set aside using the same overhead bridge crane and lifting fixture. Additional contamination surveys are performed on the waste packages as they are being incrementally removed. If no contamination is detected, the overhead five-ton crane is used to transfer the TRUPACT II closure to an adjacent laydown area and transfer SWBs or the TRUPACT II drum pallet, with seven-packs of waste containers, to the prepositioned facility pallet. A typical TRUPACT II contains fourteen 55-gallon drums that are stretch wrapped or banded together into two seven-packs. Each seven-pack, or assembly, sets on a molded slip sheet that is made of high molecular density polyethylene. A second molded slip sheet is placed on top of the seven-pack and the entire assembly is held together by stretch wrap or steel banding.

Up to two SWBs may be used in place of the 55-gallon drums and these are specially designed to fit into the TRUPACT II approximating the dimensions of the seven-packs. SWBs are also removed or inserted into a TRUPACT II by hoisting, and the need for slip sheets has been eliminated since SWBs are fabricated with their own lifting attachments.

The facility pallet is a fabricated steel structure designed to hold two TRUPACT II pallets (28 drums or four SWBs) and has a rated load capacity of 25,000 lbs. The upper surface of the CH TRU facility pallet has two recesses, sized to directly accept the SWBs or to accept a TRUPACT II pallet loaded with the seven-packs of waste drums. The drums are secured to the facility pallet with tie-down straps and the SWBs with laterial straps. When loaded with two TRUPACT II pallets, the CH TRU facility pallet will accommodate a total of 4 seven-packs stacked two high. Two rectangular tube openings in the bed permit the CH TRU facility pallet to be lifted and transferred by a forklift. Final contamination surveys are conducted and the assembly identification numbers are recorded using a bar code reader system for transfer to the inventory tracking system. The loaded facility pallet is transported, using a 13-ton electric forklift, to the conveyance loading car inside the conveyance loading room air lock at the waste shaft. A six-ton electric forklift is used for general purpose transfer operations. This forklift has attachments and adapters to handle individual CH TRU waste containers, if required.

After the waste packages are removed from the TRUPACT IIs, a final radiological survey and maintenance inspection are performed on the container and the unit is prepared for reuse and removal from the WHB. This is accomplished by a series of inspections and by replacing the pallets and container closures. The TRUPACT II is reloaded on a trailer and prepared for departure to a shipping site.

4.3.1.1.2 Overpack Operation

As required, TRUPACT II holding contaminated or damaged CH TRU waste packages are moved into the OP&RR through an air lock. A separate HEPA-filtered enclosure, sized to accommodate a TRUPACT II and to permit controlled unloading, is contained within OP&RR. The TRUPACT II is opened under appropriate radiological controls and the contaminated waste packages are unloaded. The packages are decontaminated or overpacked, as needed.

The activities in the overpack/repair area primarily involve handling contaminated material, and the area contains continuous air monitors and alarms. Personnel working in this area must wear appropriate personal protective equipment and access to the area is limited to minimize unnecessary exposure.

Overpacked containers are checked for contamination and decontaminated, if necessary. When the external surfaces meet the WP 12-5[3] limits, the data for the containers is revised and the containers are placed back into the normal waste flow for transfer underground. Due to the larger diameter of overpacked containers, conventional slip sheets and banding methods are used to construct the assemblies using four overpack containers and, for stability, the four-pack is always placed on the top row in a waste stack.

4.3.1.1.3 Shielded Holding Area

Arriving CH TRU waste packages having surface dose rates in excess of 100 mrem/h are given expeditious transfer to the conveyance loading room. If they must remain on the surface for an extended period of time, the containers are placed in the shielded holding area. This area is posted as a high radiation area and locked when waste is placed inside the enclosure. In-process use of this area is in accordance with the Waste Handling Normal Operations Procedures Manual.[2]

4.3.1.1.4 Conveyance Loading Room

The conveyance loading room is an air lock adjacent to the waste shaft. A pallet of waste packages is moved by forklift into this air lock and placed on the conveyance loading car. The conveyance loading car (Figure 4.3-7) is an electric driven car on rails designed with an adjustable height flat bed used to transfer the CH TRU facility pallets on or off the pallet support stands located in the waste hoist cage. With the outer air lock door closed, the conveyance loading car moves the pallets on the hoist cage and transfers the pallets to the pallet support stands in the waste hoist cage. The waste hoist cage (or conveyance) operating in the waste shaft is a multi-rope, friction type hoist and has inside dimensions of 9 ft by 15 ft by 24 ft high. Normally one facility pallet (two TRUPACT II loads consisting of 28 drums or four SWBs) will be carried at a time. Finally the hoist lowers the waste packages to the disposal horizon. Personnel may be carried on the upper deck when waste is not being hauled.

4.3.1.1.5 CH TRU Waste Shaft Station

At the waste shaft station, the underground waste transporter backs up to the waste hoist cage, and the pallet is pulled onto the integral tractor trailer transporter (Figure 4.3-8). The tractor is a commercially available diesel-powered unit modified as necessary to interface with the trailer and comply with mine and other safety codes. The trailer is designed specifically for transporting palletized CH TRU waste and is sized to accommodate the CH TRU facility pallet (Figure 4.3-9). The transporter then moves the waste packages to the waste disposal room.

4.3.1.1.6 CH TRU Waste Disposal Area

At the waste disposal room the waste packages are removed from the transporter using diesel and battery powered CH TRU waste underground lift trucks, and stacked in the disposal face. The lift trucks are equipped with BRUDI push/pull rack attachments to lift and move individual seven-packs of waste containers (drums) or SWB forklift fixtures to lift and move individual SWBs. Seven-packs and SWBs are stacked in such a manner that the criticality Technical Safety Requirements (TSR) administrative controls are not violated (Figure 4.3-10). Seven-packs and boxes are intermixed, as practical and for stability, overpack containers in four-pack assemblies are always placed on the top row of the waste stack. After the waste packages are removed from the facility pallets and the TRUPACT II pallets, these pallets are returned to the surface for reuse.

4.3.2 RH TRU Waste Handling System

The RH TRU waste handling system, including each function, the equipment used, and the operations performed, is discussed in this section. A schematic flow diagram of the RH TRU handling is given in Figure 4.3-11, and a pictorial view of the surface operation is given in Figure 4.3-12. The RH TRU waste handling area is designed to provide for an outdoor storage area and space exists to store six RH TRU waste trailers.

The RH TRU waste shielded road cask (shipping container) is a legal weight DOT Type B truck cask designed to transport a single canister of RH TRU waste per shipment. The cask provides two levels of containment and will be certified by the NRC per 10 CFR 71.63(b). Stainless steel is the primary structural material used for the inner and outer vessels. The outer vessel incorporates lead shielding to assure the surface radiation levels are below DOT limits. The general road cask arrangement, shown in Figure 4.3-13, includes impact limiters at each end of the road cask which function to provide protection of the seal areas during the hypothetical transport accident events.

The RH TRU waste handling system is designed to overpack up to two percent of the canisters handled at the WIPP facility.

4.3.2.1 RH TRU Waste Receiving

Each incoming shipment is inspected, which checks the shipment manifest, verifies the shipment contents, performs a security check, and performs an initial exterior radiological survey of the shipment as it arrives on the site. If any levels of radiation, contamination, or significant damage in excess of acceptance criteria are found, actions will be taken in accordance with the waste handling operations procedures.

The two impact limiters are removed from the road cask while still on the trailer. With the impact limiters removed, the gross weight of the loaded road cask is 20 tons. Overall dimensions of the shielded road cask with the impact limiters removed are a diameter of 42 in and an overall length of 142 in. A bridge crane engages the shielded road cask and rotates it to the vertical position for subsequent transfer to the road cask transfer car. The crane has a main hook capacity of 140 tons and a 25-ton auxiliary hook. Other equipment includes load measuring devices capable of measuring 150 percent of capacity and a handling yoke for upending and lifting the shielded road cask.

4.3.2.1.1 Road Cask Preparation

The road cask preparation area includes the road cask transfer car with an integral work platform, where the road cask is prepared for unloading. The road cask transfer car (Figure 4.3-14) is an electric powered tracked vehicle for supporting and transferring the shielded road cask between the road cask preparation area and the road cask unloading room of the WHB. The road cask transfer car incorporates position sensors that stop car travel when the cask is centered under the shielded road cask unloading room port of the hot cell in preparation for cask closure removal.

The outer closure is removed using appropriate radiological surveys for surface contamination and radiation level.

The shielded road cask inner closure bolts are loosened and the shielded road cask seal collar is installed. Radiological monitoring is required for these and subsequent operations that call for personnel to work in direct contact with the loaded road cask.

4.3.2.1.2 Road Cask Unloading

The shielded road cask, mounted on the road cask transfer car, is moved to the road cask unloading room and positioned under the hot cell unloading port which mates with the shielded road cask seal collar. At this point personnel leave the area and close the shield door. This area remains a very high radiation area until the road cask is unloaded and the hot cell shield plug reinstalled. Re-entry requires a radiological survey of the area.

4.3.2.1.3 Hot Cell Canister Handling

Inspection of the RH TRU waste canisters occurs in the hot cell. The hot cell is an exclusion area when canisters of RH TRU waste are present, and any reentry after RH TRU waste handling requires a radiological survey of the cell area. The hot cell area has its own 15-ton capacity bridge crane and grapple for canister handling inside the cell, and handling operations are performed in the following sequence:

- The shield plug between the hot cell and the road cask unloading room is removed from the hot cell floor and placed in the hot cell laydown area.
- The inner cask head is then lifted into the hot cell and placed in the laydown area.
- A seal protector is installed on the shielded road cask from the hot cell.
- The canister is lifted from the shielded road cask and moved to the hot cell inspection station.
- The inspection station contains the equipment holding the canister in a vertical position. Manipulators are used to swipe the canister and the swipes are removed using the shielded transfer drawer to check for contamination. If the canister is contaminated or physically damaged, the canister is placed in an overpack and the overpack head placed on the unit and welded. Upon completion of the overpack operation, the overpack is swiped to determine contamination level.
- The canister is transferred to the canister transfer cell.

4.3.2.1.4 Canister Transfer Cell and Facility Cask Loading Room

The canister is transferred from the hot cell to the shuttle car in the canister transfer cell. The canister shuttle car (Figure 4.3-15) is a long, rail-mounted, electric-powered car located in the canister transfer cell and designed to transfer waste canisters from the port in the floor of the hot cell to the port in the floor of the facility cask loading room. The shuttle car has a capacity for seven canisters, one of which can be overpacked and can be used for temporary canister storage or movement of the canisters to the facility cask loading room. Remote controlled closed circuit television (CCTV) cameras are used to monitor operations in the very high radiation area when canisters are present. The following steps are performed:

- The canister shuttle car is moved to position an empty tube directly under the hot cell shield valve and then the hot cell/canister transfer cell shield valve is opened.
- Using the crane and grapple, the canister is removed from the inspection station and lowered into the canister shuttle car, the grapple is retracted, and the shield valve closed. The canister shuttle car is moved to position the canister directly under the facility cask loading room shield valve.

- The facility cask (Figure 4.3-16) is a double end loading shielded container designed to transfer one RH waste canister at a time from the facility cask loading room to the disposal location. The shielded road cask has two gate-type shield valves for loading and unloading canisters using the hoist in the facility cask loading room and the RH TRU waste emplacement machine during emplacement. The front trunnion is used to rotate and hold the shielded road cask in the horizontal or vertical position, as required. The facility cask is positioned horizontally on the facility cask transfer car in the facility cask loading room and as the facility cask is moved into position over the loading port, a rotating fixture engages the upper trunnions and rotates the shielded road cask to a vertical position.

- The telescoping shield is raised to mate with the facility cask and the facility cask loading room shield valve is opened. The shield bell is mated with the upper shield valve on the facility cask and both facility cask shield valves are opened.

- The loading room grapple is lowered through the facility into the canister transfer cell where the grapple engages the canister lifting pintle of the canister positioned under the loading port and lifts the canister into the facility cask.

- The facility cask lower shield valve and the facility cask loading room shield valve are then closed, the telescoping shield is retracted, and the canister is lowered on the lower facility cask shield valve. The grapple is disengaged and retracted into the shield bell, the upper facility cask valve closed, and the shield bell is raised from the facility cask into its storage position.

- As the facility cask transfer car is moved toward the waste hoist, the facility cask rotates from a vertical to a horizontal position and the rotating device is disconnected. The facility cask and facility cask transfer car move on the waste hoist cage.

4.3.2.1.5 Waste Shaft Entry Room

In the waste shaft entry room with the waste hoist cage properly positioned, the shaft gates are opened, the pilot rails are positioned, and the facility cask and facility cask transfer car are loaded on the waste hoist cage. The hoist cage is lowered to the disposal horizon. The facility cask and facility cask transfer car are moved to the underground transfer area (Figure 4.3-17).

4.3.2.1.6 Transfer Area

In this area the facility cask is removed from the facility cask transfer car by forklift and moved to the disposal room.

4.3.2.1.7 RH TRU Waste Disposal

The underground handling and emplacement equipment consists of diesel-powered forklifts, a drill, and a horizontal emplacement and retrieval machine. The RH waste handling equipment is the largest equipment transporting waste in the waste disposal area and therefore defines the minimum operating sized opening of 11 ft vertical and 14 ft horizontal for waste handling transport.

A horizontal hole has been drilled in the disposal room for canister emplacement. The RH TRU waste emplacement and retrieval machine interfaces with the forklifts and facility cask, and an alignment fixture is utilized to establish alignment of the emplacement equipment with the borehole (Figure 4.3-18 and Figure 4.3-19). The alignment fixture is positioned by forklift to locate the shield collar in line with the drilled hole. The leveling jacks are adjusted until the fixture is at the proper elevation and parallel to the longitudinal axis of the hole.

The facility cask is then positioned by forklift on the emplacement machine bed which ensures that the cask is accurately located on the emplacement machine (Figure 4.3-20). The facility cask is moved forward to mate with the shield collar and the transfer carriage is advanced to mate with the rear facility cask shield valve. The shield valves are opened and the transfer mechanism advances to push the canister into the hole (Figure 4.3-21). After retracting the transfer mechanism into the facility cask, the forward shield valve is closed and the transfer mechanism is further retracted into its housing. The transfer carriage is moved to the rear about 6½ ft and the shield plug carriage containing a shield plug is placed on the emplacement machine. The transfer mechanism is used to push the shield plug into the facility cask. The front shield valve is opened and the shield plug is pushed into the hole (Figure 4.3-22) completing the process.

The transfer mechanism is retracted, the shield valves closed on the facility cask, and the facility cask removed from the emplacement machine. After all the equipment is removed from the hole, a stop plate is mounted over the installed shield plug and canister. The emplacement machine is now available for transfer to another location.

4.3.3 Process Interruption Modes

General waste handling systems of the WIPP facility are described in Section 4.3.1 and Section 4.3.2. Process interruption modes are discussed in this section and fall into two categories: routine and emergency.

4.3.3.1 Routine Interruptions

Routine interruptions are plant process interruptions, including scheduled maintenance, unscheduled maintenance, and plant inspections during the life of the facility.

Actions taken during an interruption are conducted in accordance with established procedures, and monitoring of the plant parameters during the interruption is continued to ensure that no radiological problems are encountered. Any additional surveillances that are necessary during the interruption are specified in the procedures.

4.3.3.2 Emergency Interruptions

Emergency interruptions are those process interruptions in the plant due to abnormal or accident conditions, and include earthquakes, severe weather emergencies, fires, and loss of electrical power.

Design Basis Earthquake (DBE) Interruptions - Normal plant operations may be suspended following an earthquake. If the earthquake is of sufficient magnitude, inspection of structures and equipment will be required prior to resuming normal operations. The length of the interruption will depend upon the results of the inspection and all plant recovery corrective actions will be directed toward returning the plant to normal operation.

Severe Weather Emergencies - Normal plant operations may be suspended during a tornado warning or a high wind condition. A tornado warning or high wind condition will exist based on information provided by the National Weather Service or a local observation. If a severe weather emergency condition occurs at the WIPP facility, inspections of structures and equipment will be required prior to resuming normal operations. The length of the interruption will depend on the results of the inspection and all plant recovery corrective actions will be directed toward returning the plant to normal operation.

Fires - Fire accidents, although not expected, may result in a process interruption. The occurrence of a major fire requires the evacuation of personnel and response by the fire brigade during off-shift operation, and the Emergency Response Team (ERT) and/or First Line Initial Response Team (FLIRT) during regular shift operation. After extinguishing the fire, the area will be surveyed, controls will be established to mitigate any problems, and the area returned to normal operations.

Loss of Off-Site Power - The loss of off-site power affects all electrical equipment. The plant is designed with a manually started backup power supply, which picks up selected electrical loads such as the AIS hoist, lighting, and ventilation system. Certain equipment has uninterruptible (battery) backup for loss of power so that functions such as parts of the central monitoring system (CMS) continue without power interruption. The site backup power system can maintain the containment functions (e.g., negative pressure ventilation balance) and is discussed in Section 4.6.

4.3.4 WIPP Waste Information System

The WIPP waste acceptance criteria[4] (WAC) requires specific information from the waste generators to meet the waste certification requirements. The WIPP waste information system (WWIS) was developed to provide an online source of data required by the WAC,[4] showing the waste form, packaging, weight, organic volume, and radionuclide inventory.

The WWIS includes features to automate the transfer of the data required by the WAC[4] from the waste generators to the WIPP and also includes the limiting criteria from the WAC[4] summarized in Chapter 3. The data input by the waste generators that does not meet these criteria is automatically flagged for review. In addition to providing WAC[4] related information for the repository, the WWIS provides operational information, routine and special reports, and reports required by DOE Order 5820.2A.[5] See Table 4.3-3 for a list of the information provided.

4.3.4.1 CH TRU Waste Emplacement

For inventory control purposes, waste container package identification numbers are checked against the data package in the WWIS at the time the waste is unloaded. These identifications numbers are rechecked at the time the waste is placed in the disposal array.

4.3.4.2 RH TRU Waste Emplacement

The identification number of each RH TRU waste canister is verified against the data package while the canister is in the hot cell.

4.3.5 Underground Mining Operations

4.3.5.1 Mining Method

Mining is performed by two continuous mining machines. Prior to mining in virgin areas, probe holes are drilled to relieve any pressure that may be present. After mining, vertical pressure relief holes are drilled up at the main intersections of drifts and crosscuts.

The continuous mining machine is a roadheader or boom type continuous miner operating a milling head. The milling head rotates in line with the axis of the cutter boom, mining the salt from the face. The mined salt is picked up from the floor by the loading apron. The muck (mined salt) is pulled through the miner on a chain conveyor, through a slewing conveyor, and then loaded in one of the haul vehicles.

The other machine is a drum miner operating with a head that rotates perpendicular to the axis of the cutter boom and cuts the salt away from the working face. The muck is pulled through the miner on a chain conveyor and then loaded in one of the haul vehicles.

During and immediately after mining, a sounding survey of the roofs of drifts, using a scaling bar, is made to identify areas of drummy or slabby rock, which might represent safety or stability problems. A comprehensive underground safety and maintenance program has been established and can be found in the Mining Operations Manual.[6]

Remedial work, including hand scaling of thin drummy areas, removal of larger drummy areas up to 18 in thick with the continuous miners, or rock bolting, is accomplished immediately after soundings in any areas identified as potentially unstable. Additional scaling is performed, as required, using a mechanical scaler improving the safety of this operation.

Rock bolts are used extensively throughout the underground openings for remedial work and for safety. In addition, roofs in the first waste disposal panel and high traffic areas are pattern bolted for extra safety. Both resin and mechanical bolts are used in most ground control activities. Only certified bolts are used at the WIPP, and the specifications in References 6 and 7 are used in defining bolting requirements for the underground.

The WIPP engineering staff is responsible for ensuring that ground control systems comply with all rules and regulations.

4.3.5.2 Interface Between Mining and Waste Disposal Activities

Separate mining ventilation and disposal ventilation circuits are maintained by means of temporary and permanent bulkheads. Air pressure in the mining side is maintained higher than in the disposal side to ensure that any leakage results in airflow to the disposal side. The underground ventilation system is discussed in Section 4.4.2. Rooms being mined are within the mining ventilation circuit and rooms under disposal are within the disposal ventilation circuit.

4.3.5.3 Mined Material

The salt removed during underground mining is brought to the surface by the salt handling system. From the surge pocket, salt is loaded into the 8-ton salt handling skip with a skip measuring and loading hopper, the skip is raised to the surface, and dumped through a chute to surface haulage equipment which transports the salt to an on-site storage pile.

4.3.5.4 Ground Control Program

The WIPP facility ground control program ensures underground safety from any potential unplanned roof or rib falls. Care is taken from the moment a drift is mined and throughout the life of the opening to remove or restrain any loose or potentially unsafe pieces of ground. As the opening ages, areas of the roof, ribs, and floor may require some ground control. To ensure this is achieved in a timely and efficient manner, a very comprehensive ground control monitoring program has been established.

Two major components for implementing ground control are rock bolts and supplementary systems. The rock bolt systems are mechanically-anchored bolts and resin-anchored threaded rods. The supplementary systems include cable slip with mesh, truss, and the Room 1, Panel 1 design.

The fundamentals of the ground control program at the WIPP facility are:

- Ground stability is maintained as long as access is possible
- Ground control maintenance efforts increase with the age of the openings
- Ground control plans are specific but flexible
- Regular ground control maintenance is required.

The ground control program at the WIPP facility uses observational experience and analysis of salt behavior underground to enable various projections regarding future ground support requirements. This approach recognizes that salt moves or creeps. Because of its plastic nature, salt will flow into an excavated opening. To provide long-term ground support, the ground control system must:

- Accomodate the continuous creep of salt.
- Retain broken fractured rock in the back or rib.

As more information becomes available regarding the long-term behavior of the WIPP underground excavations, the ground control maintenance plan will be revised accordingly. The ground control long-term plans provide regular reviews, evaluations, and incorporate changes as required.

4.3.5.5 Geomechanical Monitoring

The WIPP facility geomechanical monitoring program provides comprehensive data and analyses on excavation behavior. This is an important element in assessing ground control needs and requirements. The primary function of the Geomechanical Instrumentation system is to provide data:

- To evaluate the geotechnical performance of the underground facility.
- To develop techniques for the excavation configuration, modifications, and use of the underground site for waste storage.
- To develop improved characterization of phenomena related to rock fracture development, brine seepage and the geology of the Los Medanos area.
- To detect conditions that could affect operational safety of the facility.

Geomechanical instrumentation enables measuring the cumulative deformation of the rock mass surrounding mined drifts and the walls, floors and ceilings of the mined drifts. Methods of measurement include borehole extensometers, convergence points (eyebolts anchored in the rock), and sonic or wire convergence meters.

Instrumentation provides a means to monitor the liners, keys and surrounding rock structures associated with the main shafts (waste, salt, and exhaust) of the WIPP facility.

The geomechanical measurements are made at a sufficient number and variety of locations to provide a basis for:

- Early detection of conditions that could effect operational safety of the facility.
- Guidance for design modifications and remedial actions.
- Data for interpreting the behavior of underground openings.

The number and location of measurements will vary as the need for additional storage space requires the mining of additional drifts. The number and location of measurements will also vary as new data enables developing new methods to predict rock salt movement.

References for Section 4.3

1. DOE/WIPP 91-058, Radionuclide Inventory for the Waste Isolation Pilot Plant, Rev. 0.

2. WP 05-NO, WIPP Waste Handling Normal Operations Procedures Manual.

3. WP 12-5, WIPP Radiological Control Manual, Rev. 1, October 1994.

4. WIPP-DOE-069, Westinghouse Electric Corporation, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev 4., December 1991.

5. DOE Order 5820.2A, Radioactive Waste Management, 1988.

6. WP 04-2, Mining Operations Manual.

7. Title 30, Code of Federal Regulations Part 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, 8th edition, 1994.

8. Westinghouse Electric Corp., Shops Area Bolt and Mesh, Specification E404A56, Rev. 0, July 24, 1985.

9. Westinghouse Electric Corp., Rock Bolts, Specification E404A48, Rev. 0, June 20, 1985.

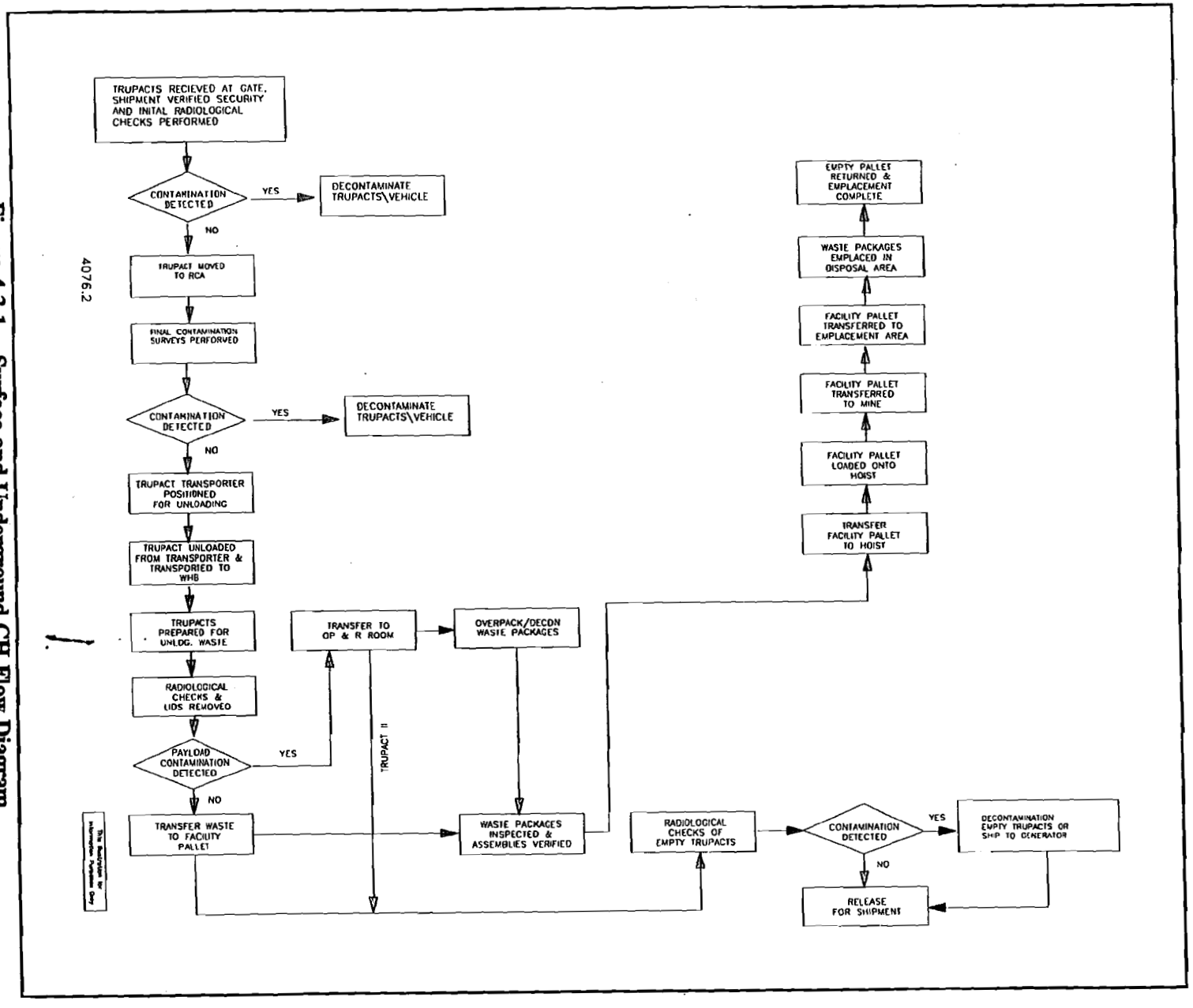
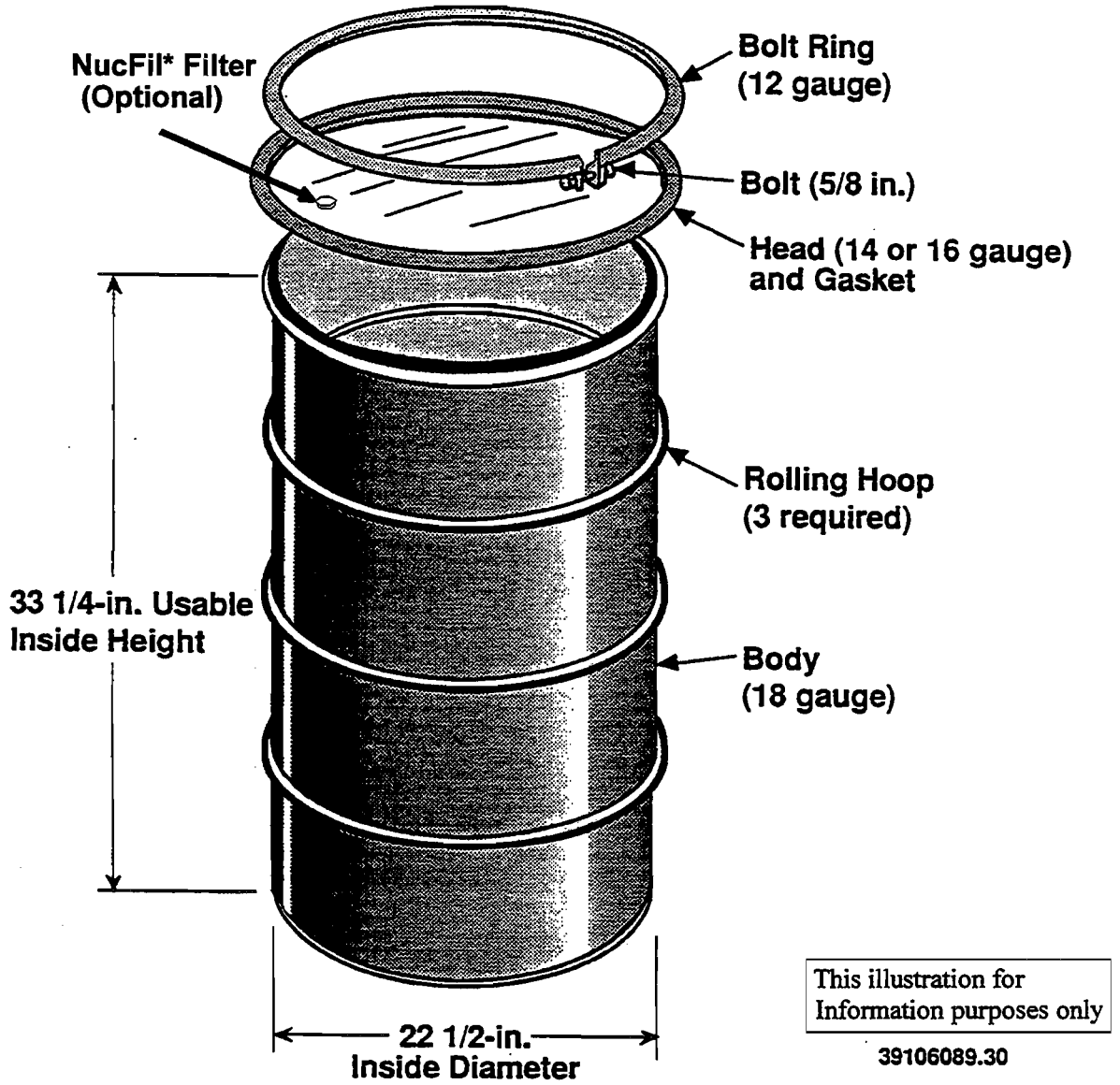


Figure 4.3-1, Surface and Underground CH Flow Diagram



*NucFil is a trademark of Nuclear Filter Technology, Incorporated
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Figure 4.3-2, Standard 55-Gallon Metal Drum

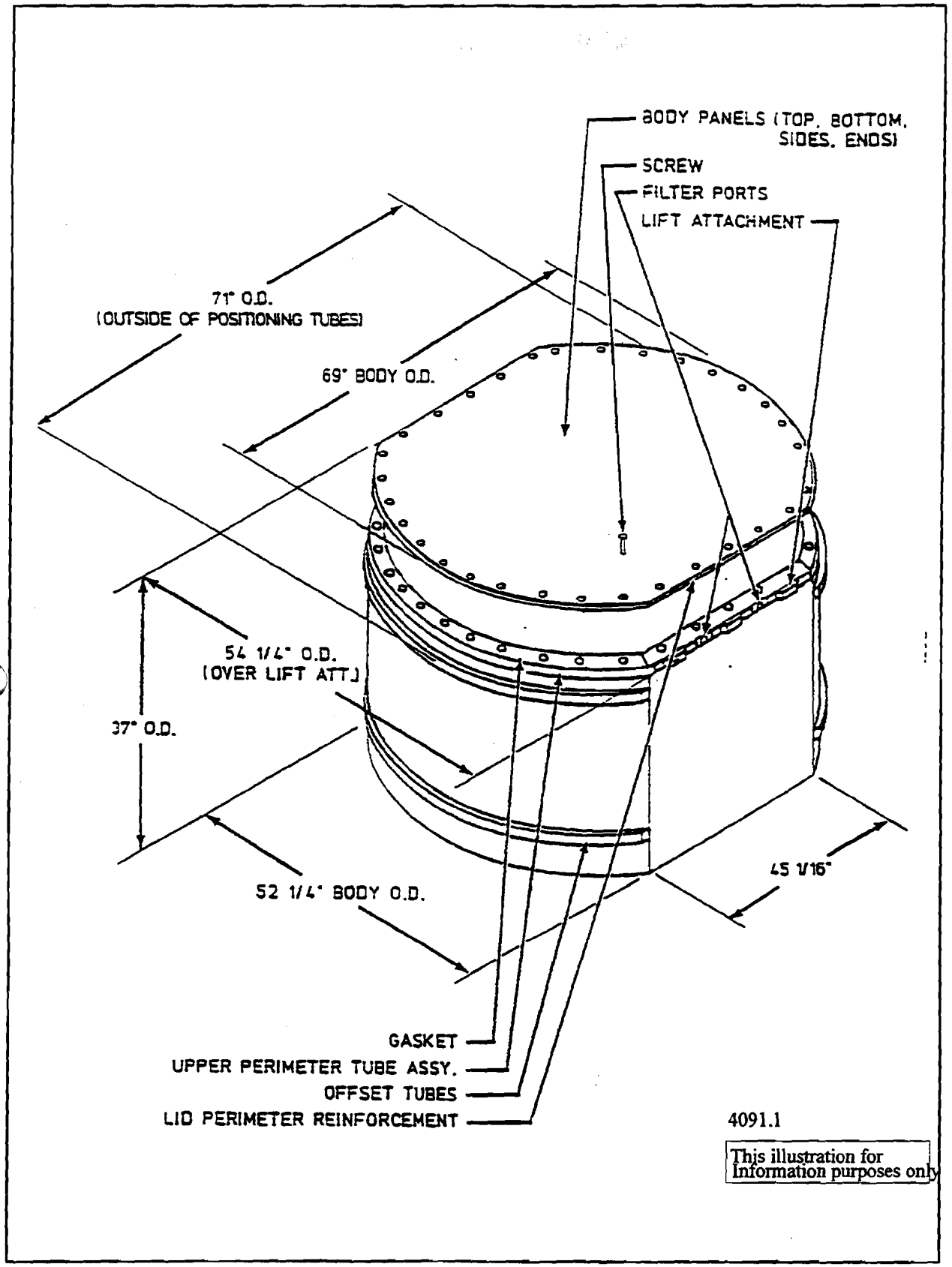

Figure 4.3-3, Standard Waste Box

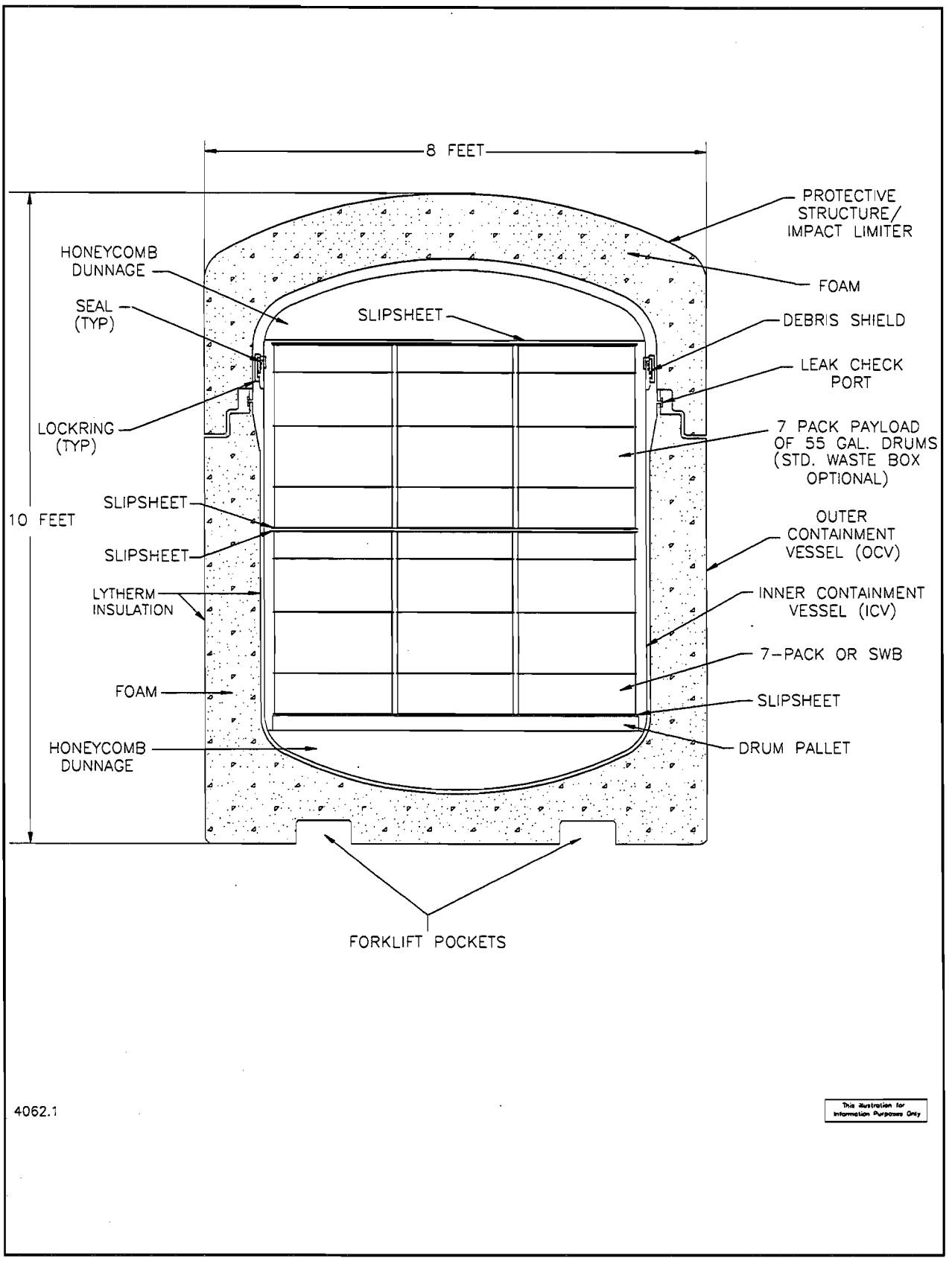

Figure 4.3-4, TRUPACT II

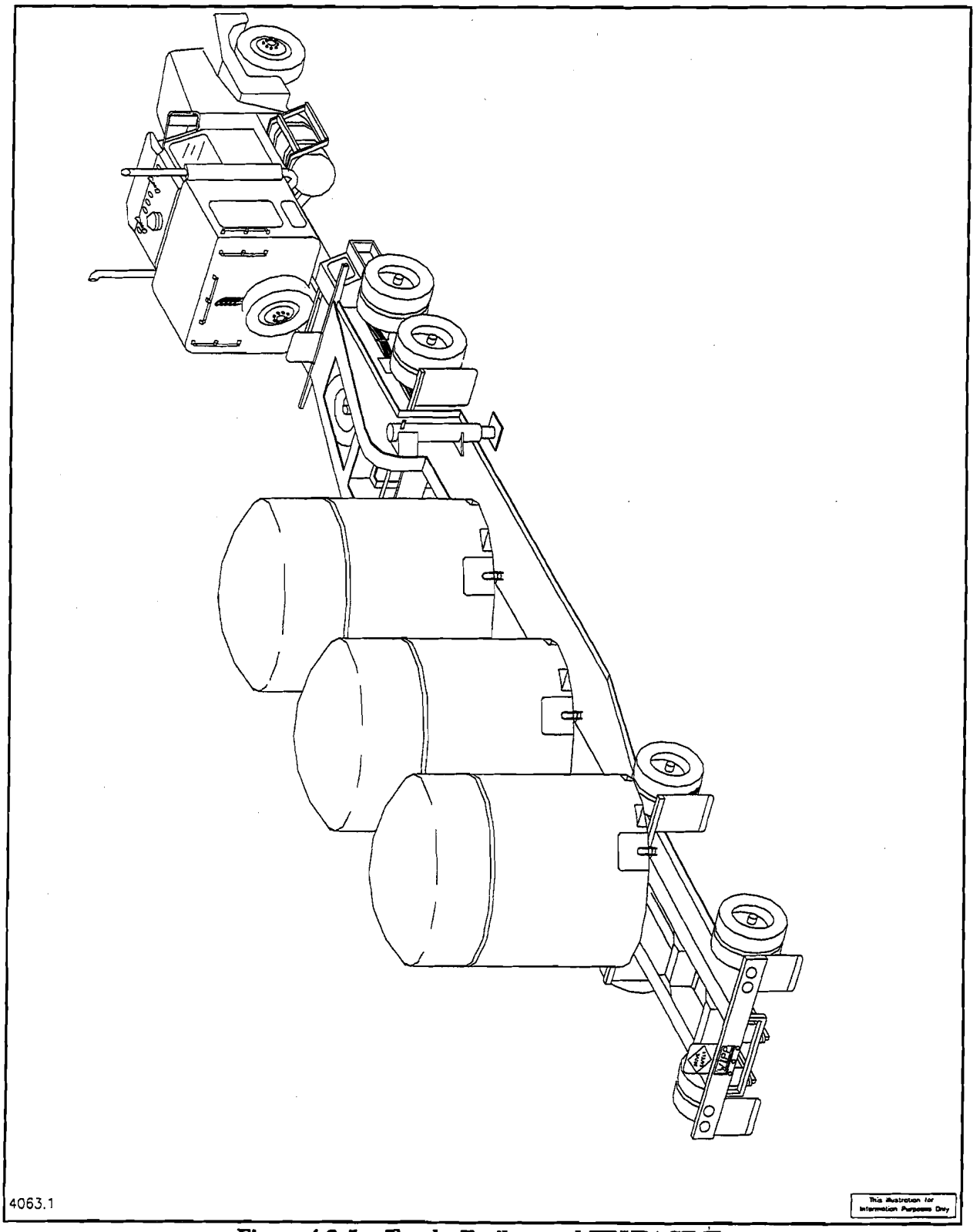

Figure 4.3-5, Truck, Trailer, and TRUPACT IIs

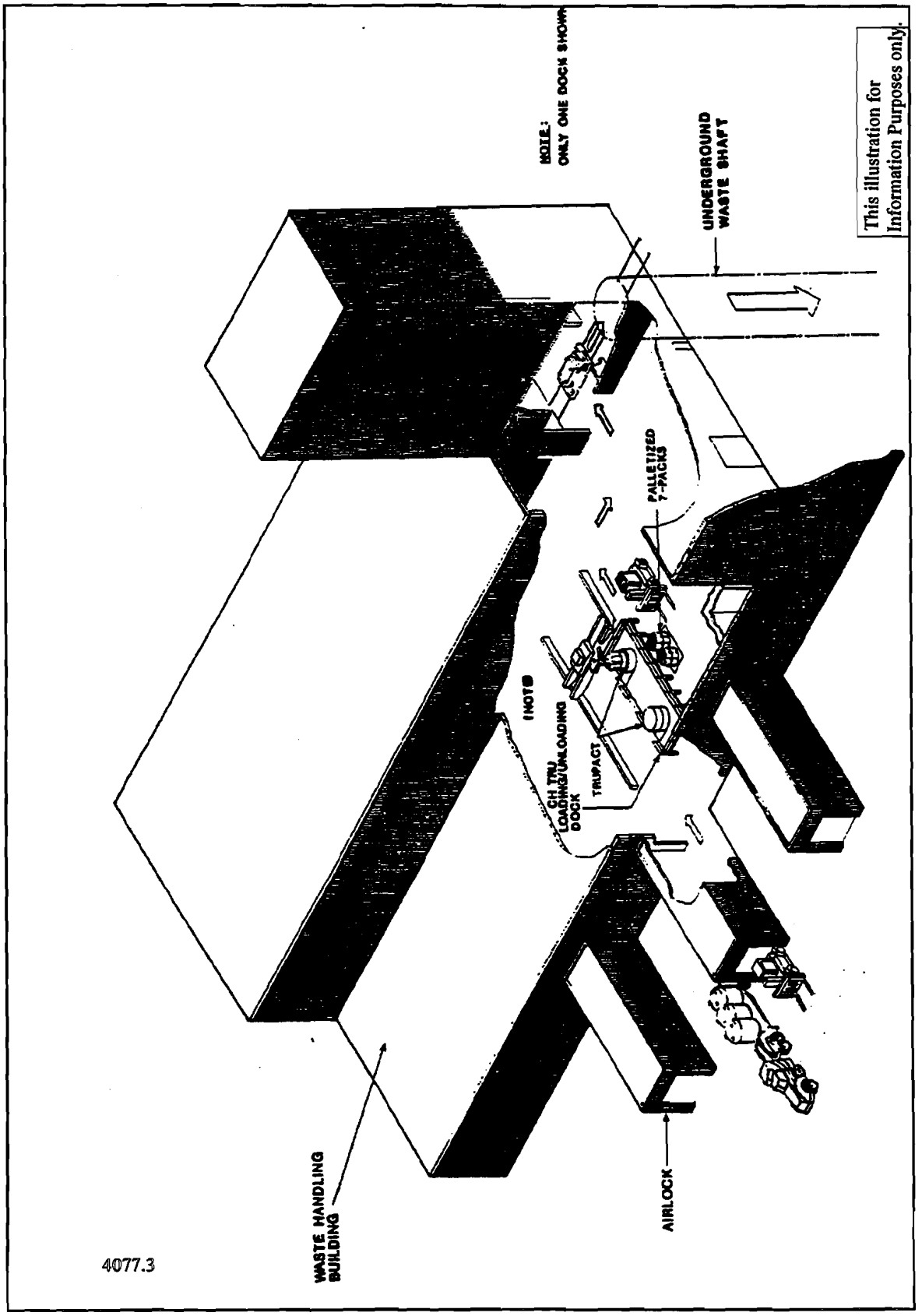

Figure 4.3-6, CH TRU Waste Handling (Surface)

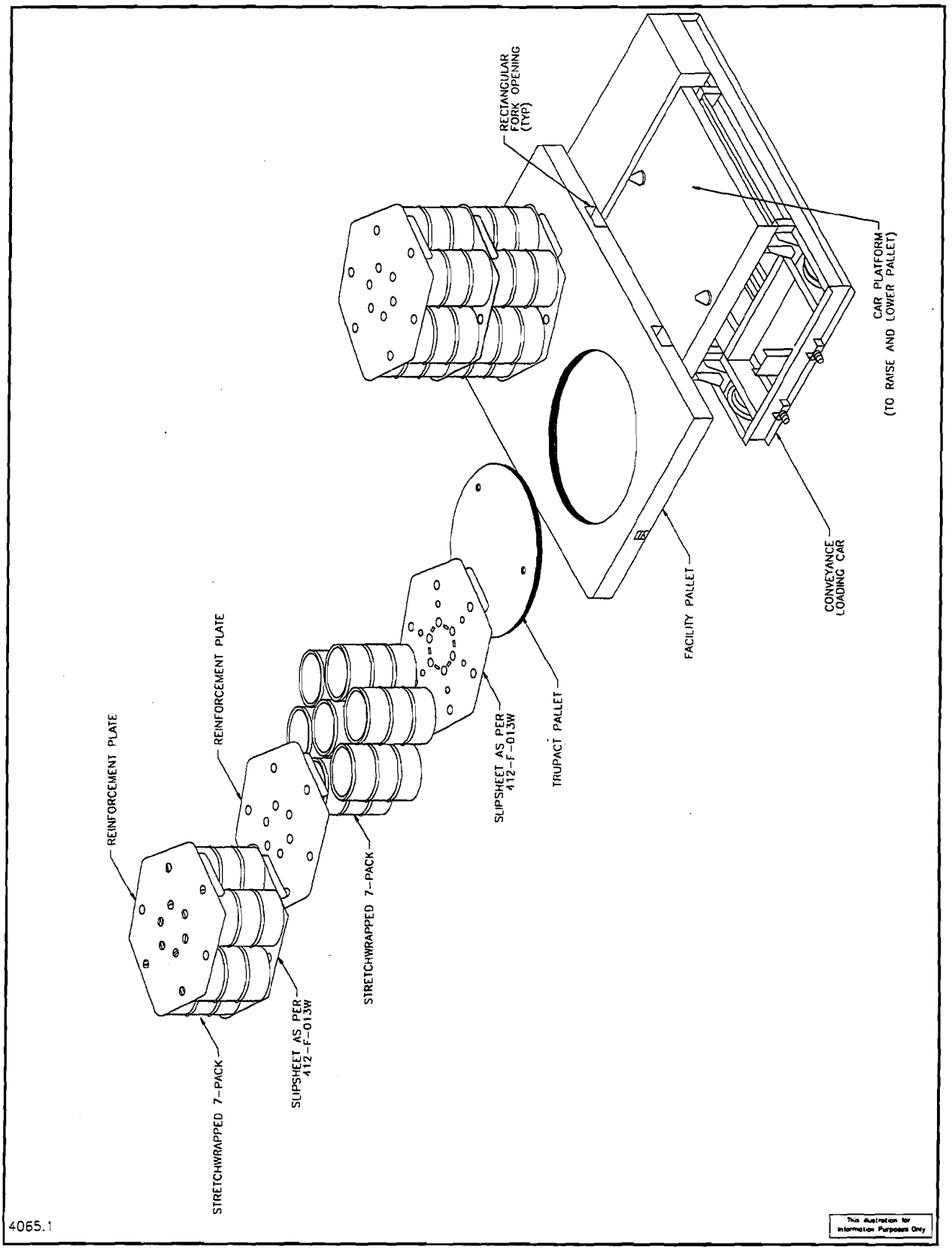

Figure 4.3-7, CH TRU Waste Pallet on Conveyance Loading Car

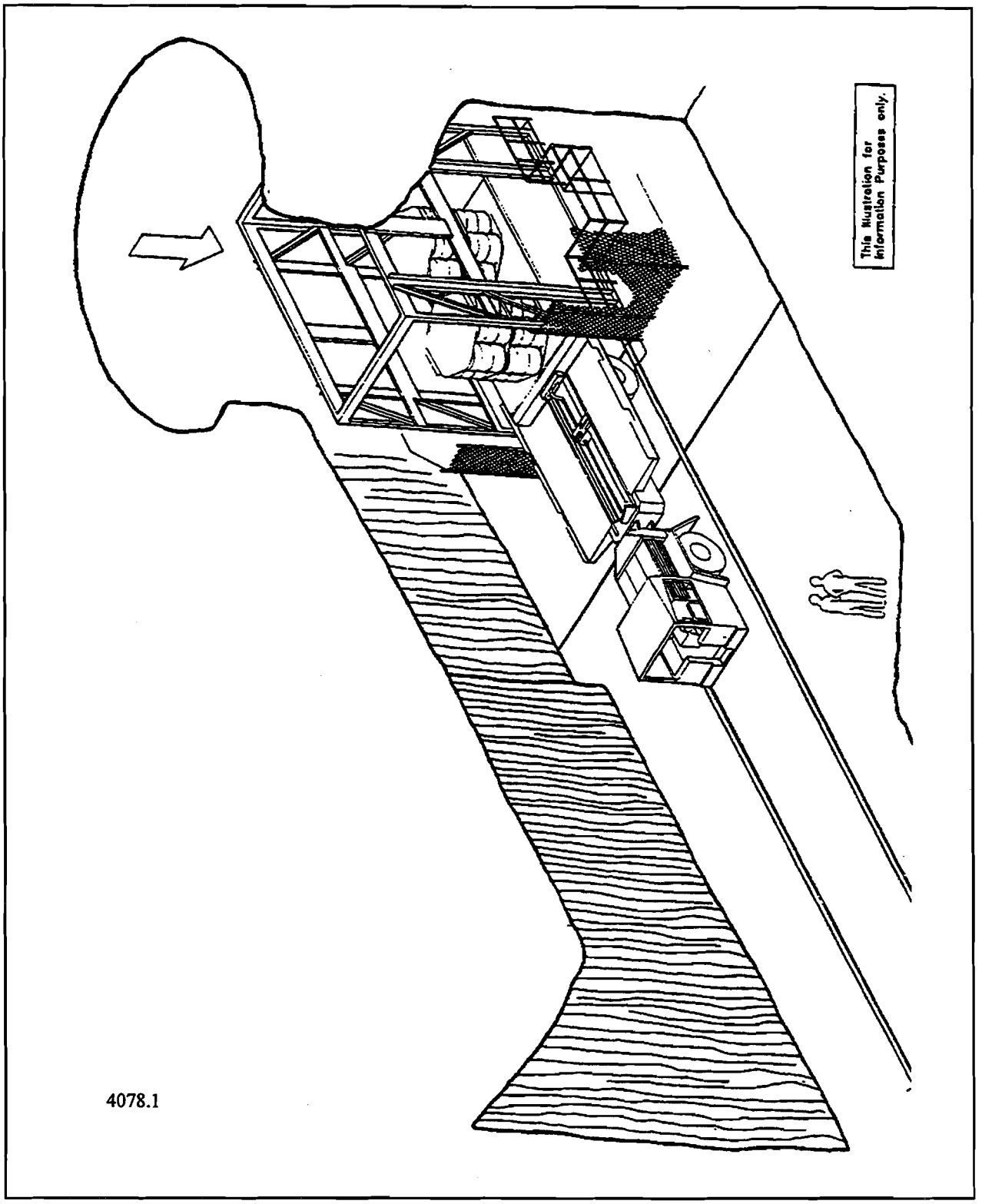

Figure 4.3-8, CH TRU Waste Handling (Underground)

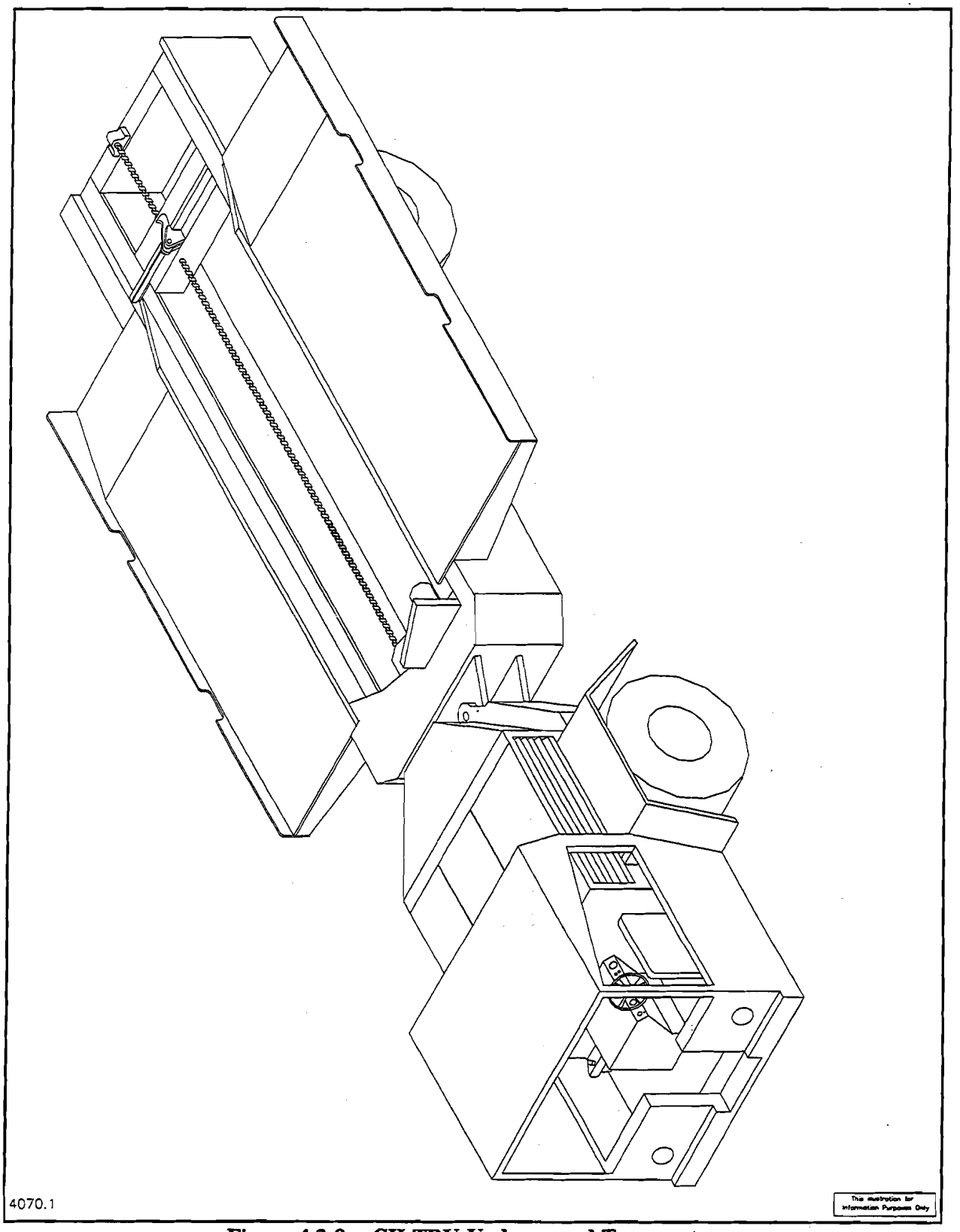

Figure 4.3-9, CH TRU Underground Transporter

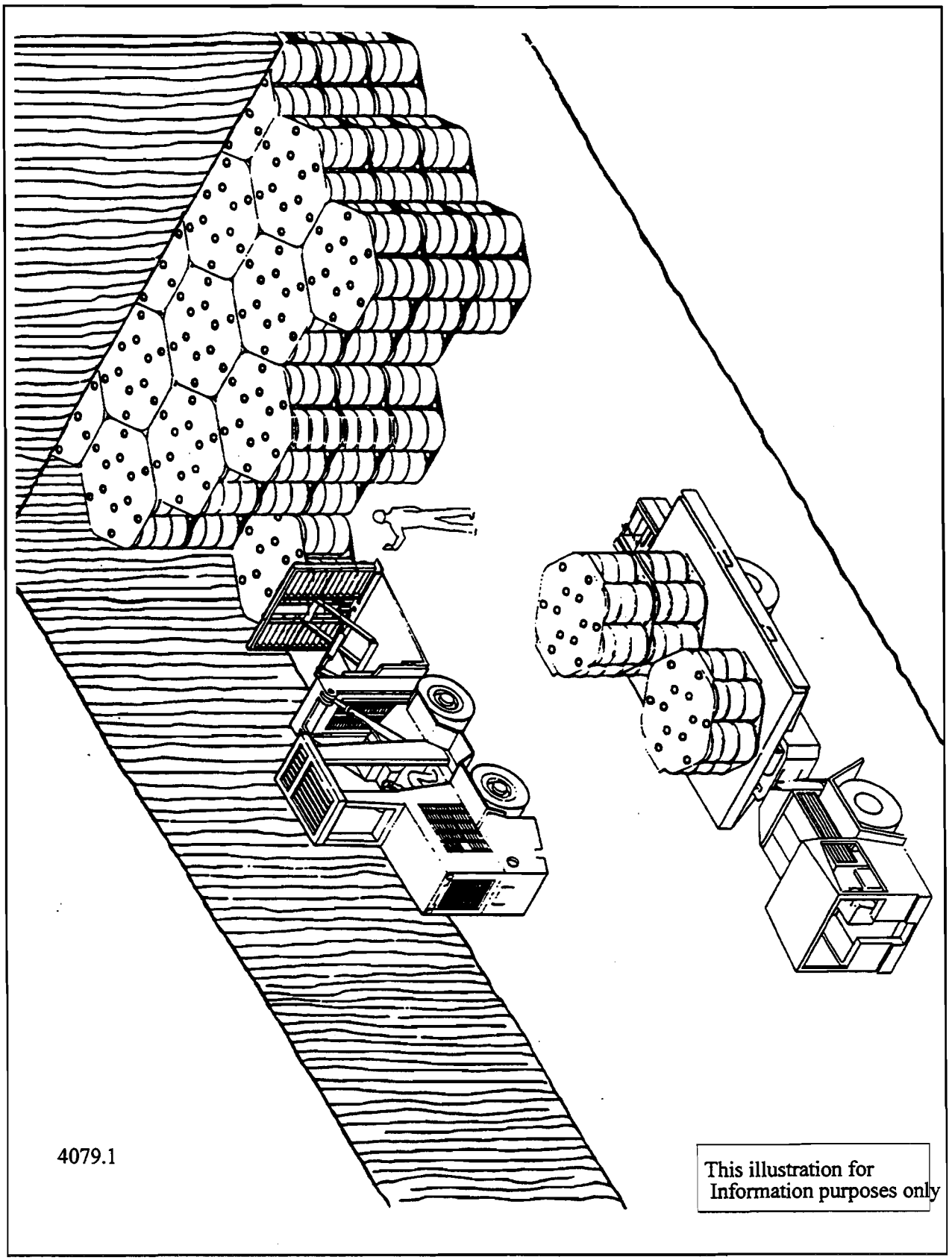

Figure 4.3-10, CH TRU Emplacement

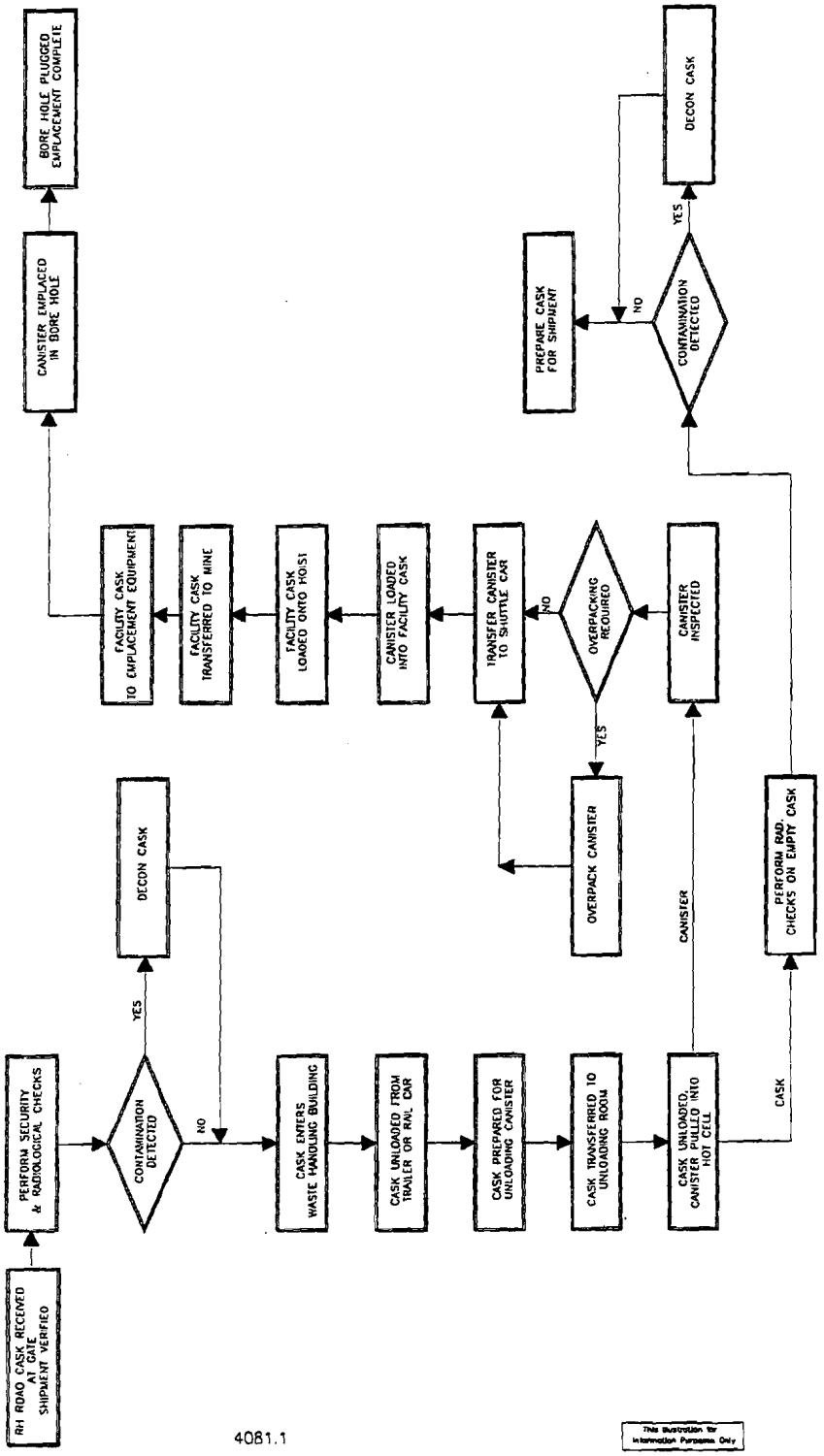

Figure 4.3-11, Surface and Underground RH TRU Waste Process Flow Diagram

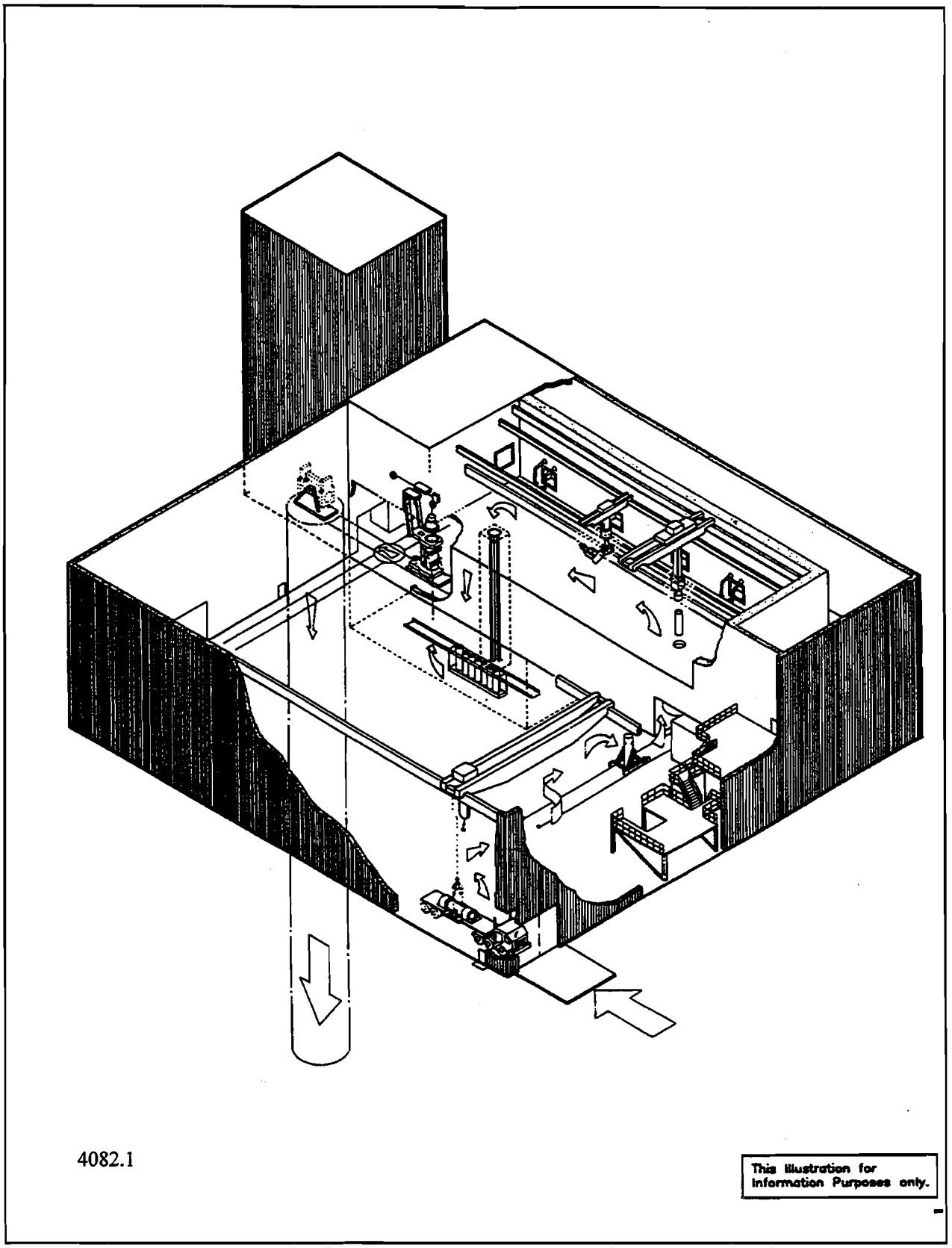

Figure 4.3-12, Pictorial View of the RH TRU Surface Operation

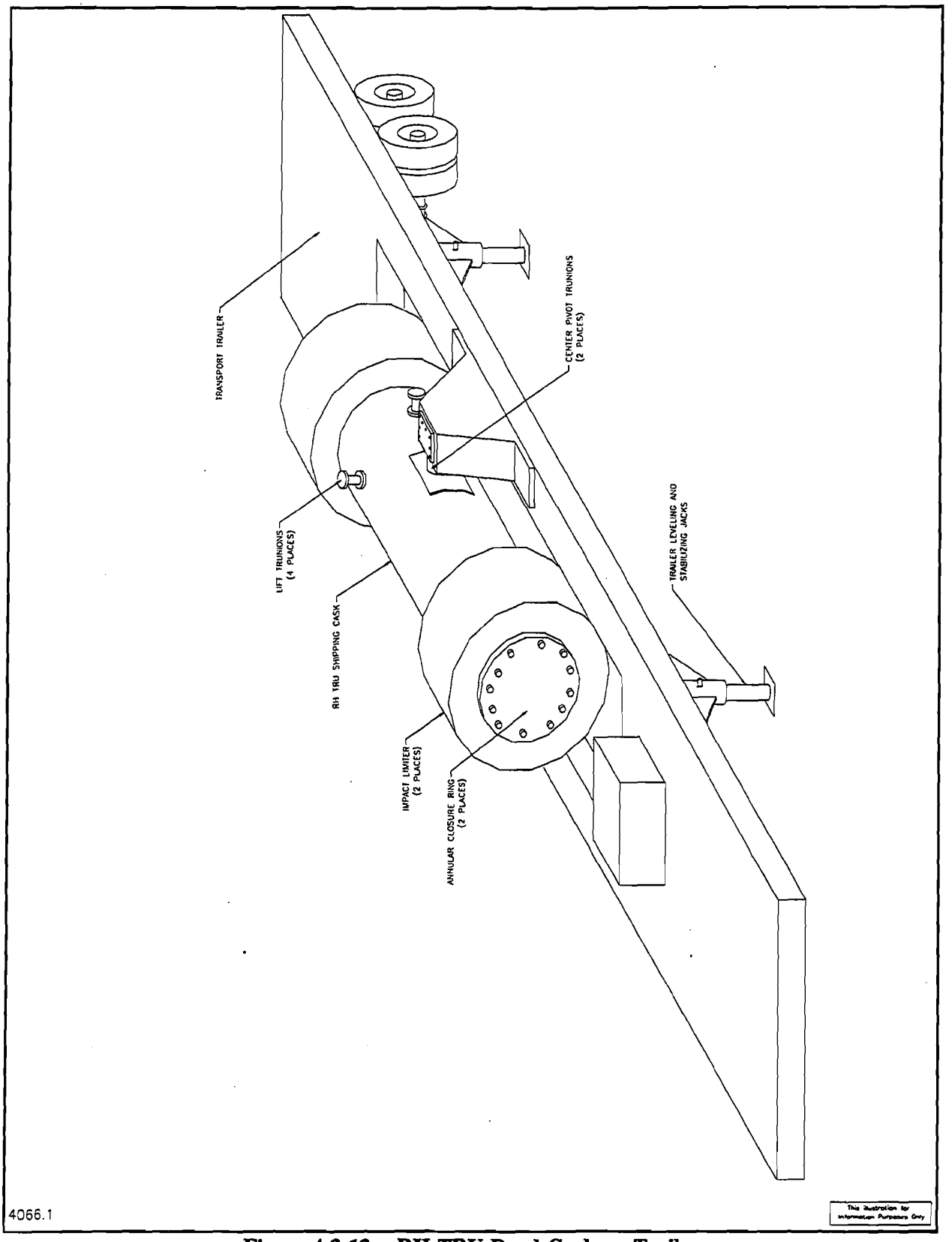

Figure 4.3-13, RH TRU Road Cask on Trailer

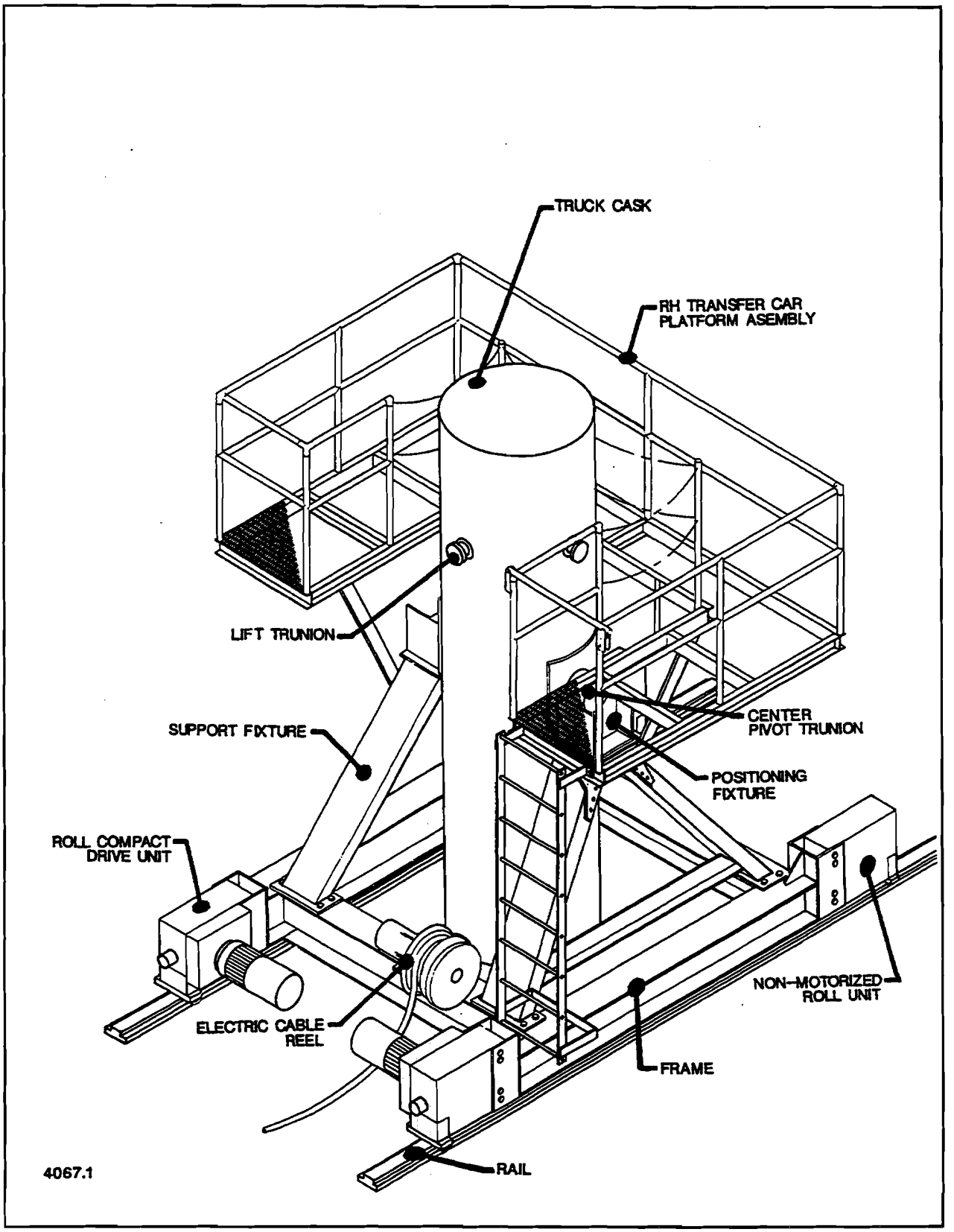

Figure 4.3-14, RH TRU Waste Shielded Road Cask on Transfer Car

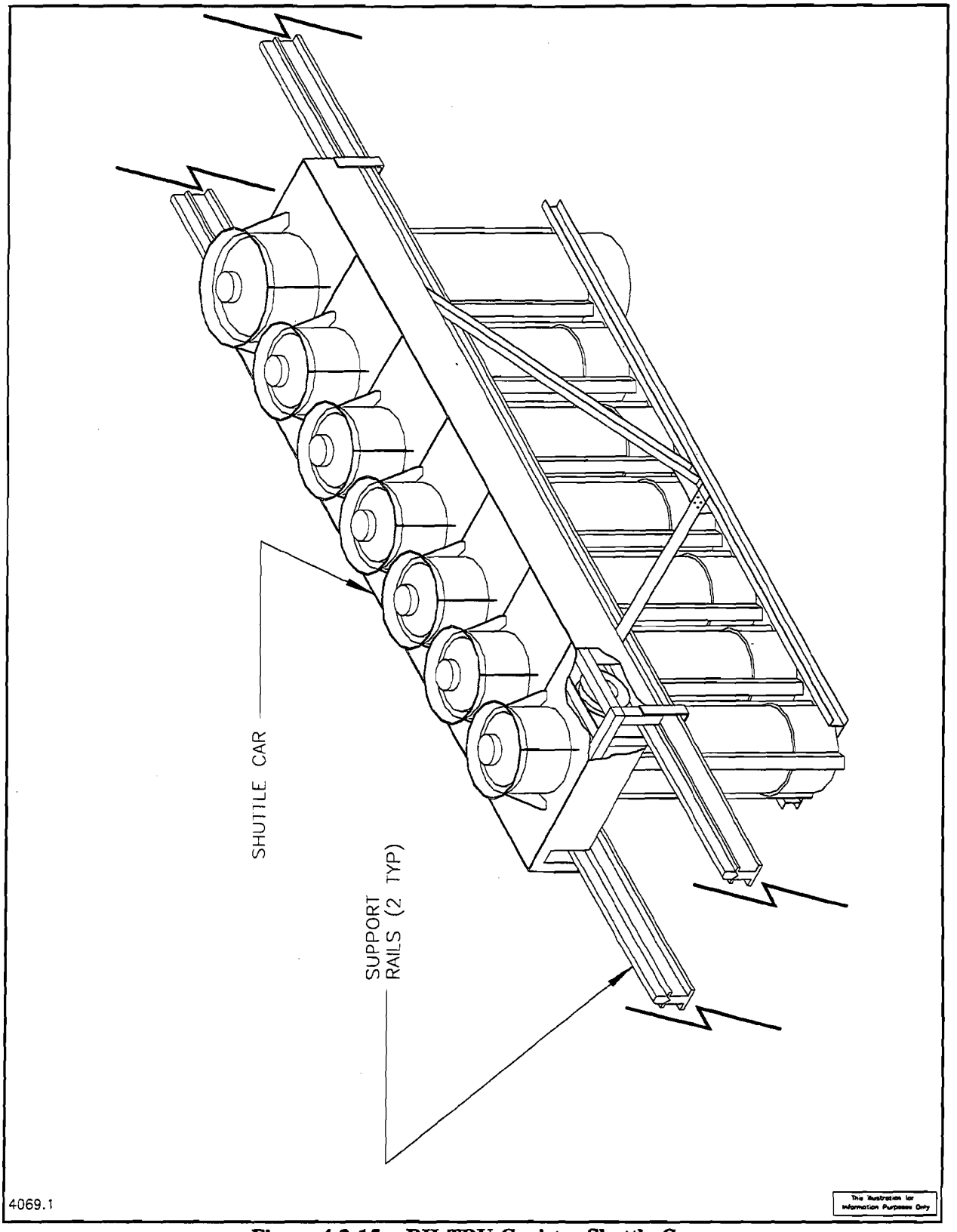

Figure 4.3-15, RH TRU Canister Shuttle Car

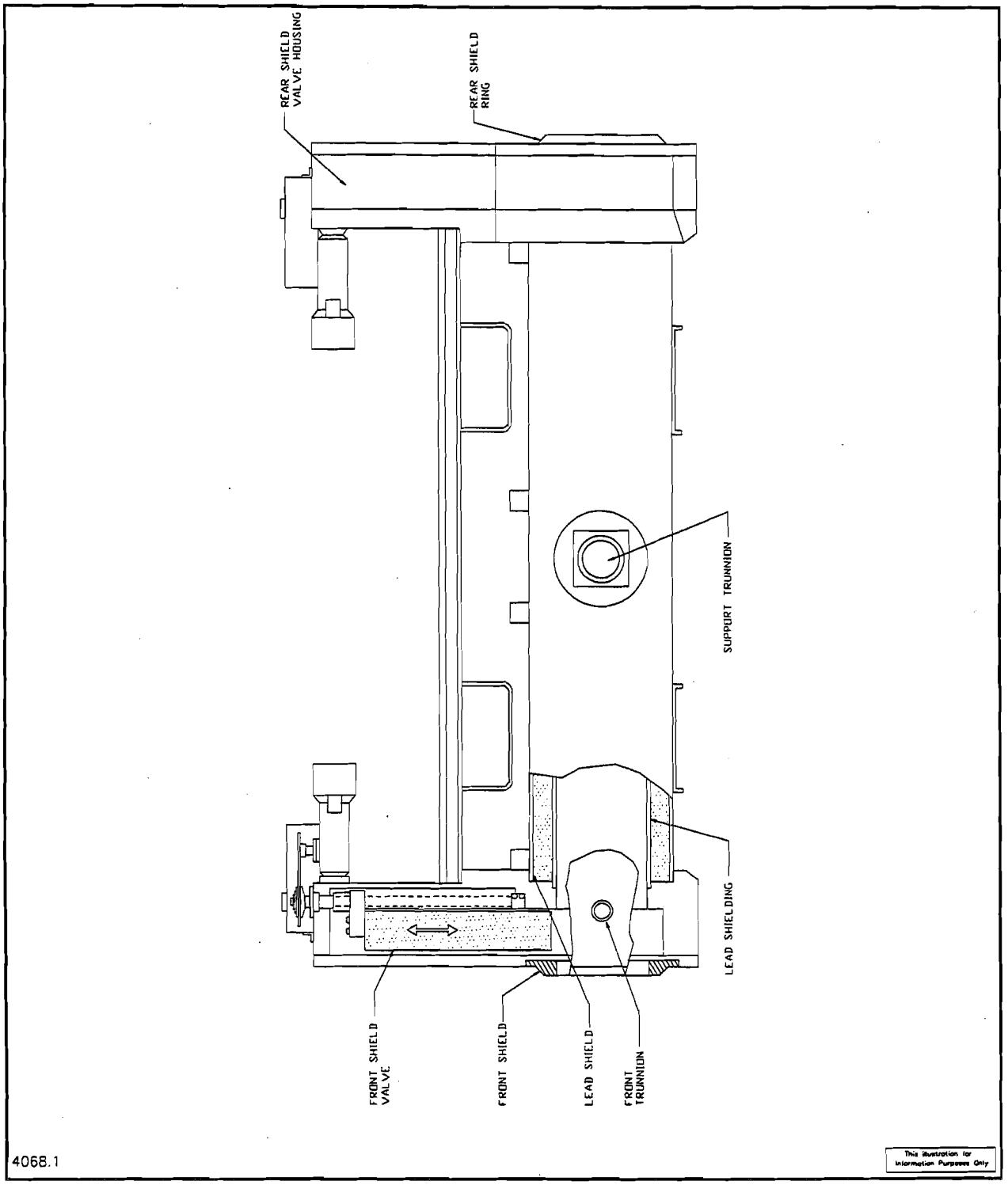

Figure 4.3-16, RH TRU Facility Cask

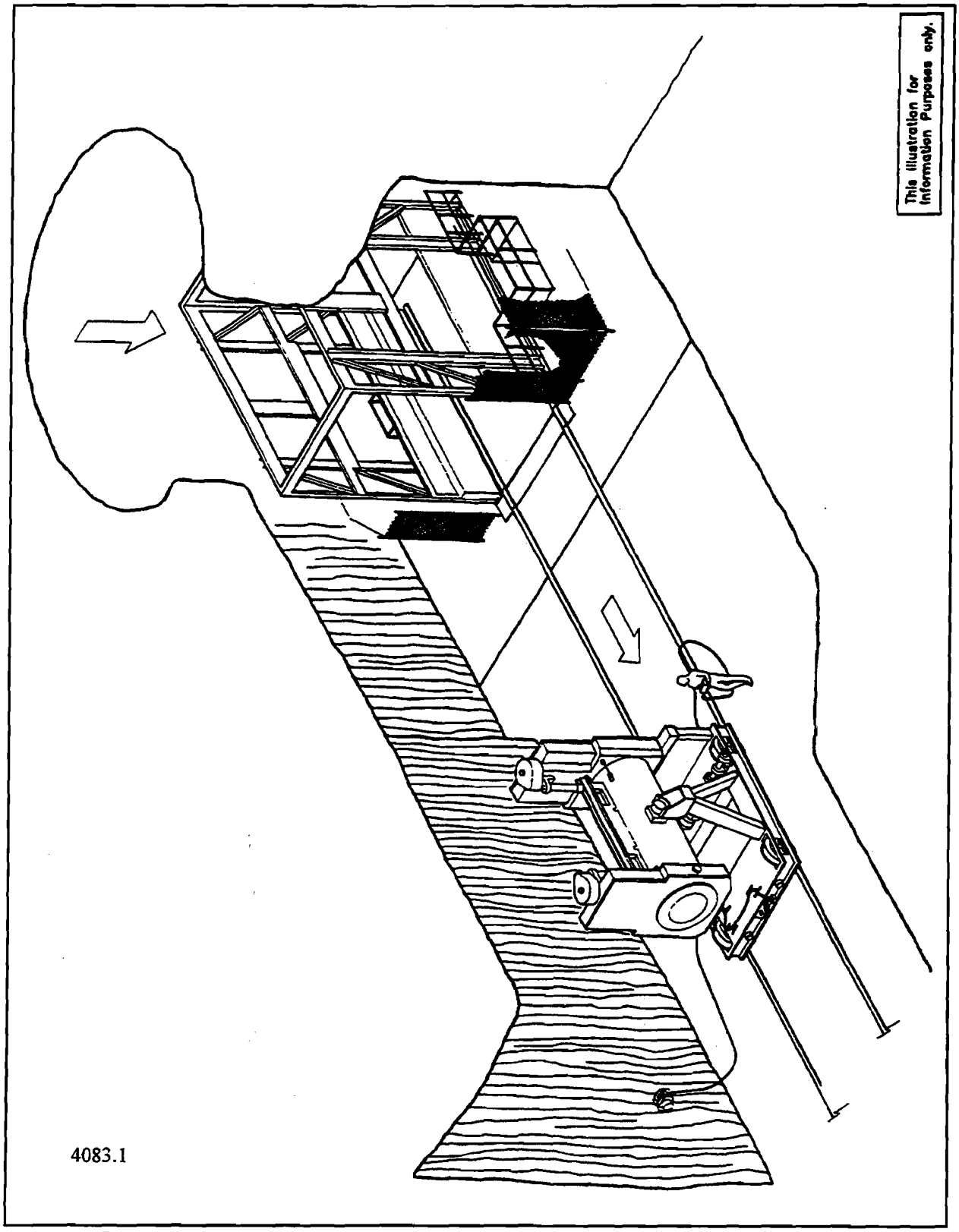

Figure 4.3-17, RH TRU Waste Handling Facility Cask Unloading from Cage

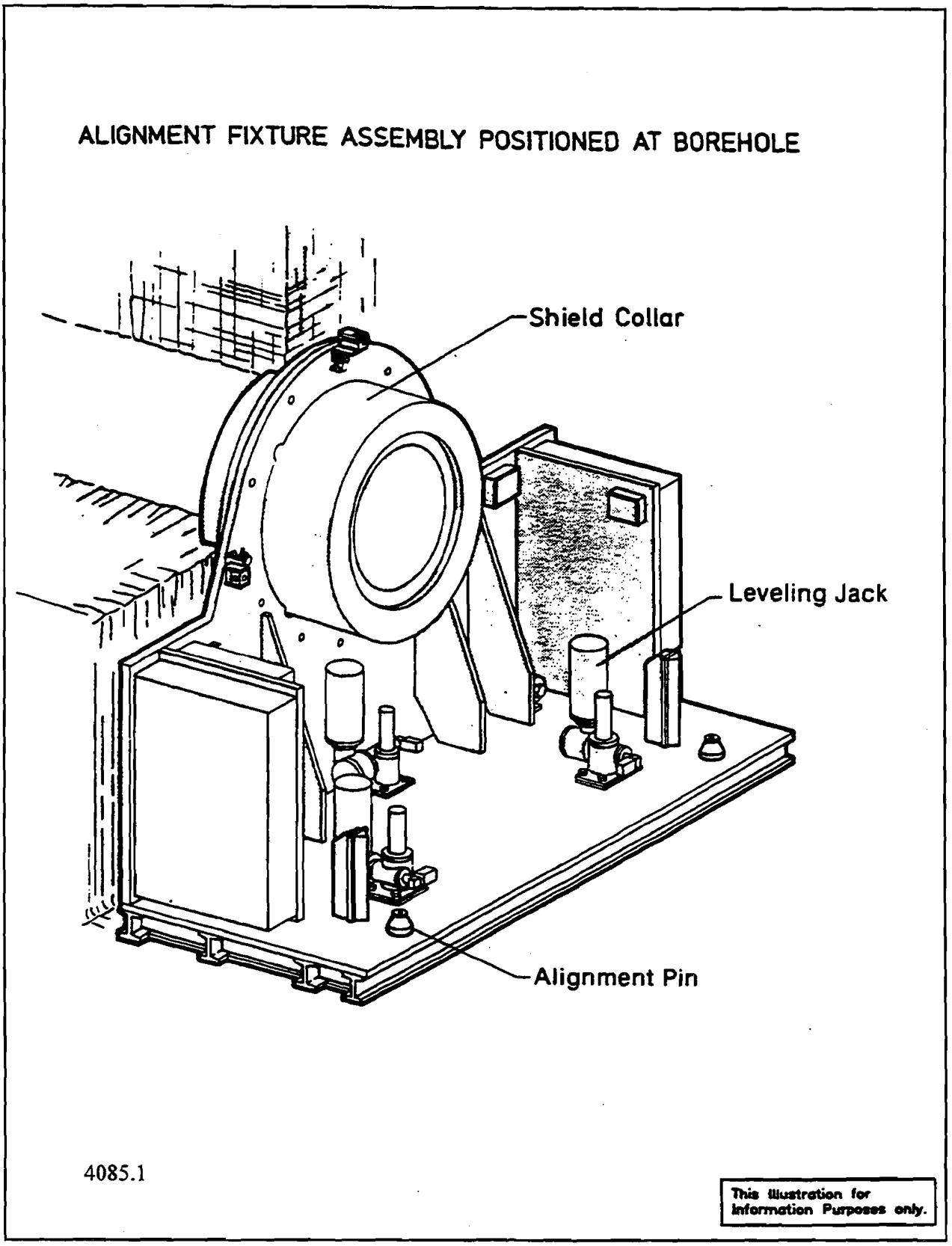

Figure 4.3-18, RH TRU Emplacement Alignment Fixture

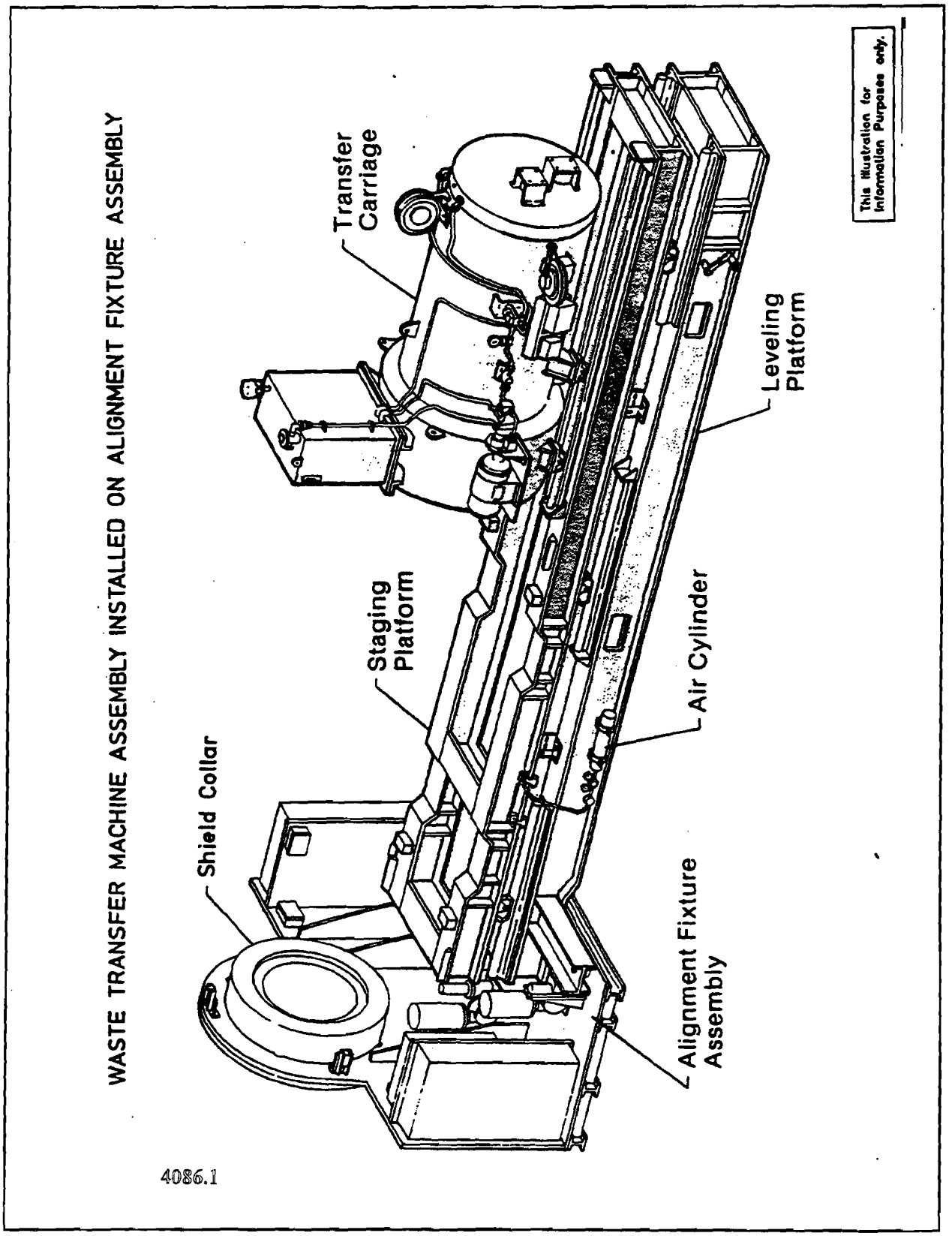

Figure 4.3-19, Waste Transfer Machine Assembly Installed on the Alignment Fixture

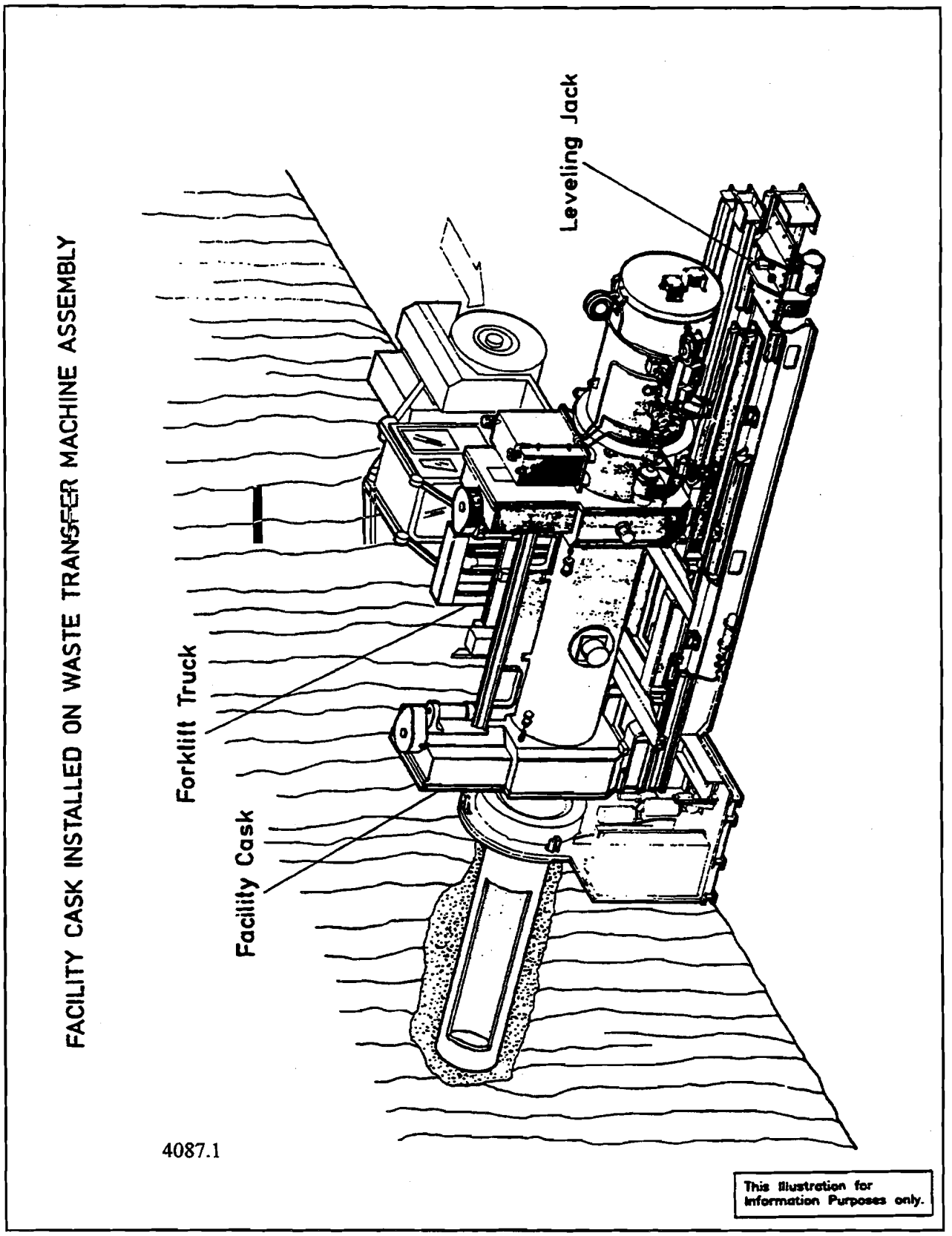

Figure 4.3-20, Facility Cask Installed on the Waste Transfer Machine Assembly

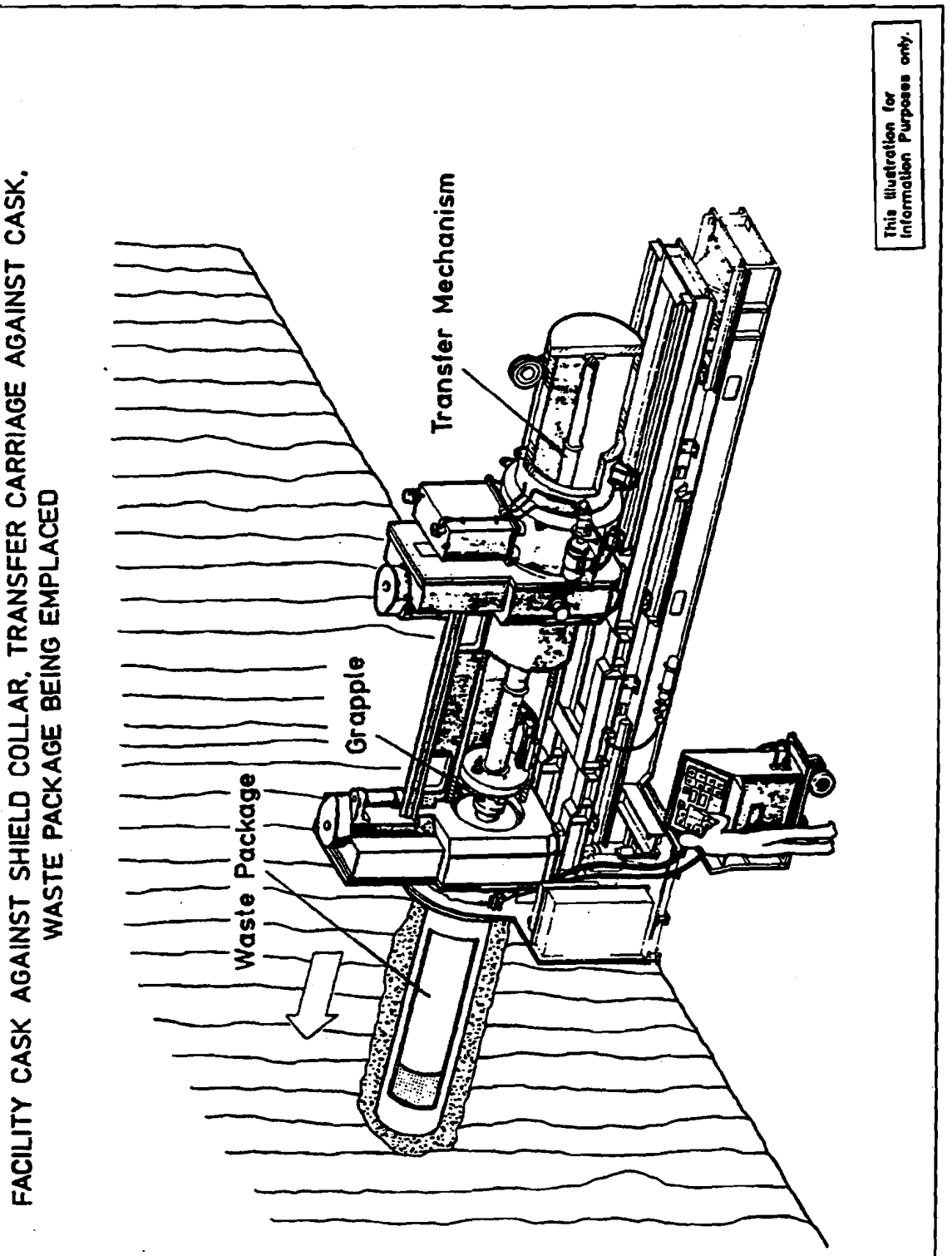

Figure 4.3-21, Waste Emplacement Equipment

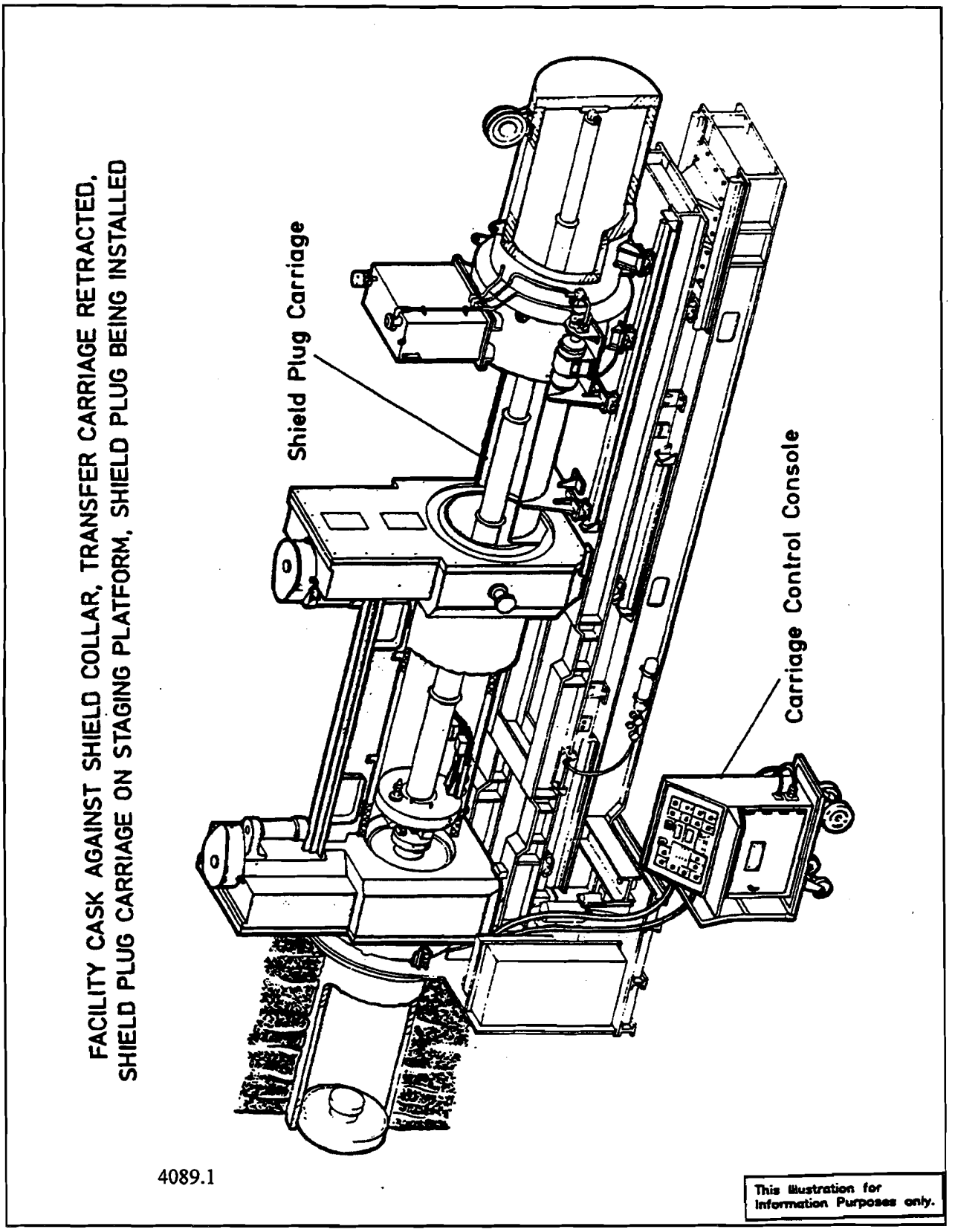

Figure 4.3-22, Installing Shield Plug

Table 4.3-1, CH TRU Waste Shipping Container

Overall Dimensions and Weights of the TRUPACT II	
Diameter,	8 ft
Height,	10 ft
Weight empty,	11,985 lb
Cargo capacity,	7,265 lb
Gross weight,	19,250 lb
No. of 55-gal drums per container Approximate Dimensions - 33¼ x 22½ dia inches Nominal Volume - 7.4 ft^3	14
No. of standard waste boxes per container Dimensions - 38 x 71 x 55 inches Nominal Volume - 64 ft^3	2

Note: The above dimensions and weights are based on the final design data of TRUPACT II.

Table 4.3-2, Average CH TRU Waste Vehicle, Container, and Drum Throughput

Vehicle	No. of TRUPACT II's Per Vehicle	Vehicles per day	TRUPACT II per day	Drums* per day	Vehicles per year	Volume per year ft^3
Truck Trailer	3	3.2	9.7	136	810	250,000

*Assumes 14 drums/TRUPACT II

Table 4.3-3, Waste Package Information

Package identification number
Package assembly identification number
Date of waste package certification
WAC exception number
Waste generation site
Date of package closure
Maximum surface dose rate, specific neutron dose rate if greater than 20 mrem/hr
Weight (in kg)
Container type
Physical description of waste form
Assay information, including radionuclide symbol, quantity, and measure
Radioactive mixed waste (identity and quantity of listed and characteristics of wastes)
Weight and volume of organic materials content
Measured or calculated thermal power (if over 0.1 watt/ft^3)
Shipment number
Date of shipment
Vehicle type
TRUPACT-II number(s) (CH-TRU waste), or number (RH-TRU)
Other information considered significant by the generator
Name of certifying official who approved the waste package
Name of person who certifies that the shipment meets the TRUPACT-II TRAMPAC

4.4 Confinement Systems

4.4.1 Confinement

The WIPP facility confinement system consists of static and dynamic barriers designed to meet the following requirements of DOE Order 6430.1A,[1] Section 1300-7:

- Minimize the spread of radioactive and other hazardous materials within the unoccupied process areas
- Prevent, if possible, or minimize the spread of radioactive and other hazardous materials to occupied areas
- Minimize the release of radioactive and other hazardous materials in facility effluents during normal operation and anticipated operational occurrences
- Limit the release of radioactive and other hazardous materials resulting from Design Basis Accidents (DBAs) including severe natural phenomena and man-made events in compliance with the guidelines contained in DOE Order 6430.1A,[1] Section 1300-1.4.2, Accidental Releases

Static barriers are structures that confine contamination by their physical presence and dynamic barriers control the flow of contamination in the air. For the WIPP, static barriers consist of waste containers, building structures, geological strata, and HEPA filtration systems, and the dynamic barriers consist of the surface and subsurface ventilation systems, that maintain pressure differentials ensuring airflow is from areas of lower to higher contamination potential.

In addition to the above general requirements, the WIPP is designed to meet the specific confinement requirements of DOE Order 6430.1A,[1] Section 1324-6 and Section 1300-1.4.

For the WIPP, the primary confinement is the static barrier consisting of the waste containers, and the secondary confinement consists of those SSCs designed to remain functional (following DBAs) to the extent that the guidelines in DOE Order 6430.1A,[1] Section 1300-1.4.2, Accidental Releases, are not violated. Based on the analyses in Chapter 5, no technical basis exists for secondary confinement at the WIPP. However, as part of the Defense-In-Depth concept, specific SSCs function as secondary confinement, which is further discussed in Chapter 5.

Consistent with DOE Order 6430.1A,[1] Section 1324-6, tertiary confinement is not required for the WIPP during disposal operations. Tertiary confinement will only be applicable during post-closure.

4.4.1.1 Waste Handling Building

Static and dynamic barriers are incorporated into the design of the WHB confinement system and the primary confinement is the drum or container holding the waste.

The secondary confinement consists of the SSCs that house the primary confinement including the shielded s, the TRUPACT shipping container, the rooms, the building walls, and the ventilation system, which maintains a static pressure differential between the primary confinement barriers and the environment. To assist the ventilation system, air locks are provided between separate areas where critical pressure differentials are necessary. The WHB HEPA filtration system connects with the ventilation systems and provides the final barrier for airborne particulates.

4.4.1.2 Underground

The primary confinement system for the underground is the drum or container being disposed in the underground. The secondary confinement consists of natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system with provisions for exhausting to the exhaust filtration system, when in use, to mitigate any accidental releases of contaminated airborne particulates.

4.4.2 Ventilation Systems

The WIPP facility air handling systems are designed to provide a suitable environment for personnel and equipment during plant operations and to provide contamination control for operational occurrences and postulated waste handling accidents. Certain components of the air handling systems are also used for functions related to space cooling and removal of heat.

The WIPP facility air handling systems serve three major plant areas: the surface facilities, the surface support facilities, and the subsurface facilities.

The air handling systems are designed to meet the emissions limitations in DOE Order 5400.5[2] using the following general guidelines:

- Transfer and leakage air flow is from areas of lower to areas of higher potential for contamination.
- In building areas that have a potential for contamination, a negative pressure is maintained to minimize the spread of contaminants.
- Consideration is given to the temporary disruption of normal air flow patterns due to scheduled and unscheduled maintenance operations by providing dual trains of supply and exhaust equipment. Air handling systems are provided with features to reestablish designed airflow patterns in the event of a temporary disruption. Generally, ducts that carry potentially contaminated air are routed away from occupied areas. In addition, potentially contaminated ducts are welded to the maximum extent practical to reduce system leakage.

The filtration system consists of prefilters and HEPA filters sized in accordance with design airflows utilizing the manufacturer's rating standards for maximum efficiency.

Dampers are described as flow control, balancing, shutoff, or back-draft and are classified by function, configuration, construction, and leak tightness in accordance with Tables 5.7 through 5.10 of ERDA 76-21[3] as appropriate for their designated application. Damper selection is based on the requirements of ERDA 76-21,[3] Table 5.12.

HVAC components are sized so that some components can be taken out of service for maintenance, allowing the system to continue operation. The schematic flow diagrams of the ventilation systems are shown in Figures 4.4-1 through 4.4-5.

4.4.2.1 Surface Ventilation Systems in Controlled Areas

There are independent ventilation systems for each of the following areas:

- Waste shaft hoist maintenance room
- CH waste handling area
- RH waste handling area
- WHB mechanical equipment room
- Waste handling shaft hoist tower
- Exhaust filter building

The waste shaft hoist maintenance room is outside the CA and the ventilation system that serves this area is not expected to contain radioactivity. The ventilation systems for the WHB and Exhaust Filter Building are "once through" systems designed to provide dynamic confinement barriers limiting the potential for releases of airborne radioactive contaminants to levels ALARA, consistent with the requirements of 10 CFR 835[4] and DOE Order 5400.5.[2] The ventilation systems are also designed to provide the necessary heating, ventilating, and air conditioning for personnel comfort and to remove heat.

The WHB ventilation system continuously filters the exhaust air from waste handling areas to reduce the potential for release of radioactive effluents to the environment. Approximately 8,000 cfm of air from the waste handling areas can flow down the waste shaft as part of the underground ventilation system.

The design provides for differentials to be maintained between building interior zones and the outside environment maintaining control of contaminated air. The pressure differentials between different interior potential for contamination areas are based on the design contamination zone designations with respect to function and permitted occupancy. ERDA 76-21[3] is used as a guide in establishing zone differential pressures.

The ventilation systems supply 100 percent outside air conditioned to provide a suitable environment for equipment and personnel. The minimum room air changes vary from 1.5 to 12 air changes an hour. Design air quantities are based on limiting the concentration of airborne radioactive contaminants and maintaining design temperatures.

Sufficient exhaust capacity and appropriate controls in the hot cell and canister transfer cell of the WHB maintain an average velocity of at least 125 linear ft/min, through maximum credible openings to capture potential airborne contaminants. The exhaust rate for chemical hoods is sufficient to maintain an average velocity of 150 ft/min across the hood.

The design provides for air locks in the following circumstances:

- At entrances to potentially contaminated areas to maintain a static barrier
- Between areas of large pressure differences to provide a pressure transition and to eliminate high air velocity, dust entrainment, and eddy currents
- Between areas where critical pressure differentials must be maintained

- To minimize air movement from the WHB to the waste shaft

The ventilation systems are designed to provide adequate instrumentation monitoring the critical operating parameters. The following parameters are monitored:

- Pressure drop across each prefilter and HEPA filter bank
- Airflow rates at selected critical points, e.g.,downstream of the filters
- Critical pressure differentials surrounding areas of high potential for contamination levels
- The radioactive material concentrations in the effluent released through the exhaust vent

Fresh air supply intakes are located away from the exhaust vent to minimize the potential for the intake and recirculation of exhaust.

The operation of the supply and exhaust fans is controlled by electrical motor interlocks to maintain the preferred air flow patterns and sufficient air leakage into the building. The exhaust fans and controls are capable of being supplied by backup power in the event that normal power is interrupted.

4.4.2.1.1 CH and RH TRU Waste Handling Area

The CH and RH TRU waste handling areas are served by separate independent ventilation systems shown on schematic flow diagrams, Figures 4.4-1 through 4.4-3.

The supply systems are Design Class IIIB, and the exhaust systems are Design Class IIIA, with the exception of HEPA filter units and associated isolation dampers, which are Design Class II.

Fan operating status, filter bank pressure drops, airborne radioactivity levels, and static pressure differentials in areas essential to waste handling will be monitored in the Central Monitoring Room (CMR). Excess filter pressure drops and low flows alarm in the CMR. Local readouts give flow rates and pressure differentials.

The radiation monitoring system at station C, as discussed in Chapter 7, has provisions for monitoring the effluent air discharged from the exhaust vent.

In the CH TRU waste handling area, the design of the battery charging area exhaust system limits the buildup of hydrogen to less than 4 percent as a result of battery recharging operations and the charging area has a separate exhaust system with prefilters and HEPA filters. The ventilation system is designed with two 100 percent capacity exhaust fans each able to remove air from high points in the forklift battery recharging area at a rate sufficient to maintain hydrogen concentration below the lower explosive limits.

In the RH TRU waste handling area, particular design consideration is given to inhibit the potential for spreading airborne radioactive particles from the hot cell. The supply air to the hot cell room is cascaded from the surrounding RH waste handling area and exhaust air from the hot cell passes through independent prefilters and HEPA filters before being discharged to the atmosphere via the exhaust vent. Sufficient exhaust capacity is provided to maintain the design pressure differential between the hot cell and the surroundings or to maintain at least 125 linear ft/min inward flow through the maximum credible breach, minimizing the potential for contaminants to escape.

The supply air to the hot cell is provided using an air handling unit and a cooling coil to condition the supply air drawn in from the RH receiving area.

The waste shaft is separated from the RH waste handling area by an air lock minimizing the air movement between the RH waste handling areas and the shaft.

Major Components and Operating Characteristics - The ventilation supply and exhaust systems for each building subsystem continuously supplies air to the rooms of the areas served. Each supply air handling unit consists of filters, cooling coils, heating elements, fans with associated duct work, and controls to condition the supply air maintaining the desired temperature during winter and summer. Exhaust air is filtered and monitored by the radiation monitoring system.

Each exhaust subsystem provides a filtered air exhaust path consisting of one stage of prefilters, two stages of HEPA filters, and two 100 percent capacity exhaust fans that discharge air through the building vent, which is continuously monitored for airborne radioactivity.

Safety Considerations and Controls - The exhaust system remains functional to the extent that confinement and differential pressures are maintained, exhaust air is filtered, and during a tornado excessive flow that could cause duct damage is prevented by tornado dampers.

In case of an off-site power failure, the capability exists to selectively switch one exhaust fan to the backup power system in order to continue to exhaust air in the preferred flow pattern. The WIPP Facility Normal Operations Manual[5] provides procedures for applying backup power to the exhaust fans.

The supply and exhaust fans are designed and interlocked to maintain building pressure sub-atmospheric and maintain the preferred airflow pattern. During normal operation, if one of the two exhaust fans fails on subsystems other than the CH TRU area, the corresponding supply fan is stopped in order to prevent positive building pressure. If the operating CH area exhaust fans fail, the corresponding supply fan stops and the standby train is started manually.

Sufficient remote instrumentation is provided enabling the operator to monitor equipment from the CMR. The monitored parameters include fan operating status, filter bank pressure drop, level of radioactivity in the exhaust, and static pressure differential in the critical areas of the hot cell, the overpack and repair room, and the preparation station. Fan failure and excessive radiation levels are annunciated and low flow conditions of the main exhaust fans produces an alarm in the CMR.

Filter differential pressure is displayed locally as well as in the CMR and an alarm for a pressure drop indicating filter replacement is needed actuates at 1 inch water gage (w.g.) across the prefilters and 2.5 inches w.g. across the HEPA filters.

Instruments and system components are accessible for, and will be subject to, periodic testing and inspection during normal plant operation.

For those HEPA filters which are on-line continuously in the WHB, the CMS continuously monitors prefilter pressure differential (D/P) and HEPA (D/P) ensuring satisfactory system operation. The Exhaust Filter Building HEPA filters are normally off-line, and not subject to dust buildup during normal operation. All HEPA filters are tested for conformance with ANSI N510.[6]

4.4.2.1.2 Mechanical Equipment Room

The mechanical equipment room is maintained at a pressure slightly below atmospheric to minimize leakage of room air, which may contain airborne radioactive contaminants. Negative pressure is maintained by the same exhaust fan systems that exhaust air from the CH TRU and RH waste handling areas. This equipment room is maintained within acceptable temperature limits by air handling units similar to those for the CH bay.

4.4.2.1.3 Waste Handling Shaft Hoist Tower

The ventilation system provides for the filtration of supply air, unit heaters to prevent equipment from freezing, and a unit cooler to provide supplementary cooling of equipment in summer. Exhaust airflow is down through the tower and into the waste shaft, where it combines with incoming air from the waste shaft auxiliary air intake tunnel (Figure 4.4-3).

A pressurization system serves the air lock to the crane maintenance room at 142 ft 1 in elevation and pressurizes the air lock preventing the release of potentially contaminated air from the crane maintenance room to the 142 ft 1 in elevation access corridor.

4.4.2.1.4 Exhaust Filter Building

A schematic flow diagram of the Exhaust Filter Building ventilation system is shown in Figure 4.4-4, and this building supports the operation of the underground ventilation system and contains the underground ventilation system filters.

The function of the ventilation system in the Exhaust Filter Building, major components, operating characteristics, safety considerations, and controls, are similar to the CH TRU waste handling area in the WHB.

Each supply air handling unit in the Exhaust Filter Building consists of prefilters, an electric heating coil, and a fan to condition the air as required to maintain the desired temperature.

The Exhaust Filter Building ventilation system exhausts air from all potentially contaminated areas of the building through two filter housings, each containing a bank of prefilters and two stages of HEPA filters, and two exhaust fans before discharging to the atmosphere. The building's exhaust air is discharged to the underground exhaust duct so that it can be continuously monitored for airborne radioactive contaminants.

4.4.2.2 Surface Support Structures Ventilation System

The following surface support facilities are served by separate heating, ventilation, and air-conditioning systems:

- The Support Building including:
  - Central monitoring room (CMR)
  - Administration area
  - Underground personnel area
  - Laboratory areas
  - Locker room area
- Main Warehouse/Shops Building
- Water Pump House
- Guard and Security Building
- Maintenance Shop

- Compressor Building
- Safety and Emergency Services Building
- Engineering Building
- Training Building

The design of the surface support facilities HVAC systems provides for:

- Regulating temperature for the comfort of personnel and satisfactory operation of equipment
- Filtering the air supply for personnel
- Maintaining building spaces at slightly positive pressures with respect to the outside, except radioactive materials areas, where negative pressures shall be maintained relative to the outside and to adjacent accessible nonradioactive building spaces
- Confining ventilation air to preferred airflow paths for discharge to the atmosphere
- Minimizing the possibility of exhaust air recirculation by an adequate distance between fresh air supply intakes and exhaust air outlets

The design of the ventilation system for the CMR requires functions to be performed with respect to environmental control for personnel and equipment following a postulated accident, such as a fire or accidental radioactivity release. The CMR system is manually switched to the backup power supply to ensure operation monitoring and control of the HVAC systems if the normal power supply is lost.

In addition, the independent CMR HVAC system provides for:

- 100 percent equipment redundancy in the HVAC system (except ductwork)
- Make-up air being processed through HEPA filters in the event of a high airborne radioactivity signal
- Controls to regulate the amount of outside air that may be drawn into the system through the HEPA filters before it is supplied to the CMR permitting continuous occupancy

Safety Considerations and Controls - The HVAC systems for these surface support facilities, with the exception of the CMR, are not required to perform functions that are essential to safety. Fan motor interlocks, dampers, temperature indicators, filter pressure differential alarms, and other required instrumentation and controls are provided.

CMR

The Support Building CMR area HVAC system serves the computer room, CMR and associated vestibule, vault, office, and storage room. This HVAC system also supplies the radiation calibration room. Equipment redundancy is provided for the following: supply air handler, air cooled condensing unit, and exhaust fan.

The HVAC system provides a suitable environment for continual personnel occupancy, and equipment integrity under normal and emergency conditions and maintain a slightly positive pressure in the CMR. Air passes through at least a two-stage filtration system before it enters the above listed areas.

A HEPA filter and pressurizing fan system upstream of the supply units, bypassed during normal operation, may be automatically activated upon the detection of airborne radioactivity levels above the sensor set point at Stations B or C.

Major Components and Operating Characteristics - Major components of this HVAC system consist of supply air handling units (containing fans, direct expansion cooling coils, and filters), air cooled condensing units, humidifiers, duct heaters, exhaust-return fans, booster fans, HEPA filter units, dampers, instrumentation, and controls.

The schematic airflow diagram for the CMR area HVAC system is shown in Figure 4.4-5.

The CMR area is served by two 100 percent capacity air-conditioning units. One in service and one in standby status, available for automatic start in the event the operating unit fails.

Under normal operating conditions (recirculation mode), outside makeup air and return air are filtered by a two-stage air filter system. The first stage of filtration consists of nominal 2-inch thick low efficiency filters and the second stage consists of high efficiency filters rated at 85 percent efficiency (atmospheric dust) by ASHRAE Standard 52-76.[7] After the second stage of filtration, the air supply temperatures are thermostatically controlled, as necessary to maintain desired temperatures. The filtered and conditioned air supply is distributed to the various rooms within the CMR area by means of ductwork and air outlets.

Safety Considerations and Controls - The main function of the HVAC system is to provide a suitable environment enabling the CMR area to be occupied under normal and emergency operating conditions including the prevention of airborne radioactive contaminants entering the supply systems.

A backup air conditioning system (air handler, air cooled condensing unit, and exhaust fan) is available to automatically start in the event an operating component fails. The supply and exhaust air handling systems are capable of being manually connected to the backup power system for operation during a loss of off-site power.

Locally-mounted instruments are provided for monitoring the HVAC system and filter pressure drop is monitored and alarmed, locally and in the CMR.

The supply and return exhaust blowers are electrically interlocked, to maintain the preferred airflow pattern, and the entire HVAC system is interlocked with the fire protection system.

4.4.2.3 Subsurface Facilities Ventilation System

The subsurface ventilation system serves all underground facilities and provides confinement of radioactivity, acceptable working conditions, and a life-sustaining environment during normal operational occurrences and postulated waste handling accidents. Operation of diesel equipment in the underground repository is limited to the available airflow in the area.

Subsurface ventilation is divided into four independent flow paths on the disposal horizon supporting the waste disposal area, the mining area, the experimental and underground shop areas, and the waste shaft and waste shaft station area. The waste disposal, mining and experimental areas receive their air supply from common sources (the AIS and the SH shaft) and are independent of each other after the initial distribution/split is made. The waste shaft station receives its air supply from the waste shaft and is kept completely isolated from the other three. All four air circuits combine near the exhaust shaft which acts as the common discharge from the system.

All bulkheads and ventilation controllers used to maintain the independence of the underground ventilation circuits are made of fire resistant material and can support the maximum pressure differential that could occur under normal operating conditions. These structures are designed, installed and maintained in such a manner that they can accommodate the ground deformation (salt creep) occurring in the underground.

Three low volume surface exhaust fans are capable of being connected to the backup power supply in the event that normal power is lost. Changeover to backup power on one or more fans is manual. The ventilation system is instrumented to provide for continuous verification of proper system function and for sampling radioactive particulate concentration.

The design and operation of the underground ventilation system meets or exceeds the criteria specified by 30 CFR 57[8] and the New Mexico Mine Safety Code for All Mines.[9]

The exhaust air is discharged through the exhaust shaft by the exhaust system under the following modes of operation:

Normal Mode - During normal operation, the main surface exhaust fans allow continuous discharge of unfiltered air to the outside atmosphere.

Filtration Mode - This mode mitigates the consequences of a waste handling accident by providing a HEPA filtered air exhaust path from the waste disposal areas and also reducing the air flow. Manual activation is required if the CMR is notified of an underground occurrence involving the waste packages. This mode may also be activated automatically by the radiation monitoring instruments.

Fire Isolation Mode (Air Reversal Mode) - An underground fire or an emergency may necessitate air reversal in the affected area(s). This reversal can be achieved through the control of pertinent ventilation devices, including bulkheads/doors, regulators, and fans. The air reversal capability is provided for all areas underground except the waste handling and waste disposal areas, thereby preventing the possible spread of radioactive contamination to the other parts of the underground structure.

The ventilation system is designed as an exhausting system that maintains the working environment below atmospheric pressure. Schematic diagrams of the underground ventilation system are presented in Figures 4.4-6 and 4.4-7.

Provisions are included for detecting airborne radioactive contaminants in the waste disposal areas, in the waste shaft and station, and in the discharge to the surface exhaust vent. The monitors used, their locations, and the expected radioactive releases to the atmosphere are discussed in Chapter 7.

Major Components and Operating Characteristics - The ventilation system consists of five centrifugal exhaust fans arranged in parallel, two identical HEPA filter assemblies arranged in parallel, isolation and back draft dampers, filter bypass arrangement, and associated ductwork. Operation of the underground ventilation system is detailed in the WIPP Facility Normal Operations Manual.[5]

The five fans are divided into two groups. One group consists of two fans which are used during normal operation to provide a underground flow of 425,000 CFM and are located near the exhaust shaft. The remaining three fans, rated at 60,000 CFM each, are located at the Exhaust Filter Building, and are capable of being used during the filtered mode of operation. This mode of operation requires the use of only one of the three fans at any given time with all other fans stopped and isolated. Two of the three filter mode fans can also be operated (with the HEPA system bypassed) to provide other underground ventilation requirements, when needed.

Each filter assembly consists of two banks of prefilters and two banks of HEPA filters arranged in series and each assembly will handle 50 percent of the filtered mode airflow (30,000 CFM each).

The ventilation path for the waste disposal side is separated from the mining side by means of air locks, bulkheads, and salt pillars. A pressure difference is maintained between the mining side and the waste disposal side (mining side being higher) to assure that any leakage is towards the disposal side. The pressure differential between the mining and disposal sides is produced by the surface fans in conjunction with air regulators underground. Pressure differentials across these bulkheads between the mining and disposal sides (located nearer to the disposal panel) are continuously monitored from the CMR.

Outside air is supplied to the mining areas, the waste disposal areas, and the experimental complex via the AIS, the SH shaft and access entries. A small quantity of outside air flows down the waste shaft to ventilate the waste shaft station. Fan failures alarm in the CMR and are monitored by a flow sensing device at the discharge side.

The ventilation system is designed to operate with the AIS as the primary source of fresh air providing sufficient air to conduct all underground operations (waste handling, mining, experimentation, and support) simultaneously.

Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the CMR operator, or automatically due to a CAM alarm logic sequence. The reduced exhaust flow is diverted to the HEPA filters by isolation and diversion dampers on the exhaust fans and duct work preventing unfiltered flow escaping to the atmosphere.

Any one of the three Exhaust Filter Building fans is capable of delivering 100 percent of the design flow rate with all filters at their maximum pressure drop. Fan failure is monitored by a flow sensing device on the fan's discharge side and alarms in the CMR.

The system provides air reversal modes in the mining area, experimental area, the AIS and station, and the SH shaft and station. In these modes, the air is reversed by opening and closing certain ventilation doors and air regulators and by operating the underground booster fans in either forward or reverse direction. The surface exhaust fans will be stopped prior to attempting any air reversals underground. The AIS and SH Shaft may each, be isolated by control doors on either side of the shaft during abnormal operation.

Safety Considerations and Controls - The operating status of the exhaust fans and the airborne contamination level of the effluent discharged are displayed in the CMR.

An alarm for excessive pressure drop across the filters is actuated at 1 inch w.g. across the prefilters and 3 inches w.g. across the HEPA filters. Filter differential pressure is displayed locally and in the CMR.

Instruments and system components are accessible for periodic testing and inspection during normal plant operation. Under normal operating conditions, the ventilation system functions continuously.

4.4.2.3.1 Natural Ventilation Pressure

The air flow in the underground is normally driven by the negative pressure induced by the exhaust fans. There can be a second pressure resulting from the difference in density between the air entering and leaving the repository which can influence airflow. This phenomenon is called the natural ventilation pressure (NVP). It is experienced on days when outside temperatures are either very hot or very cold.

Hot Weather NVP - During hot weather, the air going down to the underground is warmer and less dense (lighter) than the air returning from the underground. This lighter air has a natural tendency to resist being drawn down into the repository (hot air rises). Hence in hot weather there is a (negative) NVP which opposes the fan pressure. This reduces the flow down the AIS and SH shaft. It also reduces the differential pressures between the waste shaft station, waste storage area and the other areas. The air in the waste shaft will be cooler than that in the AIS and SH shaft, which further reduces the waste shaft station to W30 differential pressure. (See Figure 4.1-3 for U/G locations).

Under ordinary operating conditions, the pressure in W30 is higher (less negative) than that in the waste shaft station (S400). On very hot days (exceeding 100 degrees F) the reduction of this differential pressure caused by the negative NVP can result in the pressure in S400 being higher than in W30. Without corrective actions, this would allow airflow from the CA area into a non-CA area.

A pressure chamber has been constructed on the west side of the waste shaft station to ensure that leakage from the CA side into the non-CA area does not occur. The pressure chamber is manually activated when ever waste handling is occurring in the waste shaft or waste shaft station and outside temperatures are hot enough to anticipate a negative NVP. The chamber is pressurized by small fans mounted on the W30 side. The fans are operated in various combinations to provide the airflow necessary to maintain the pressure buffer. The pressure inside the chamber (2.0 in. w.g +/- 10%) is monitored to ensure that it is sufficient to prevent airflow reversal even if the differential pressure from S400 to W30 (which is also monitored) is in the wrong direction.

Cold Weather NVP - During cold weather, the air going down to the underground is colder and denser (heavier) than the air returning from the underground. This denser air has a natural tendency to sink down the AIS and SH shaft (cold air sinks). In cold weather there is a positive NVP which augments the fan pressure. This increases the airflow down the intake shafts, reduces the fan suction pressure (constant flow control) and increases the differential pressure between the waste shaft station, waste storage area and the other areas.

The WIPP mine ventilation system is designed for intake air to downcast in the AIS, SH shaft and waste shaft. The system pressure required to induce those down drafts is supplied by the surface fans. On extreme cold weather days, a portion of the air entering the repository through the AIS and SH shaft may be the result of a positive NVP. This air is entering the repository <u>without</u> the aid of the mechanical fans. The fans in turn reduce their operating pressure because they are receiving a sufficient and constant volume of air.

The air feeding the waste shaft comes partly from leakage from the auxiliary air intake tunnel, partly from leakage into the waste hoist tower, and partly from the Waste Handling Building. The result is that the air feeding the waste shaft tend to be warmer than the surface air feeding the AIS. The reduction in fan pressure, coupled with the warmer air in the waste shaft is only under alternate, reduced, and minimum ventilation modes.

Administrative action is required to adjust the underground ventilation configuration to avoid reverse flow in the waste shaft. There are several alternatives which can be performed concurrently to prevent or correct this problem should it occur. They include:

- Start second main exhaust fan (normal ventilation mode)
- Open the regulator to the waste shaft station
- Cover the AIS and/or the SH shaft on the surface
- Close the regulators to the mining, waste storage and experimental areas

References for Section 4.4

1. DOE Order 6430.1A, General Design Criteria, April 1989.

2. DOE Order 5400.5, Radiation Protection of the Public and the Environment, June 1990. (Latest is Chapter 2, January 7, 1993)

3. Energy Research and Development Administration, 76-21.

4. 10 CFR 835, Occupational Radiation Protection, December 14, 1993.

5. WP 04-NO, WIPP Facility Operations Normal Operations Procedures Manual.

6. ANSI N510, American National Standards Institute, Standard for Testing of Nuclear Air Cleaning Systems.

7. ASHRAE, Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter, 52-76.

8. 30 CFR 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, 8th edition, 1994.

9. New Mexico Mine Safety Code for All Mines, 1990.

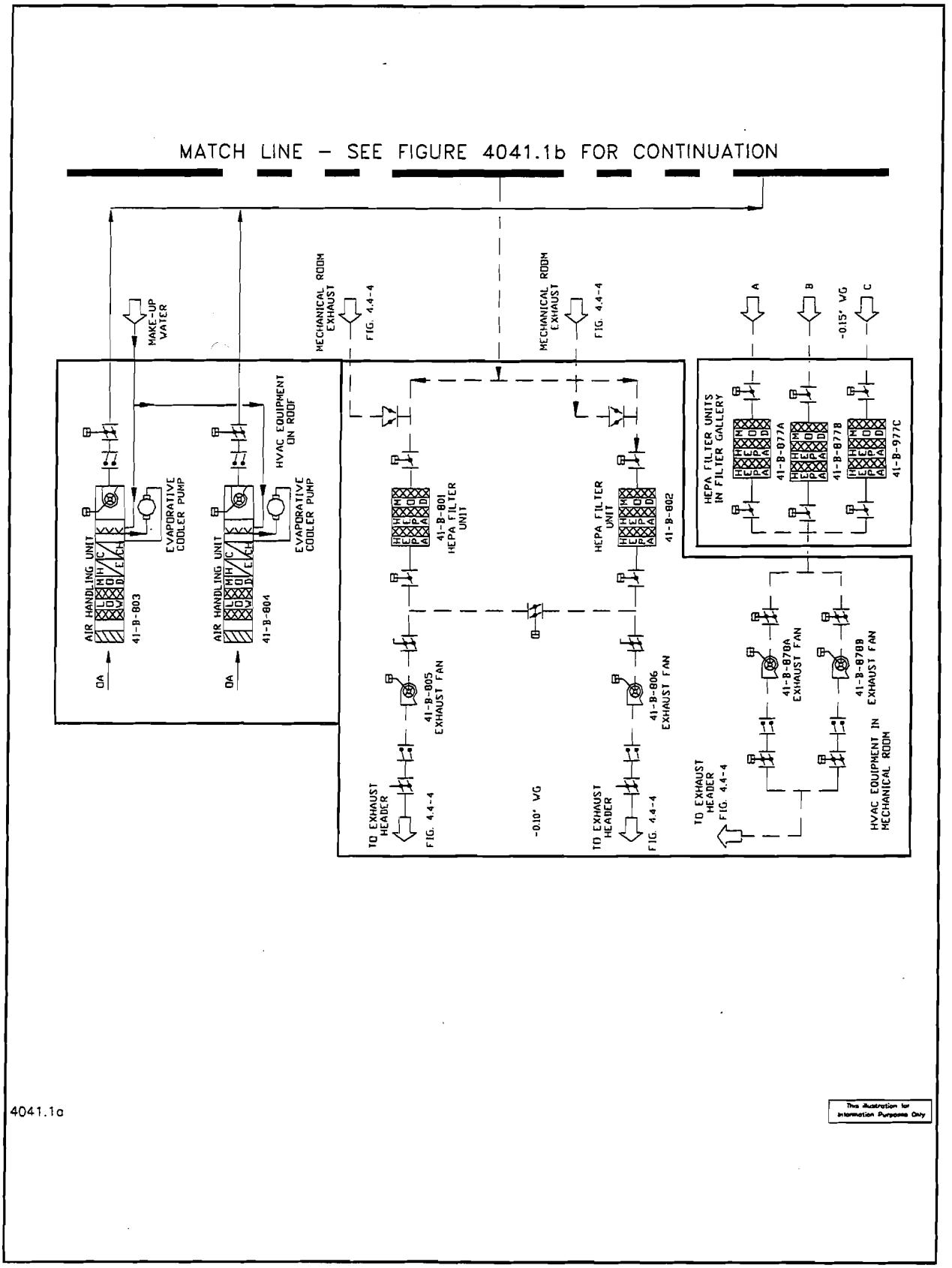

Figure 4.4-1a, WHB and TRUPACT Maintenance Facility

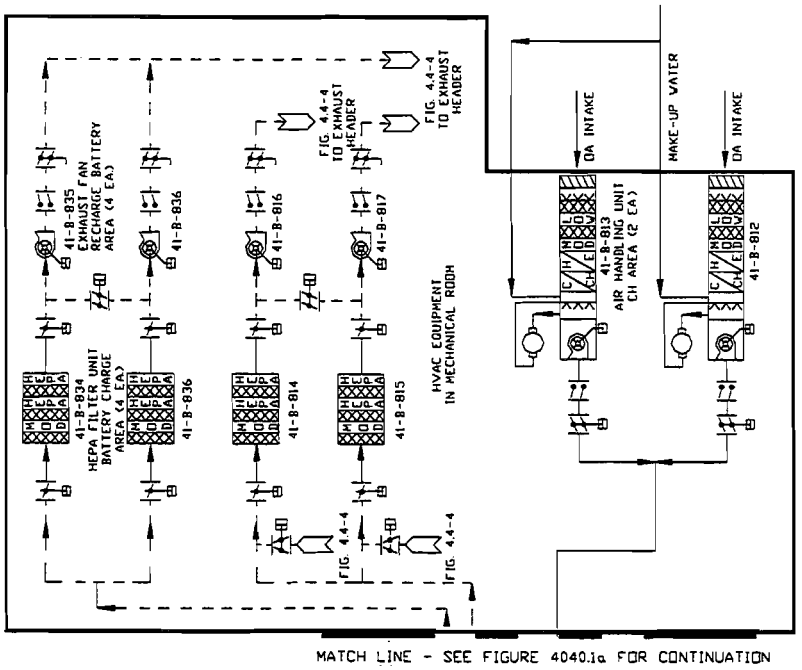

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Figure 4.4-1b, WHB and TRUPACT Maintenance Facility

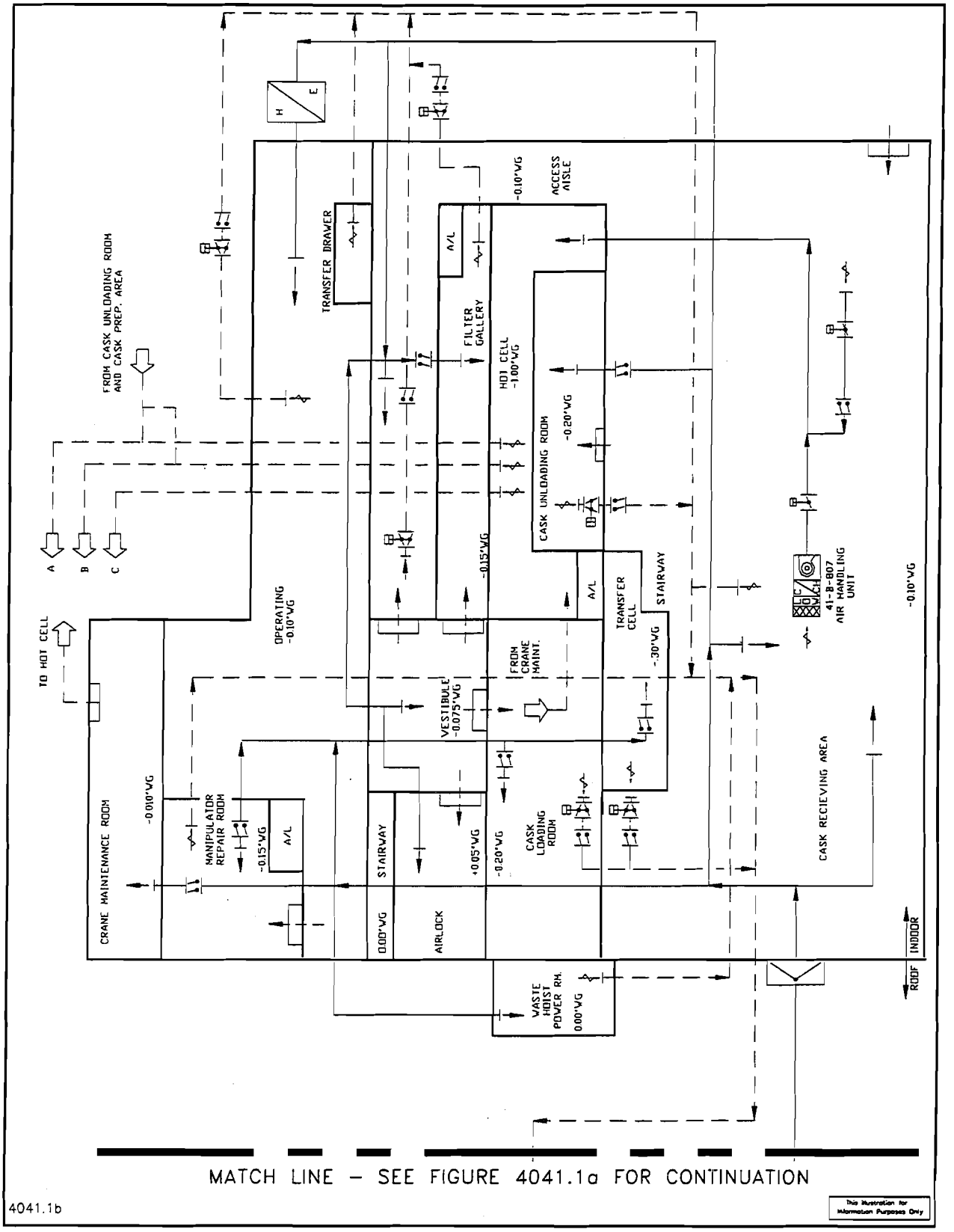


Figure 4.4-2a, WHB RH Handling HVAC Flow Diagram

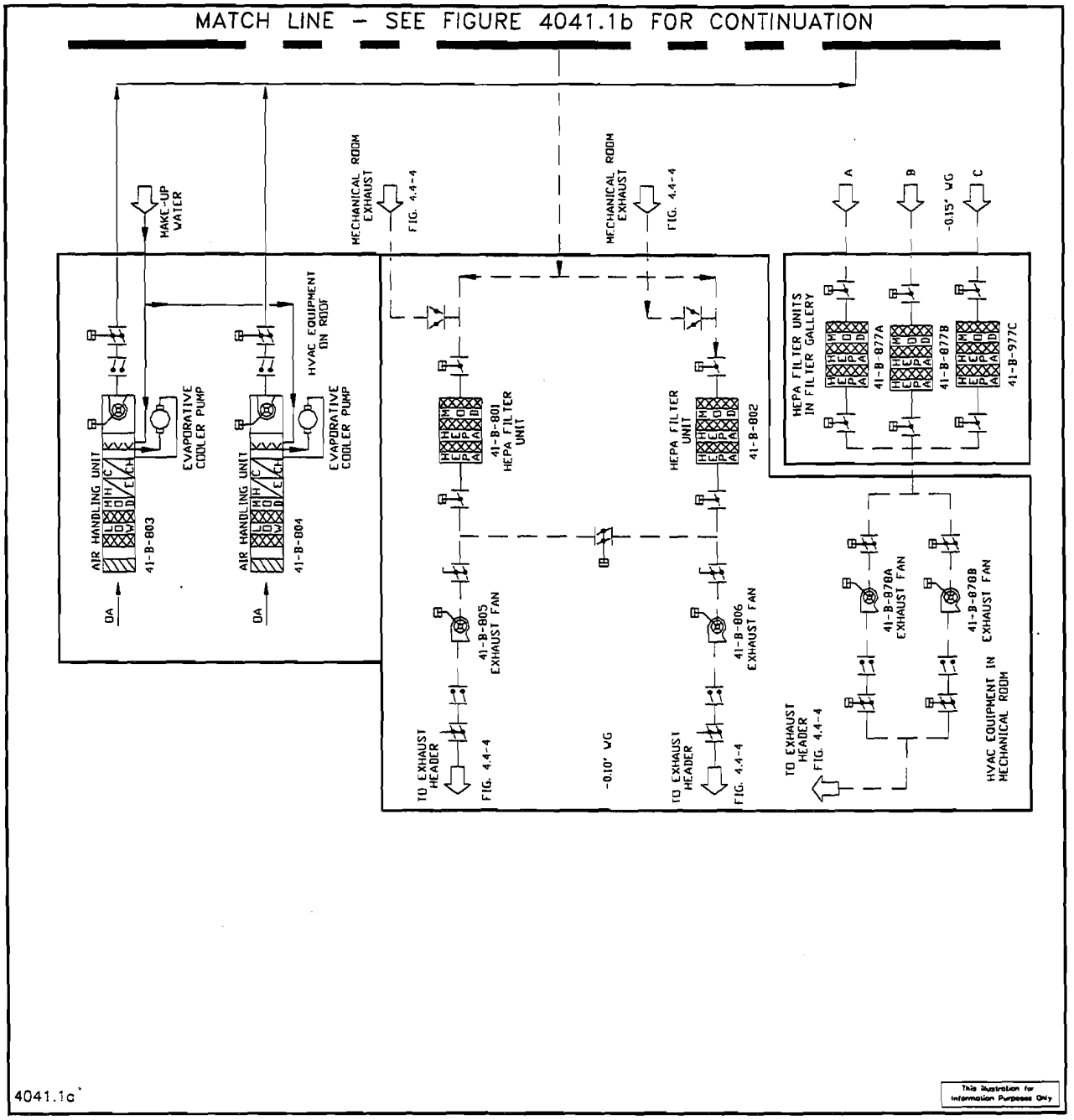


Figure 4.4-2b, WHB RH Handling HVAC Flow Diagram

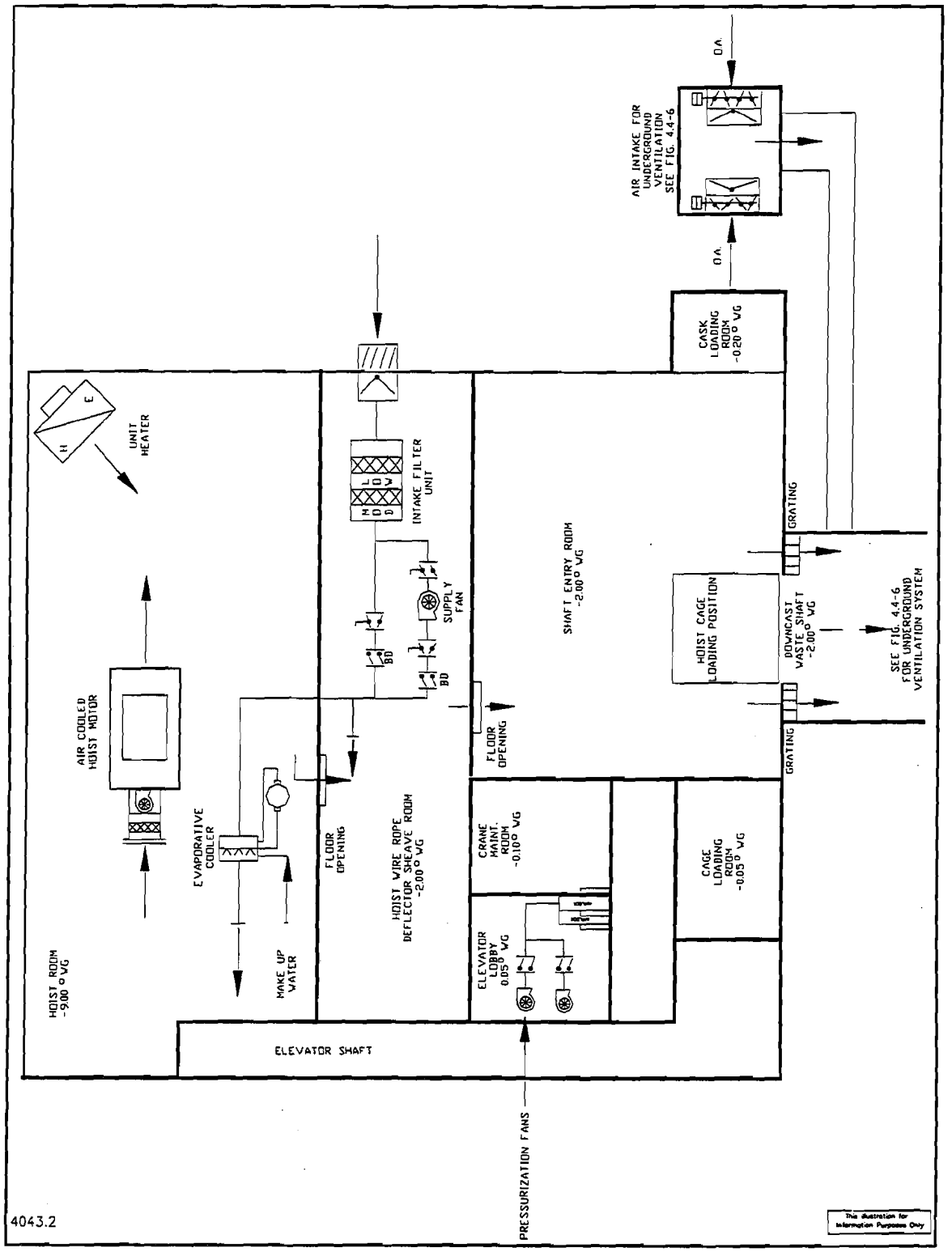


Figure 4.4-3, Waste Handling Shaft/Hoist Tower HVAC System Flow Diagram

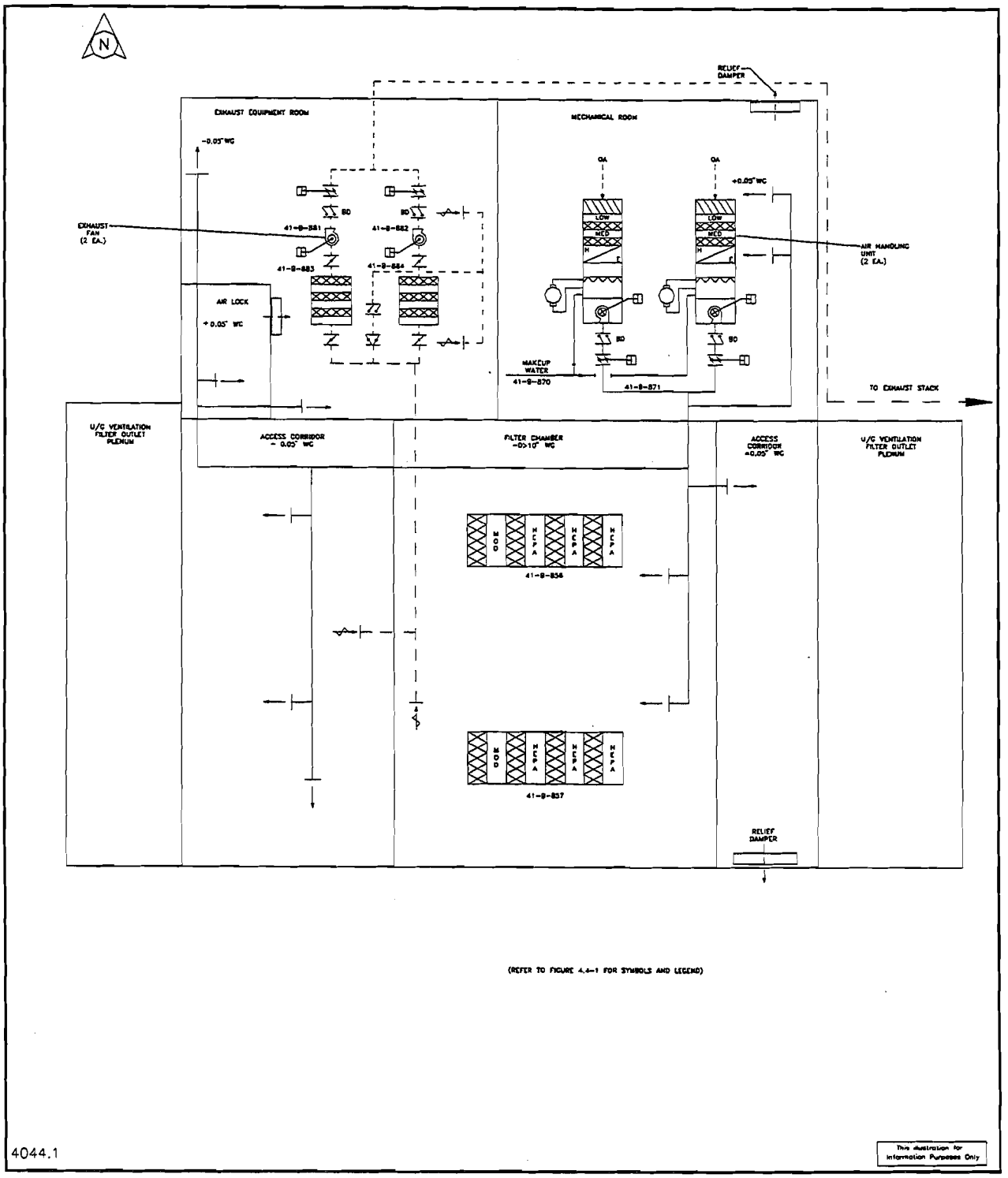


Figure 4.4-4, Exhaust Filter Building HVAC Flow Diagram

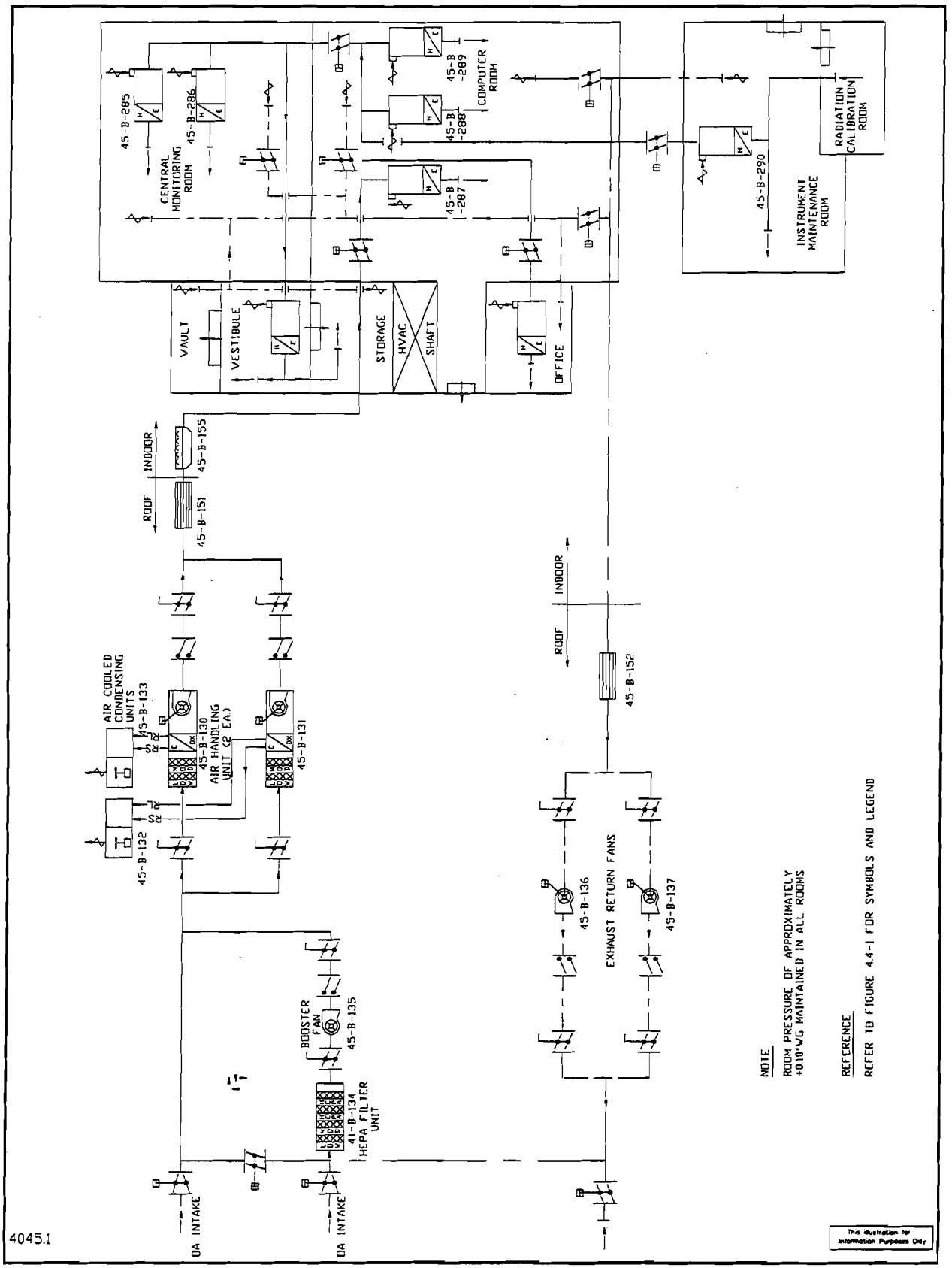


Figure 4.4-5, Support Building CMR Area HVAC Flow Diagram

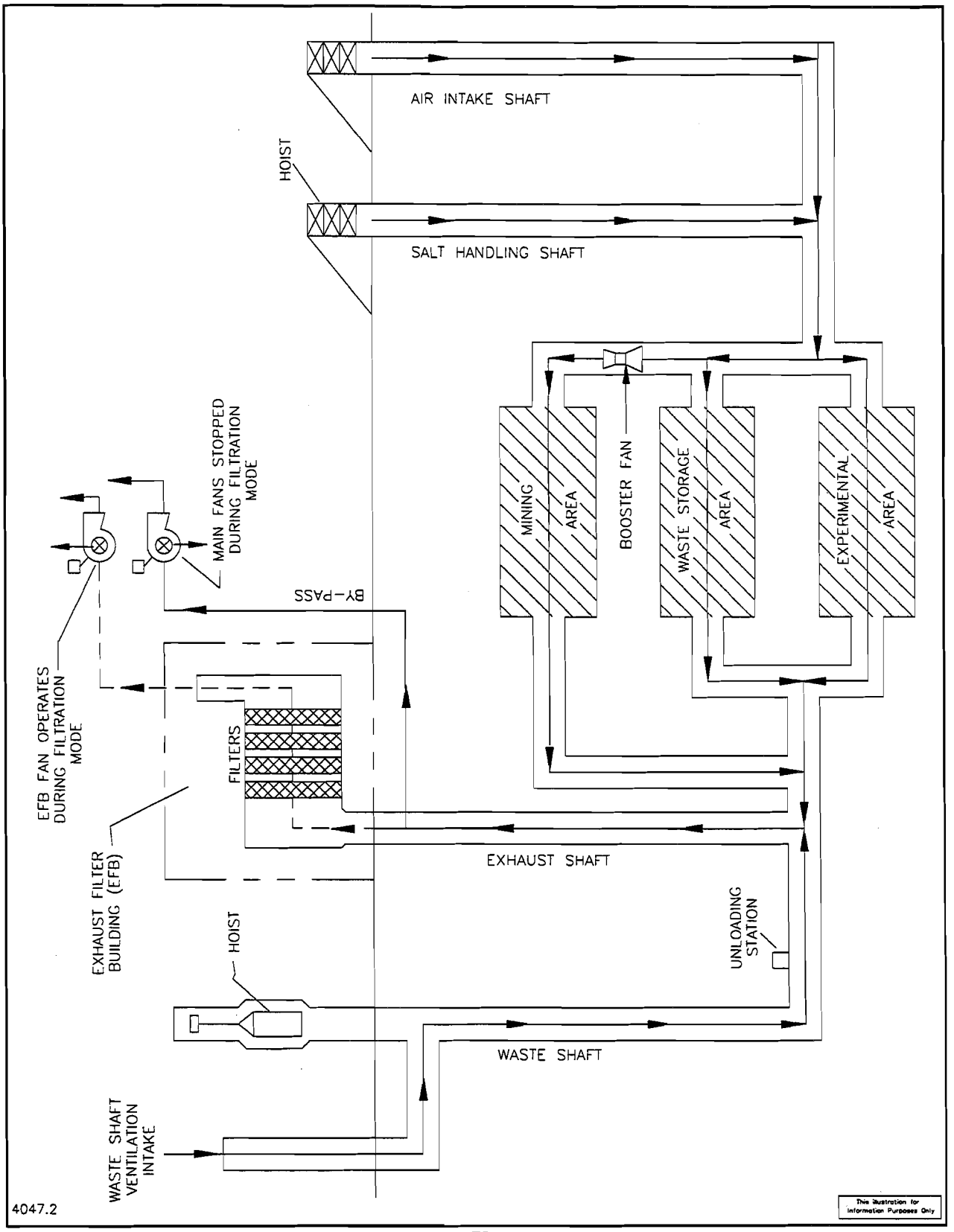


Figure 4.4-6, Underground Ventilation Air Flow Diagram

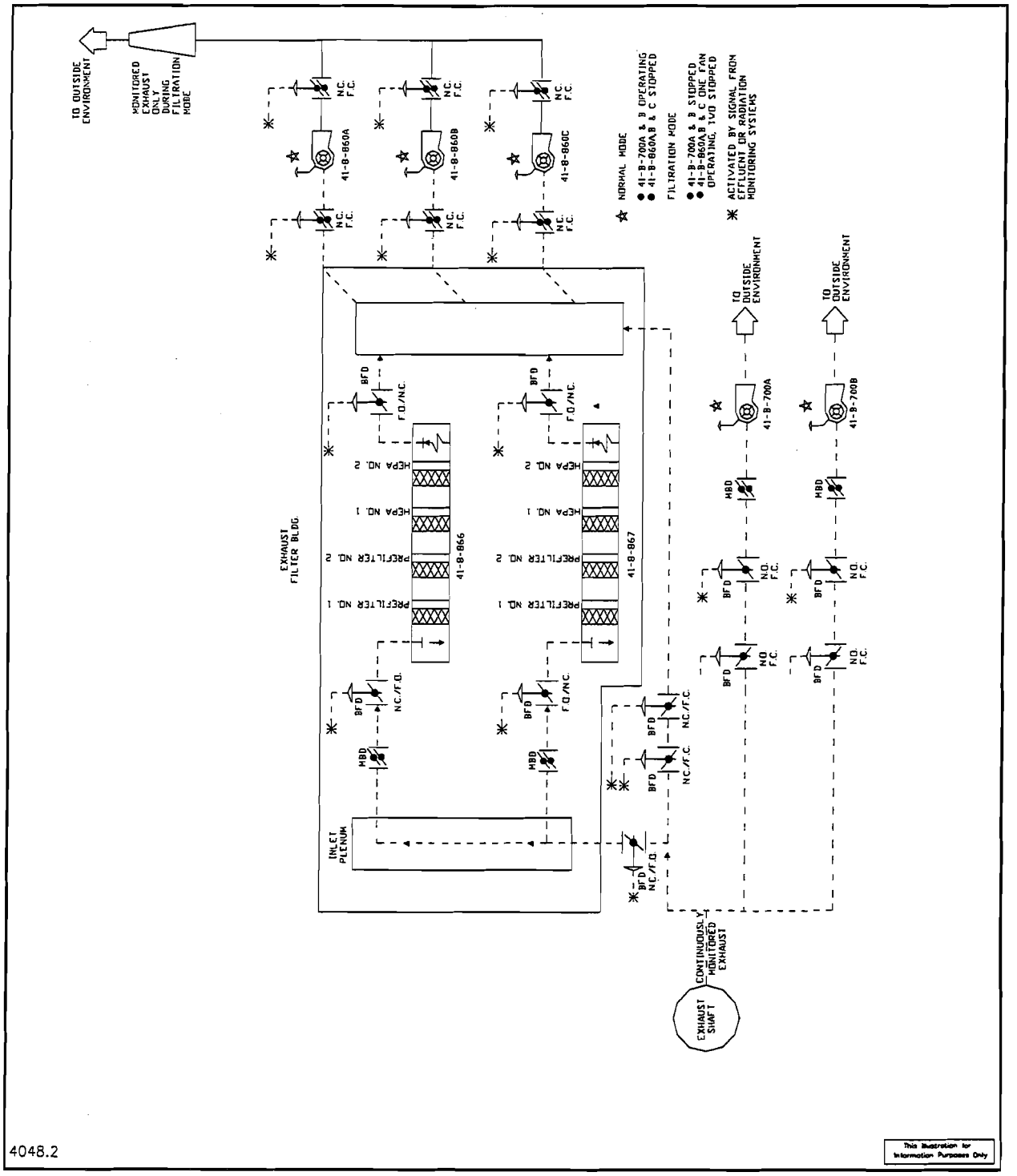


Figure 4.4-7, Underground Ventilation System

4.5 Safety Support Systems

4.5.1 Fire Protection System

The WIPP fire protection system is designed to ensure personnel safety, mission continuity, and property conservation. Building designs incorporate features for fire prevention, control and extinguishment, and, in addition, fire hazards are controlled throughout the WIPP. The plant design meets the "improved risk" level of protection defined in DOE 5480.7A[1] and satisfies the applicable sections of the National Fire Protection Association codes, DOE Orders, and federal codes.

To meet these objectives, the WIPP facility design incorporates the following features:

- With the exceptions of some temporary and other noncritical structures (such as the off-site air monitoring system), all buildings and their support structures are protected by fixed, automatic fire suppression systems designed to the specific, individual hazards of each area
- Noncombustible construction, fireproof masonry construction, and fire resistant materials are used whenever possible
- Fire separations are installed where required because of different occupancies per the Uniform Building Code (UBC)
- In buildings where compartmentation is required, vertical openings are protected by enclosing stairways, elevators, pipeways, electrical penetrations, etc., to prevent fire from spreading to upper floors

The exhaust ventilation systems which remove hot fire gases, toxic contaminants, explosive gases, and smoke, are designed with a high fire integrity. The subsurface and surface structures are served by these systems.

The components of the electric service and distribution systems are listed by Underwriters' Laboratory or approved by Factory Mutual Engineering Corporation, and are installed to minimize possible ignition of flammable material and maximize safety.

Adequate provisions for the safe exit of personnel are available for all potential fire occurrences with evacuation alarm signals provided throughout occupied areas.

Building emergency evacuation plans help ensure the safe evacuation of all building occupants during emergency conditions. The WIPP Emergency Plan[2] contains the underground emergency procedures, the underground evacuation routes, and the designated assembly areas.

The WIPP Fire Protection System consists of four subsystems. They are:

- Fire Water Supply and Distribution System
- Fire Suppression System
- Fire Detection and Alarm System
- Radio Fire Alarm Reporter (RFAR) System

All fire protection system components are classified as Design Class IIIB, with the exception of fire pumps and their structural supports, which are classified as Design Class IIIA.

4.5.1.1 System Descriptions

The WIPP facility fire protection systems service the WHB, the support structures, and the underground support areas.

4.5.1.1.1 Fire Water Supply and Distribution System

The fire water supply and distribution system receives its water supply from two independent, above ground water storage tanks. Each tank reserves 50 percent of the 180,000 gallons required to be available at all times for fire fighting purposes. The flow rate of 1500 gallons/min for two hours is based on the calculated water estimated for fire control.

Fire water is supplied to the WIPP facility structures by a compound loop distribution system serving the entire plant. Fire water system flow requirements are automatically provided by one of two 100 percent capacity centrifugal pumps. One fire water pump is electric motor driven, the other fire water pump is diesel-engine driven, and both are rated at 1500 gallons/min at 125 psi.

A small jockey pump is provided to automatically maintain the desired static pressure on the water supply system and minimize unnecessary operation of the main pumps.

The fire water pumps have a flooded suction from the storage tanks and discharge water into a 10 in fire loop equipped with sectional valves. All sectional and control valves are locked, sealed, and visually checked monthly. There is no remote indication of valve positioning. The fire loop is separate and independent of the domestic water distribution system.

4.5.1.1.2 Fire Suppression System/Fire Detection and Alarm System

The fire suppression system consists of several different fire extinguishing systems or equipment that service the surface buildings and facilities and for the underground areas. These may include any one or more of the following fire extinguishing capabilities: automatic wet pipe sprinkler system, standpipe and hose reels, automatic dry chemical extinguishing system, and portable fire extinguishers. The fire detection and alarm system consists of multiple systems, each utilizing most or all of the following components: heat sensing fire detectors, smoke detectors, sprinkler system water flow alarm devices, manual fire alarm systems, control panels, audible warning devices, and visual warning devices. The following fire suppression and fire detection and alarm systems are provided in the following areas.

<u>Waste Handling Building</u>

- Automatic Wet Pipe Sprinklers in all areas except Hot Cell (all elevations), Unloading Room, Subfloor Area
- Interior Fire Hose Connections in all areas except Hot Cell (all elevations)
- Fire Detection in the following areas:
  - CH TRU Waste Area
  - RH TRU Waste Area
  - Hot Cell Complex (all elevations)
  - Waste Hoist Tower (all elevations)
  - Shielded Holding Area

- Manual Pull Stations
- Portable Fire Extinguishers

Support Building

- Automatic Wet Pipe Sprinklers
- Interior Fire Hose Connections
- HVAC Fire Detection Instrumentation
- Manual Pull Stations
- Portable Fire Extinguishers

Exhaust Filter Building

- Automatic Wet Pipe Sprinklers
- Interior Fire Hose Connections
- Manual Pull Stations
- Portable Fire Extinguishers

Water Pumphouse

- Automatic Wet Pipe Sprinklers
- Interior Fire Hose Connections
- Manual Pull Stations
- Portable Fire Extinguishers

Underground Support Areas

- Automatic Dry Chemical Extinguishing System at the Fuel Station (actuated by thermal detectors)
- Manual Pull Stations
- Portable Fire Extinguishers
- Rescue Truck

Diesel oil fire fighting capability consists of a rescue truck, stationed underground, that carries a Dry Chemical extinguisher system as well as an Aqueous Film Forming Foam (AFFF) extinguishing system, designed specifically for combating combustible liquid fires.

Station A Effluent Monitoring Shed

- Smoke Detection

- Manual Pull Stations
- Portable Fire Extinguishers

Station B Effluent Monitoring Shed

- Smoke Detection
- Manual Pull Stations
- Portable Fire Extinguishers

4.5.1.1.3 Radio Fire Alarm Reporter System

The radio fire alarm reporter system provides annunciation to the CMS for indication of local fire panel fire or trouble alarm signals.. This system consists of radio transmitters that relay alarm and trouble signals via an FM signal to a central base station/receiver located in the warehouse (bldg.453). The signal is processed by the CMS and displayed in the CMR. The following buildings and trailers are monitored by this system:

- Building 362 - Air Intake Shaft/Winch House
- Building 454 - Vehicle Service Building
- Building 455 - Auxiliary Warehouse/Maintenance Building
- Building 463 - Compressor Building
- Building 486 - Engineering Building
- Building 489 - Training Building
- Building 459 - Core Storage Building
- Trailers 950, 951, 952, and 965

4.5.1.2 Fire Protection System Design, Installation, Testing and Maintenance

The following NFPA[3] standards apply at the WIPP facility:

- The fire water supply and distribution system (pumps, and hydrants) is designed, installed, tested, and maintained according to NFPA[3] 20 and NFPA[3] 24
- The automatic wet pipe sprinkler systems are designed, installed, tested, and maintained in accordance with NFPA[3]13
- The dry chemical fire suppression systems are designed, installed, tested and maintained in accordance with NFPA[3] 17
- The fire detection and alarm systems are designed, installed, tested, and maintained in accordance with NFPA[3] 72
- The radio fire alarm reporter system is designed, installed, tested, and maintained in accordance with NFPA[3] 72 and 1221

4.5.2 Plant Monitoring and Communications

The plant monitoring and communications systems include on-site and plant to off-site coverage. The systems are designed to provide immediate emergency instructions to facility personnel to assure personnel and WIPP facility safety, WIPP facility security, and efficient WIPP facility operations under normal and emergency conditions.

Plant Monitoring and Communications includes the following systems:

- Central monitoring room
- Central monitoring system
- Plant communications
  - Touch tone phones
  - Mine pager phones
  - Plant PA (including the Site Notification System) and alarm systems
  - Radio

4.5.2.1 Central Monitoring System

The CMR is the central location for the collection and monitoring of real time site data, automatically and manually, during normal and emergency conditions. The CMR was not intended to be designed or operated in a manner similar to the control room of a nuclear power plant. Most of the underground and surface data monitored in the CMR is gathered, processed, stored, logged and displayed by the CMS, which collects the data continuously from approximately 1500 remote sensors.

The CMS is a Design Class IIIA computer-based, monitoring and control system. It is used for real-time site data acquisition, display, storage, alarm and logging and for the control of site components. The CMS monitors the following systems:

- Radiation monitoring, with input from the area radiation monitoring system (ARMS) detectors and continuous air monitoring systems (CAMS) including those associated with the effluent monitoring system
- Electrical power status, including back-up diesel operation
- Fire alarm system, including system status parameters
- Ventilation system, including damper position, blower status, flow measurement, and filter differential pressure
- Meteorological data, including wind speed and direction, temperature, and barometric pressure
- Facility systems, including air compressors, vacuum pumps, and storage tank levels

The CMR has four operator consoles, which display alarms, status, trends, graphics, and interactive operations. The CMS electronic data storage devices are located in the computer room adjacent to the CMR. Operator's consoles and an engineer's console are located in the CMR, and the backup operator's consoles are located in the security control room.

The CMR has special features to allow its use during both normal and emergency conditions. These features include two-hour fire walls and redundant ventilation systems, including HEPA filtration of intake air to allow occupancy during radiological releases. The CMR sources of back-up AC electrical power include an uninterruptible power supply (UPS), with a minimum life expectancy of 30 minutes, and the diesel generator used to power priority loads (including the CMR) as discussed in Section 4.6.

4.5.2.2 Plant Communications

The dial phone system includes a private automatic branch exchange (PABX) network providing conventional on-site and off-site telephone services. Major uses of this subsystem include the reporting of occurrences (DOE Order 5000.3B)[4] and communications between the CMR and the following:

- Roving operators and instrumentation technicians
- The Emergency Operations Center (EOC)
- Various departments such as Health Physics, Transportation and Security

The mine pager phones make up an independent, hard wired, battery operated system for two-way communications between the surface and underground operations.

The plant public address (PA) and alarm systems provide for the initiation of surface and underground evacuation alarms and public address announcements from the CMR and local stations. The plant PA and alarm systems includes the site-wide PA and intercom installations, the Site Notification System (plectrons) for remote locations, and an additional underground evacuation alarm system. These alarms are supplied with backup power if the off-site power supply fails. The PA system master control console is located in the CMR, with paging stations located in the support building, waste handling building, water pumphouse, guard and security building, salt handling hoist house and head frame, exhaust filter building, safety and emergency services facility, engineering building, warehouse/shops building, and underground.

Radio includes two-way and paging on-site and off-site radio systems. These systems include base stations in the CMR, security control room, and emergency operations center, and mobile and portable units.

References for Section 4.5

1. DOE Order 5480.7A, Fire Protection, February 17, 1993.

2. WP 12-9, WIPP Emergency Plan, Rev. 9.

3. National Fire Protection Association.

4. DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information, February 22, 1993.

4.6 Utility and Auxiliary Systems

4.6.1 Electrical System

Unless otherwise indicated all electrical system components are Design Class IIIB. The electrical system is designed to provide: normal and backup power to WIPP electrical equipment, grounding for electrically energized equipment and other plant structures, lightning protection for the plant, illumination for the plant surface facility, and for related underground operations.

Standard industrial electrical distribution equipment is used throughout. Equipment used includes medium voltage switchgear buses, medium voltage to low voltage step-down unit substations, motor control centers, small distribution transformers and panels, relay and protection circuitry, station batteries along with associated synchronous inverters, diesel generator sets and the cabling, enclosures, and other structures required to locate and interconnect these items.

The electrical system is designed to supply power at the following nominal bus voltages:

- 13.8 kVAC, nominal, 3-phase, 3-wire, 60-Hz - Power supply for the main plant substation, underground switching stations, and surface and underground unit substation transformers
- 4.16 kVAC, nominal, 3-phase, 3-wire, 60 Hz - Power supply for the main exhaust fan drive motors
- 2.4 kVAC, nominal, 3-phase, 3-wire, 60 Hz - Power supply for the drive motor for the M-G set which provides the backup supply for the Salt Handling Shaft Drive Motor
- 480/277 VAC, nominal, 3-phase, 4-wire, 60 Hz - Power supply for motor control centers, the AIS drive motor, solid state DC converter systems for the SH and waste hoists, underground filtration fans, lighting and power distribution transformers
- 120/208 VAC, nominal, 3-phase, 4-wire, 60 Hz - Power supply for control systems, instrumentation, lighting, communication, and small (fractional horsepower) motor-driven equipment
- 120/208 VAC, nominal, 3-phase, 4 wire, 60 Hz - Uninterruptible power supply for control and instrumentation which must be continuously energized under all plant operating modes

4.6.1.1 Major Components and Operating Characteristics

There are three sources of power at the WIPP facility: normal power, backup power, and UPS.

4.6.1.1.1 Normal Power Source

The WIPP facility normal power is supplied by a public utility company and is the preferred power source supplying power to the WIPP facility at all times.

Southwestern Public Service Company supplies electrical power from their 69-kV Potash Junction/Kerrmac transmission line through a 115-kV single circuit open wire transmission line about 9 mi long. The Potash Junction Substation has two feeders from multiple generating stations and loss of one generating source does not interrupt power to the WIPP facility.

The main substation at the WIPP facility is located in the switchyard within Property Protection Area, and area substations are located at the various surface facilities. Underground conduits, cable duct banks, and buried cables connect the main substation with the area substations.

4.6.1.1.2 Backup Power Source

In case of a loss of utility power, backup power to selected loads can be supplied by either of the two on-site Design Class IIIA 1,100 kW diesel generators. These generators provide reliable 480-V power and are sized to feed the loads listed in Table 4.6-1. Backup power is fed from buses A and B (Figure 4.6-1). Each of the diesel generators can carry all preselected monitoring loads (see Section 4.4.2.1.3 for a discussion of essential loads) plus operation of the AIS hoist for personnel evacuation and other selected backup loads in accordance with procedures in the Facility Normal Operations Manual.[1]

Upon loss of normal power, the diesel(s) is started manually by the facility operator within 30 minutes using the electric starter/batteries. Only one diesel may be loaded at a time.[2] The starter system is a 24 V battery system with a 300 amp-hour capacity. The diesel automatically attempts 4 starts of 15 seconds each. Additional manual start capability exists after those automatic start attempts. Although it is standard practice to start the diesel generators from the local control panel each unit can be remotely started from the CMR via a local processing unit (LPU). This capability is maintained by leaving the generator start switch in the "remote" position. Monitoring of the diesel generators and associated breakers is possible at the CMR, thus providing the ability to feed selected facility loads from the backup power source, in sequence, without exceeding generator capacity. The on-site total fuel storage capacity is sufficient for the operation of one engine generator at full load for one day, and additional fuel supplies are readily available within a few hours by tank truck allowing on-line refueling and continued operation.

The diesel generators and the generator load center are located outside between the Safety and Emergency Services Building and Exhaust Filter Building. A 480-V backup power indoor switchgear is located in the main electrical room in the Support Building. Area substations are located at various surface facilities.

Operation of backup power supplies and the selection of loads is covered in the Facility Normal Operations Manual.[1]

4.6.1.1.3 Uninterruptible Power Supply (Essential Loads)

A central UPS providing power to essential equipment (Table 4.6-2) is located in the Support Building and the Waste Handling Building. The central 100 kVA UPS is a design class IIIA system and is located in the Support Building. In addition, individual UPS's provide transient-free power to strategically located LPUs for the radiation monitoring system on the surface, in selected areas in the exhaust shaft, and underground passages and waste disposal areas.

The purpose of the 100 kVA UPS is to supply (120/208 VAC, 222 A) transient-free, reliable power to the essential loads listed in Table 4.6-2. This ensures continuous power to the radiation detection system for airborne contamination, LPUs, computer room, central monitoring room, and primary analytical chemistry laboratory instruments, even during the interval between the loss of off-site power and initiation of backup diesel generator power.

In case of loss of AC power input to the UPS's, the dedicated batteries can supply power to a fully loaded UPS for 30 minutes. The AC power input to the UPS will be restored within 30 minutes via operator action.

All monitoring loads fed from the UPS system are shown on Westinghouse Drawing 45-J-032-W.[3] The connected load, as measured, is shown in Table 4.6-2.

4.6.1.1.4 Safety Considerations and Controls

Failure of the normal distribution system or any of its components will not affect safe conditions of the WIPP facilities. Upon loss of normal off-site power, the Exhaust Filter Building isolation valves fail to the filtration mode. The simplified single-line diagram for the normal and manually switched backup loads is shown in Figure 4.6-2 and Figure 4.6-2b (switching devices and equipment are symbolically represented).

4.6.2 Compressed Air

The compressed air system is Design Class IIIB, however, the HEPA filters for the compressors that supply air to the CMR are Design Class II. The compressed air system is diverse and redundant in the types of compressors, the numbers of compressors, and the diversity of drives for those compressors.

There are two general types of compressors -- compressors using pistons to effect compression and rotary screw type compressors. Each piston-type compressor with one exception is a two-stage compressor supplying 125 psig. The other piston-type compressor is a four-stage compressor for filling the breathing air bottles and is capable of delivering pressures as high as 5,000 psig. There are two compressors utilizing intermeshing helical rotors compressing the air to 125 psig.

There are two main compressors (41-G-021A and 41-G-021B) either of which can supply the needs for compressed air for the site. These are backed up by 300 Hp Atlas-Copco 1250 CFM compressors that can supply the site needs for compressed air. In addition, each of the buildings and the underground using compressed air have an adequate number of compressors and receivers to handle the needs in the event the normal supply fails. In addition, two buildings use compressed air but are not connected to the compressed air system. The vehicle service area and the maintenance shop have two stand-alone compressor/receiver systems and the Engineering Building has one stand-alone compressor system.

The above ground compressors are electric driven and the backup compressor underground is driven by a diesel engine. The underground compressor is used to control bulkhead doors when the above ground air supply fails.

Each compressor has inter-cooling and after-cooling of the compressed air. All compressor systems except the main compressors are cooled by forced air. The main compressors use a closed loop water system with final cooling of the water in a finned tube heat exchanger using forced air circulation.

All compressed air used above ground is filtered and dried except air from the stand-alone compressors.

Compressed air from the main compressors is supplied to the major users of air on site. In addition, compressed air is supplied to the underground distribution system by piping in the SH shaft and in the waste handling shaft.

Compressed gases sub-systems are installed in three site locations. The dosimetry laboratory uses nitrogen in processing the thermo-luminescent detectors. The counting laboratories use P-10, hydrogen, and liquid nitrogen in various analytical procedures. Mine Rescue uses high-pressure oxygen to refill breathing pack bottles. The commercial gas bottles are installed with safety binding and supply manifolds.

Inlet Air Filters (45-K-100A and B)

The compressed air supplied to the CMR in the Support Building must be free of radioactive particulates and since these compressors only operate when the plant air supply fails or when radiation has been detected, HEPA filters are used as the inlet filters for these compressors. One HEPA filter supplies two compressors -- one compressor on each receiver; a second filter supplies the other two compressors. These filters preclude the entry of airborne radioactive particulates into the compressed air stream.

4.6.3 Domestic Water System

The domestic water system is Design Class IIIB. It is designed to receive water from a commercial water department, transport the water to the WIPP Site, chlorinate and store the water, and distribute it for personnel, processes, HVAC, dust control and irrigation. The domestic water system also provides storage for the required reserve of fire water.

4.6.4 Sewage Treatment System

The sewage treatment facility collects and treats sanitary waste and nonradioactive liquids from the surface and the underground.

References for Section 4.6

1. WP 04-NO, WIPP Facility Operations Normal Operations Procedures Manual.

2. Air Quality Permit No. 310-M-2.

3. 45-J-032-W, Main UPS System Panel Schedules 41P-DP03/10, 41P-DP03/11, 45P-DP03/15, 45P-DP03/17.

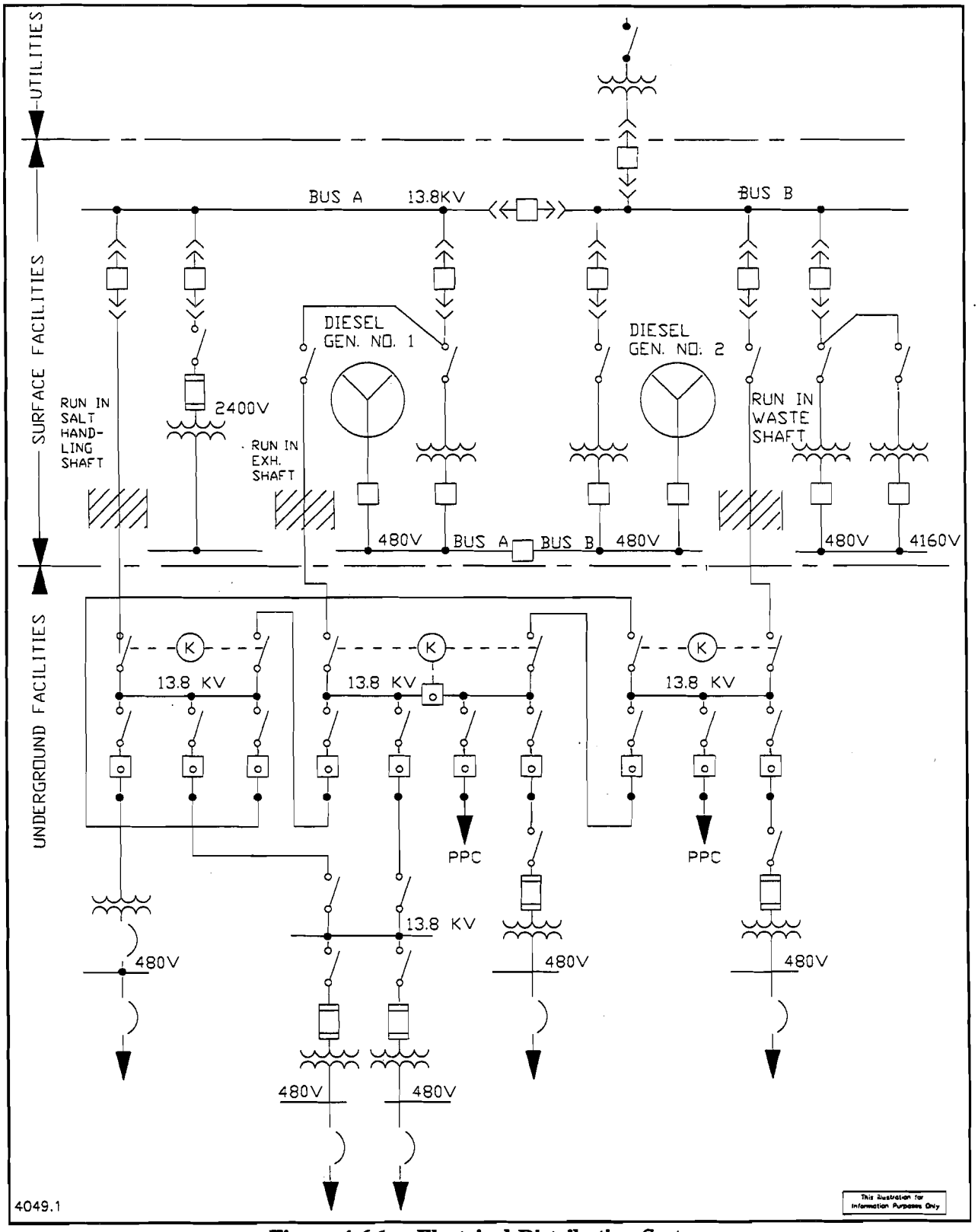


Figure 4.6-1, Electrical Distribution System

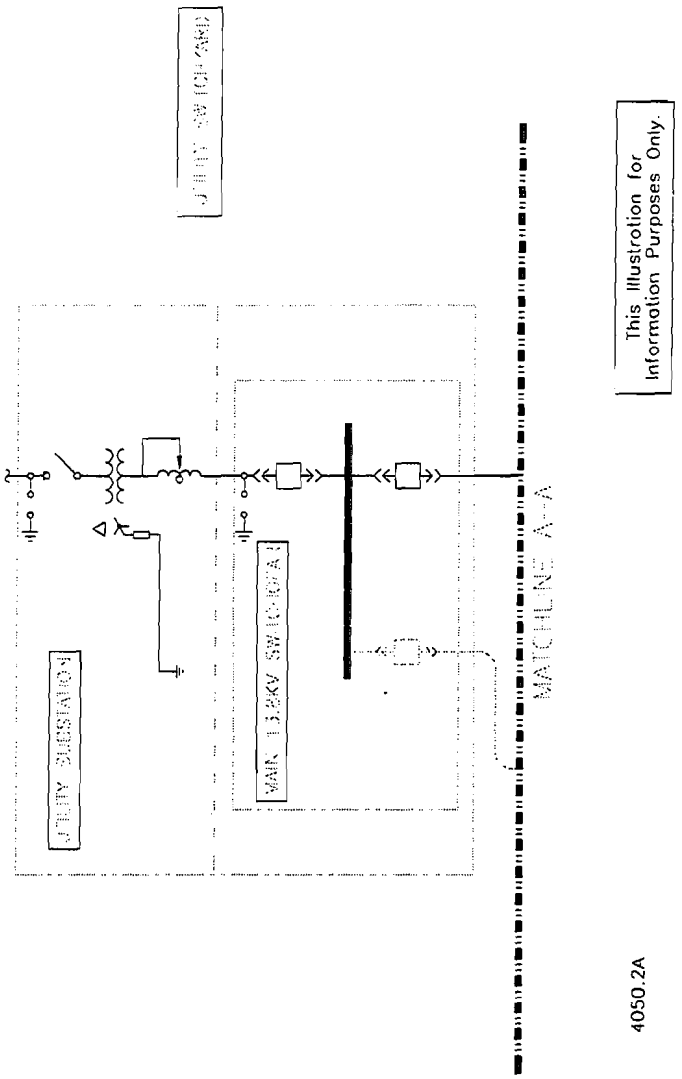


Figure 4.6-2a, 13.8 kV Power Distribution System Single Line Diagram

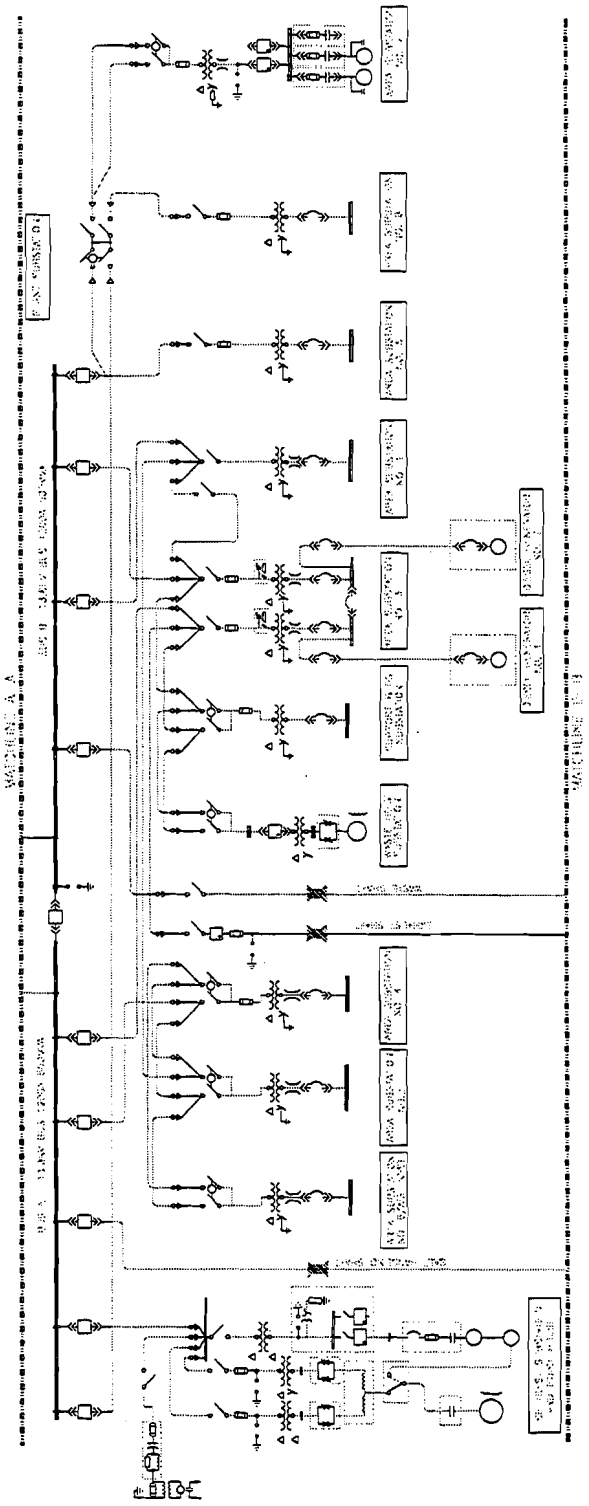
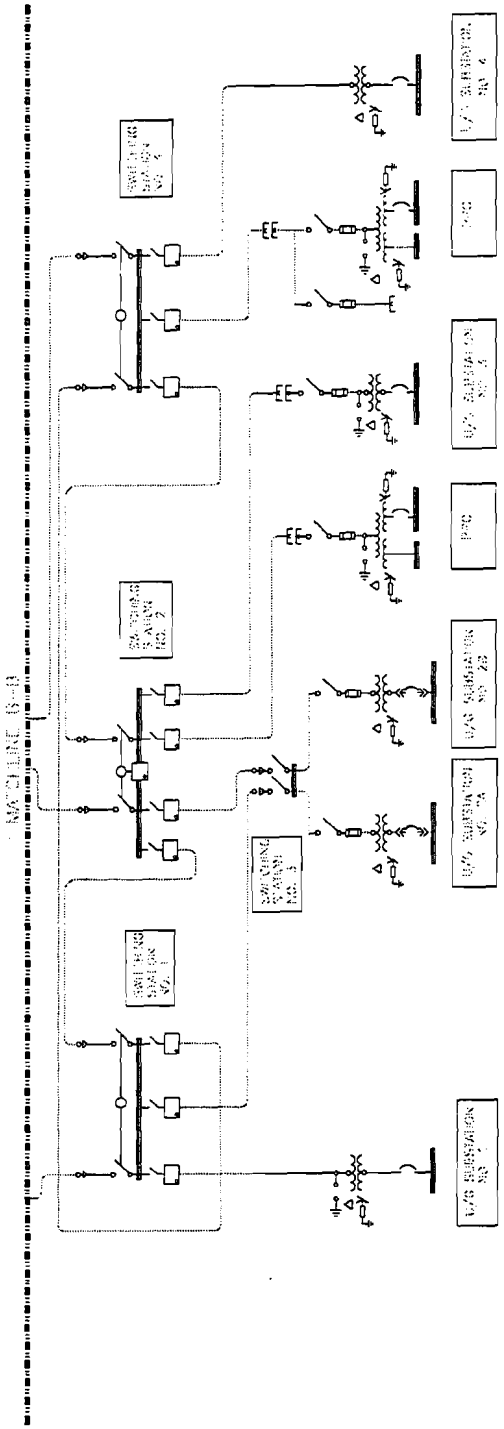


Figure 4.6-2b, 13.8 kV Power Distribution System Single Line Diagram



4050.2C

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Figure 4.6-2c, 13.8 kV Power Distribution System Single Line Diagram

Table 4.6-1, Diesel Generator Load

Manually Switched Backup		
Loads	**kW**	**Remarks**
Uninterruptible Power System* Central Monitoring System* WHB Continuous Air Monitors*	72	
Central Monitoring Room HVAC System Utilities	20	
Fire Protection Systems in the Waste Handling Building Support Building	30	Battery power is provided in fire protection system until the diesel generator is started and loaded.
Fire Pump	160	
Communications Systems	16	
Guard & Security Building	35	
Air Intake Shaft Hoist (If necessary for U/G evacuation)*	330	
WHB Lighting	45	
WHB Cranes	80	After the diesel generator is started cranes are energized as required to land their loads.
WHB Vacuum Pumps	50	
Main Air Compressors (1-200 hp)*	160	
U/G Exhaust Fans (1-235 hp)*	188	
Waste Handling Building Fans*	100	
U/G Sandia other Experimental Loads	400	
Safety & Emergency Services Building (EOC)*	10	
* Priority Back-up loads. Other loads picked up depending on actual kW loading of diesel or by load shedding.		

Table 4.6-2, UPS Loads

LOAD ON MAIN UPS	
• Radiological Monitoring System (ARM & CAM), • Central Monitoring System - Computer in Support Bldg Local Process Units (LPU) in Waste Handling and Support Bldg, • Communication System in Waste Handling and Support Bldg, • Seismic Trip in Waste Handling Bldg.	
Total Connected Load	88 kW
Running Load	60 kW
Loads on Individual UPS Units	
• LPU's in facilities other than Waste Handling and Support Buildings. • Selected Surface and Underground Radiological Monitoring Units, • Emergency Operations Center and Safety and Emergency Services Facility Guard and Security Building, • CMS Operator Consoles Safety Communication and Alarm System in facilities other then Waste Handling and Support Buildings.	
Total Independent Backup System Load	66 kVA

4.7 Radioactive Waste (Radwaste) and Hazardous Waste Management

Since the WIPP facility operational philosophy is to remain radiologically clean, decontamination operations following detection of contamination may generate some radioactive waste. The plant-derived waste could originate in both the surface and underground facilities. High activity waste is not expected to be generated during any normal operating sequences.

4.7.1 Liquid Radwaste System

Water used as a fire suppressant is the largest potential source of liquid radwaste. Another source would be any liquid used for decontamination. The fire potential in waste handling areas is remote and contaminated water from fire fighting is not expected. If fire water is generated, it is collected in trenches and sumps throughout the WHB. All suspect liquids are sampled and analyzed for radioactivity and if the liquid exceeds the uncontrolled release limit of Order DOE 5400.5,[1] it is collected and made acceptable for disposal in the WIPP.

All non-fire water liquid radwaste is collected in portable tanks or drums and handled in accordance with procedures in the Waste Handling Operations Manual[2], and the RCRA Compliance Manual.[3]

4.7.2 Solid Radwaste System

The solid radwaste system provides for the collection and packaging of site-derived solid radwaste. It is anticipated that all on site-derived waste will be contact handled, due to its low activity and the nature of the potential for sources of site-derived solid waste at the WIPP facility.

The maximum estimated solid radwaste volumes derived at the WIPP facility are listed below.

Source	Estimated Annual Volume (cubic feet)
Health Physics Laboratory	4
Solid Waste	205
Decontamination efforts	200
Sweeping	8
TOTAL	417

These maximum solid radwaste volumes are extremely conservative and actual volumes are expected to be much less. Solid radwaste is collected in disposal containers, accounted for, and emplaced when full.

4.7.3 Hazardous Waste System

Nonradioactive hazardous waste generated on-site typically includes absorbed liquids from spills and routine usage of maintenance products, including oils, coolants, and solvents. Safe storage of these materials and associated hazards are administered by the Nonradioactive Hazardous Material Environmental Compliance Manual[4] and the WIPP Safety Manual[5], and WIPP Emergency Plan and Administrative Procedures.[6]

A Hazardous Waste/Material Storage Facility is provided for storage of various types of incoming and outgoing hazardous materials prior to shipment to a Treatment Storage and Disposal Facility and is shown in Figure 4.1-2a.

References for Section 4.7

1. DOE Order 5400.5, Radiation Protection of the Public and the Environment, January 7, 1993.
2. WP 05-NO, Waste Handling Operations Manual.
3. WP 02-7, Resource Conservation and Recovery Act (RCRA), Rev. 0.
4. WP 02-5, Non-Radioactive Hazardous Materials Environmental Compliance Manual, Rev. 0.
5. WP 12-1, WIPP Safety Manual.
6. WP 12-9, WIPP Emergency Plan and Administrative Procedures.

4.8 Human Factors Engineering Considerations

Human factors engineering considerations are primarily important to safety class systems and equipment. The WIPP plant systems and equipment are classified as Design Class II or below and none is classified as Design Class I, as shown in Table 4.1-1. Therefore, there are no safety class systems or equipment at the WIPP.

An evaluation of the effectiveness of the human-machine interfaces to support actions important to the design functions of the Table 4.1-1 Design Class II and IIIA systems was performed[1] and is summarized in Table 4.8-1. It can be seen that most of the WIPP systems and equipment of Design Class II and IIIA do not require human actions to initiate or sustain their functions relative to the release of radiological or nonradiological waste materials. As shown in Table 4.8-1, in most cases these functions are accomplished with automatic passive mechanisms designed to provide the containment of waste materials, making immediate actions by operators unnecessary thus eliminating the need for human actions requiring complex human-machine interfaces. Accordingly, as shown in Table 4.8-1, human-machine interaction considerations for the WIPP systems and equipment are considered adequate.

References for Section 4.8

1. PLG-1004: Waste Isolation Pilot Plant Human Factors Evaluation, July 1994.

Table 4.8-1, Human Factors Evaluation Requirements for Design Classification II/IIIA SSCs 1 of 5

SSC with Table 4.1-1 Design Classification of II or IIIA	Function Relative to Radiological or Chemical Consequences	Allocation of Function	Human Actions Impacting Function and Consequence of Error	Human Factors Screening Results
Waste Handling Building, including Interfaces with Other Buildings - II	Contains releases and provides permanent shielding. Confinement boundary.	Automatic passive mechanisms.	None.	Adequate.
Exhaust Filter Building Station A Structure and Duct Elbow - II	Houses Station A CAMS and HEPA filters. Confinement boundary.	Automatic passive mechanisms.	None.	Adequate.
Building 412 (TRUPACT Maintenance Facility) -IIIA	TRUPACT container empty when maintained. No consequences. (Interface with WHB is Design Class II.)	Automatic passive mechanisms.	None.	Adequate.
Support Building - IIIA	Houses central monitoring room and computer room. Mitigation support.	Automatic passive mechanisms.	None.	Adequate.
Water Pumphouse - IIIA	Houses two fire pumps. Mitigation support.	Automatic passive mechanisms.	None.	Adequate.
Waste Shaft, Waste Hoist System - IIIA	Transports radioactive waste between surface and underground. Failure could initiate a release.	Automatic	None.	Adequate.
RH Road Cask Receiving Bridge Crane/Strong Back - IIIA	Transfers shipping cask to shipping cask transfer car. No consequences, as cask is designed to withstand impact of a 30-foot fall.	Automatic passive mechanisms. Designed to hold in place.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
RH Cask Road Unloading Room and Crane Maintenance Room Shield Doors - II	Provides permanent shielding.	Automatic passive mechanisms.	None.	Adequate.
Cask Vent/Sampling System - IIIA	Deleted from the design. Canister contamination and damage assessment is done within the hot cell.	Not applicable.	Not applicable.	

Table 4.8-1, Human Factors Evaluation Requirements for Design Classification II/IIIA SSCs 2 of 5

SSC with Table 4.1-1 Design Classification of II or IIIA	Function Relative to Radiological or Chemical Consequences	Allocation of Function	Human Actions Impacting Function and Consequence of Error	Human Factors Screening Results
Canister Storage Racks, Inspection Station - IIIA	Holds canister in position for visual inspection. Failure could damage canister, resulting in release to hot cell.	Automatic passive mechanisms. Functions inside contained environment.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Remote (15-Ton) Bridge Crane - IIIA	Handle RH canisters in hot cell. Failure could damage canister, resulting in release to hot cell.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Bridge Mounted Power Manipulator Rail and Bridge - IIIA	Perform work in hot cell. Failure could damage canister, resulting in release to hot cell.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Overpack Welding Equipment, Structure - IIIA	Provide remote welding capability within hot cell. Failure could damage canister, resulting in further release to hot cell.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Shielding Windows, Hot Cell - II	Permit viewing activities in hot cell, confinement barrier, and shielding of workers.	Automatic passive mechanisms. Designed to survive credible impacts.	No credible errors identified.	Adequate.
Facility Cask - II	Transfer RH waste from cask loading room to the storage horizon. Provides permanent shielding and protection to canister.	Automatic passive mechanisms. Facility cask designed to align by direct mating. Cask designed to survive all credible impacts.	No credible errors identified. Interlocks prevent undetected mating errors prior to transfer of RH canisters.	Not applicable.
Transfer Cell Canister Shuttle Car - IIIA	Transfer waste canisters. Potential for collision, which could initiate a release.	Automatic passive mechanisms, functions within a Class II confinement. Telescoping port shield with interlocks limits motion.	No credible errors identified. Interlocks prevent undetected mating errors prior to transfer of RH canisters.	Adequate.
Shield Components (Total of Six Listed) - II	Provide permanent shielding.	Automatic passive mechanisms.	None.	Adequate.

Table 4.8-1, Human Factors Evaluation Requirements for Design Classification II/IIIA SSCs 3 of 5

SSC with Table 4.1-1 Design Classification of II or IIIA	Function Relative to Radiological or Chemical Consequences	Allocation of Function	Human Actions Impacting Function and Consequence of Error	Human Factors Screening Results
Master/Slave Manipulator - IIIA	Enable personnel to perform work in hot cell. Improper operation could initiate a release.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Grapple, Hot Cell - IIIA	Lifts canister for transfer to and from hot cell. Potential for droppage, which could initiate a release.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Transfer Drawer - II	Part of hot cell structure. Provides permanent shielding.	Automatic passive mechanisms. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
RH Underground Waste Emplacement Equipment - IIIA	Emplace RH waste from the facility cask into sleeved horizontal boleholes. Provides permanent shielding and protection to canister.	Automatic passive mechanisms. Designed to align by direct mating of interfacing components. Designed to maintain integrity under all credible impacts.	No credible errors identified. Interlocks prevent inadvertent opening of shield doors before mating is completed.	Adequate.
Overhead Crane for CH Waste Handling - IIIA	Transfer shipping container closures to adjacent laydown area. Potential for droppage, which could initiate a release.	Automatic passive mechanisms. Designed to hold load in place in event of loss of power or DBE. Functions within a Class II confinement.	Error during normal waste handling operations in accordance with training and procedures. Possible accident initiating event.	Adequate.
Area Radiation Monitors - IIIA	Provides local and remote alarms when the radiation environment is above limits in assessable areas.	Automatic alarms. Personnel must respond to alarms to mitigate.	Failure to recognize alarms, accomplish facility mitigation actions. Operators trained to secure operations and evacuate area. The facility then responds in a deliberate fashion following emergency plans. No human mitigation of ongoing scenario.	Adequate.

Table 4.8-1, Human Factors Evaluation Requirements for Design Classification II/IIIA SSCs 4 of 5

SSC with Table 4.1-1 Design Classification of II or IIIA	Function Relative to Radiological or Chemical Consequences	Allocation of Function	Human Actions Impacting Function and Consequence of Error	Human Factors Screening Results
Station A - Effluent Monitoring System and Alarms for HEPA Systems - II	Detect presence of airborne particulate in mine exhaust and provide signal for HEPA changeover.	Automatic with alarms and readout in CMS.	CMRO fails to verify operation and notify plant personnel. FOSS fails to initiate facility emergency plans. No human mitigation of ongoing scenario.	Additional screen of CMS documented in Reference 1.
Station B - Effluent Sampling System - IIIA	Monitors effectiveness of exhaust shaft HEPA filters. Support mitigation.	Automatic with alarms and readout in CMS.	CMRO fails to monitor and back up automatic functions. No human mitigation of ongoing scenario.	Additional screen of CMS documented in Reference 1.
Airborne Particulate Monitors - IIIA	Detect presence of airborne particulate in ventilation duct airstream. Provide quantitative indications and both audible and visible alarms.	Automatic alarms. Personnel must respond to alarms to mitigate.	CMRO fails to monitor and back up automatic functions. No human mitigation of ongoing scenario.	Additional screen of CMS documented in Reference 1.
Station C (WHB) Isokinetic Monitoring System (CAM) - IIIA	Monitors effectiveness of WHB exhaust HEPA filters. Support mitigation.	Automatic with alarms and readout in CMS.	CMRO fails to monitor and back up automatic functions. No human mitigation of ongoing scenario.	Additional screen of CMS documented in Reference 1.
WHB - Air Sampling System - IIIA	Provides radiological air concentration of record. No safety function.	Not applicable.	Not applicable.	Not applicable.
Computer System, CMS - IIIA	Provide monitoring and alarms functions for use of the Central Monitoring Room Operator. Detect initiating events and support mitigation.	Interactive.	CMRO fails to monitor plant functions. Accomplish selected immediate actions and notify plant personnel. FOSS fails to initiate emergency plans. No human mitigation of ongoing scenario.	Additional screen of CMS documented in Reference 1.
CMR HVAC System - IIIA	Maintain suitable environment for personnel occupancy and equipment integrity. Support mitigation.	Automatic.	None.	Adequate.

Table 4.8-1, Human Factors Evaluation Requirements for Design Classification II/IIIA SSCs 5 of 5

SSC with Table 4.1-1 Design Classification of II or IIIA	Function Relative to Radiological or Chemical Consequences	Allocation of Function	Human Actions Impacting Function and Consequence of Error	Human Factors Screening Results
Onsite Engine Generator and Auxiliaries - IIIA	Provide power to selected facility loads, given loss of offsite power. Support mitigation by providing power for CMS, ventilation, and evacuation.	Manual startup and loading, either locally or from the CMR, within 30 minutes to prevent loss of UPS. Loss of active ventilation allows only very minor leakage of airborne radioactive materials loss of ΔP.	None. Sufficient time for suspension of underground activities and evacuation of personnel to surface to comply with mine safety requirements.	Adequate.
Uninterruptible Power Supply System - IIIA	Ensure power is always available for radiation detection system, hydrogen detection, computer room, and CMR.	Automatic. Requires backup power source within 30 minutes to maintain load.	None.	Adequate.
Fire Water Supply Pumps - IIIA	Supply water to suppress fires. Support mitigation.	Automatic.	None.	Adequate.
Waste Handling Area Exhaust System (Fans and Ducting) - IIIA	Minimize the concentration and spread of radioactive materials within the Waste Handling Area. Support accident mitigation.	Automatic. System must be functional during waste handling operations.	None.	Adequate.
Waste Handling Area Exhaust Filtration Systems - II	Minimize the release to the environment of airborne radioactive active released into the Waste Handling Area. Support accident mitigation.	Automatic passive mechanisms. Filters required to be online during waste handling.	None.	Adequate.
Waste Handling Area Tornado Dampers - II	Prevent reversal of exhaust airflow during passage of a tornado. Prevent an initiating event.	Automatic.	None.	Adequate.
Underground Ventilation Exhaust Fans - II	Control of radioactive effluent in the event of accident. Accident mitigation.	Failure will enable material to settle within mine.	None.	Adequate.
Underground Ventilation Filters (Prefilters, HEPA filters, and Isolation Dampers) - II	Control of radioactive effluent in the event of accident. Accident mitigation.	Automatic transfer with operator backup.	None.	Adequate.

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HAZARD AND ACCIDENT ANALYSIS

This chapter: (1) systematically identifies the potential hazards resulting from Waste Isolation Pilot Plant (WIPP) disposal-phase handling and emplacement normal operations, and (2) assesses those hazards to evaluate abnormal, internal operational, external, and natural phenomena events that could develop into accidents. The hazard analysis: (1) considers the complete spectrum of accidents that may occur and qualitatively analyzes the accident likelihood and the resultant potential consequences to the public, workers, facility operations, and the environment, (2) identifies and assess associated preventative and mitigative features for defense in depth, and (3) identifies a subset of accidents to be quantitatively evaluated in the accident analysis. The accident analysis evaluates these accidents against acceptance criteria to verify the adequacy of the preventative and mitigative systems.

The methodology and requirements of DOE Order 5480.23[1] and its implementing standards DOE-STD-1027-92[2] and DOE-STD-3009-94[3] were utilized in the development of this chapter. The potential hazards associated with the long-term waste isolation phase will be addressed in the WIPP performance assessment scheduled for late 1996. The current status of the performance assessment is summarized in Section 5.4, and will be updated to include the final assessment in future annual updates to this chapter.

This chapter only addresses contact handled (CH) transuranic (TRU) waste handling and emplacement operations described in Chapter 4. Future updates of this chapter (currently scheduled for FY 1998) will include a hazard and accident analysis of remote handled (RH) TRU waste handling and emplacement operations.

5.1 Contact Handled (CH) Transuranic (TRU) Hazard Analysis

The CH TRU hazard analysis involved a multi-step process which included (1) identification of the potential hazards associated with WIPP operations, (2) characterization of the waste expected at the WIPP, (3) a hazard evaluation in the form of a Hazard and Operability Study[4] (HAZOP) for the CH TRU waste handling and emplacement process, (4) the identification of potential accidents requiring quantitative accident analysis, (5) development of the WIPP defense-in-depth philosophy, and (6) an evaluation of worker protection from those accidents identified in the qualitative hazards analysis.

The hazard evaluation included a thorough review of existing documentation [Final Environmental Impact Statement (FEIS),[5] Final Supplement Environmental Impact Statement (SEIS),[6] and the existing hazard analysis Failure Modes and Effects Analyses (FMEA)] to ensure hazards were thoroughly evaluated.

5.1.1 Hazard Identification

A hazard is defined as a material, energy source, or operation that has a potential for causing injury or illness in humans, or damage to a facility or the environment without regard for the likelihood or credibility of accident scenarios or consequence mitigation.[3] Hazards associated with normal WIPP operations include mining dangers, high voltage, compressed gases, confined spaces, radiological and nonradiological hazardous materials, nonionizing radiation, high noise levels, mechanical and moving equipment dangers, working at heights, construction, and material handling dangers. Operations at the WIPP do not involve high temperature and pressure systems, rotating machinery, electromagnetic fields, or use of toxic materials in large quantities.

Routine occupational hazards are clearly regulated by DOE-Prescribed Occupational Safety and Health Act (OSHA) and by Mine Safety and Health Act (MSHA) standards. Programs for protecting WIPP workers from routine occupational hazards are discussed in Chapter 8.

As part of normal operations activities at the WIPP, the waste containers having met the WIPP Waste Acceptance Criteria[7] (WAC) are closely inspected and surveyed for radiation, contamination, and damage before transfer to the underground repository. Most significantly, the cleanliness of containers is required prior to shipment from the generator sites and as such are at levels undetectable. WIPP normal operations do not entail any planned or expected releases of airborne radioactive materials which may present an internal occupational radiological hazard to workers, or present a hazard from the airborne pathway to the offsite public. Therefore, the radiological hazards for normal operations are limited to worker occupational external radiation exposure from the waste containers. Nonradiological hazards to the public and worker during normal operations may result from small releases of Volatile Organic Compounds (VOCs) from waste containers. Protection of the public and the worker from hazards involved with radiological and nonradiological materials during normal WIPP operations are further discussed in detail in Chapter 7.

Operational, natural phenomena (such as earthquakes and tornadoes), and external hazards (such as aircraft crashes) are considered further in this chapter when they are identified as an initiating event leading to an uncontrolled abnormal or accidental release of waste container radiological or nonradiological materials. Therefore, for the purposes of establishing an inventory of radiological and nonradiological material, only that material contained in the waste drums is considered.

For all conceivable operations and activities during the operational disposal-phase, few credible mechanisms can be identified that could lead to accidental releases of waste container radiological and nonradiological materials. The CH waste containers are designed and fabricated in accordance with stringent regulatory requirements. The integrity of the waste containers is ensured during the design life in relation to the time interval of the disposal-phase. While accidents or incidents could occur to individual waste containers, the structural capabilities of the containers as designed can sustain anticipated waste container drops from waste handling equipment. In addition, as discussed above, WIPP operations do not entail any dispersal energies from high pressure, high temperature, or high energy systems that could result in breach of waste container integrity.

Additionally, it should be noted that the hazards identified as a result of WIPP operations, in relation to most high or moderate hazard nuclear facilities, do not require safe shutdown of the facility in a specific manner in terms of time and technical conditions. The WIPP facility and operations either individually, or collectively, can be shutdown or stopped at any time.

Inventory of Hazardous Materials

The hazard identification process resulted in identifying process operation locations within the Waste Handling Building (WHB) and the underground disposal horizon for which an inventory of radiological material could be identified. The anticipated inventory was determined based on material form, location and quantity associated with the process of receipt, handling, and disposal of CH TRU waste.

These process operation locations include:

1. Waste Handling Building (CH Bay)

   - Inventory and Preparation Area
   - Overpack and Repair Room
   - Shielded Holding Area
   - Conveyance Loading Room

2. Underground Horizon

   - Waste Shaft Station
   - Disposal Panel

Table 5.1-1 summarizes the estimated CH TRU waste container inventory by facility process location. The radiological and nonradiological waste container contents are characterized in Section 5.1.2. The bounding radiological and nonradiological hazardous material inventory for each process location may be obtained by multiplying the number of waste containers by the waste container contents derived in Section 5.1.2.

5.1.2 CH Waste Characterization

This section describes the methodology used in the development of waste container contents (radioactive/chemical content) to be disposed of at the WIPP. A description of waste containers, types, volumes, radioactive and nonradioactive constituents, and discussions on content development are included for use in the hazards and accident analysis.

Waste container types considered for this analysis are standard DOT Type A 55-gallon drums or standard waste boxes (SWBs).

5.1.2.1 CH TRU Wastes

As defined in Public Law 102-579, WIPP Land Withdrawal Act,[8] the term transuranic waste means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half lives greater than 20 years, except for; a) high-level radioactive waste, b) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations, or c) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations.

TRU waste is classified as either CH or RH, depending on the external dose rate at the waste container surface. CH TRU wastes are packaged with an external surface dose rate of up to 200 millirem per hour. CH TRU waste decays principally by alpha emission, with some beta, gamma, and neutron emissions. Alpha emitting radionuclides result in no external radiation exposure to humans, but are hazardous if inhaled or ingested. Since beta emissions, like alpha, have limited penetrating energy, adequate personnel protection is provided by the waste container. Gamma and neutron radiation are more penetrating and require shielding for safe management and storage. CH TRU waste contains predominantly alpha-emitting radioisotopes and closed containers provide protection from inhalation or ingestion.

The WIPP TRU Waste Baseline Inventory Report[9] (BIR) provides estimated volumes of CH TRU waste to be supplied by the 19 DOE waste generator and/or storage sites including small quantity sites. Historically, ten generator/storage sites had been listed as sources of TRU waste for disposal at WIPP. Activities associated with the Federal Facilities Compliance Act[10] (FFCA) resulted in the identification of nine additional sites that routinely engage in TRU waste activities. The wastes from these additional sites are included in the totals in the BIR. The radionuclide inventory by waste site is shown in Appendix A.

Radionuclide Inventory for Waste Containers

As can be seen from Table A-1 in Appendix A, the radionuclide composition of CH TRU waste varies widely among the DOE waste generator facilities. Additionally, the radioisotopes found in waste containers are the result of various plutonium "processes" with very specific "mixes" or radionuclide distributions. The Pu-mixes and the associated isotopic weight distributions used for this analysis are identified in DOE/WIPP 91-058, Radionuclide Inventory for the Waste Isolation Pilot Plant.[11] Waste received at WIPP will include waste contaminated with the Pu-51 through Pu-83 mixes which include weapons grade, fuel grade, reactor grade, and heat source mixes.

A review of the BIR[9] volume (see Appendix A) of waste contaminated by Pu-239 and Pu-238 mixes indicates that the ranking of sites by importance (by volume percent of stored CH TRU waste) are: (1) the Idaho National Engineering Laboratory (INEL) (48%), (2) the Savannah River Site (SRS) (21%), (3) Los Alamos National Laboratory (LANL) (15%), and (4) Hanford (13%). The 1992 Integrated Data Base indicates that over 50% of the SRS waste is from Pu-238 operations, while the waste from the other identified sites are primarily from Pu-239 operations with the Pu-51 through Pu-57 mixes. Approximately 90%, by volume, of the CH TRU waste is contaminated by the Pu-239 operations mixes. Additionally, a review of the waste containers from SRS contaminated from Pu-238 operations indicates that approximately 10% of the Pu-238 waste contain greater that 100 Ci.

Past safety analyses have calculated inventories based: (1) strictly on the weapons grade mix (Pu-52 distribution), or (2) based average or representative waste container content for use in accident analysis consequence calculations. The weapons grade or average drum clearly masks the importance in terms of the radiological inhalation hazard of Pu-238 in the Pu-83 mix. Therefore, a radionuclide inventory is required that is based on the individual plutonium (Pu) mixes and their associated isotopic mass distributions that will; (1) encompass and allow for disposal at WIPP the stored waste contaminated from Pu-239 operations when considering the WIPP WAC[7] nuclear criticality limits, and (2) ensure that the estimated exposure to the public from postulated accidents from high curie content Pu-238 operations waste is within the established accident acceptance criteria.

As shown in Table A-2 of Appendix A, each Pu-mix is scaled to the WAC[7] nuclear criticality limit of 200 fissile-gram equivalents (FGE) for 55-gallon drums and 325 FGE for SWBs, using the isotopic weight distributions in DOE/WIPP 91-058,[11] and converted to Plutonium-239 Equivalent Curies (PE-Ci) (see Appendix B for a discussion of the PE-Ci concept). The scaled drum PE-Ci values range from 16.8 PE-Ci for the Pu-52 mix to 47.2 PE-Ci for the Pu-57 mix, and 9070.0 PE-Ci for the Pu-83 mix; the values for the scaled SWB range from 27.4 PE-Ci for the Pu-52 mix to 76.7 PE-Ci for the Pu-57 mix, and 14,739.0 PE-Ci for the Pu-83 mix.

The waste container radionuclide inventory for use in accident consequence analyses is established by multiplying the Pu-52 mix scaled 16.8 PE-Ci by a factor of five and rounded down to 80 PE-Ci for conservatism to encompass the waste contaminated by Pu-239 operations mixes. The SWB radionuclide inventory is established by multiplying the Pu-52 mix scaled value of 27.4 by a factor of five and rounding down to 130 PE-Ci. These values will also introduce conservatism into the accident analysis material-at-risk (MAR) ensuring that accident consequences involving drums or SWBs with Pu-238 waste mix remain well within the established accident acceptance criteria.

As shown in Appendix A, the drum MAR of 80 PE-Ci will encompass and allow for disposal all PU-239 operations waste even when scaled to the WAC[7] nuclear criticality limits. Additionally, a review of stored waste inventory records indicates that a majority of PU-238 waste may be accepted for disposal.

Receipt of waste for disposal at WIPP with a PE-Ci content greater than 80 PE-Ci will first require the performance of an Unreviewed Safety Question Determination (USQD) in accordance with the requirements of DOE Order 5480.22, Unreviewed Safety Questions.[12]

5.1.2.2 TRU Mixed Waste

Hazardous waste, as defined in 40 CFR 261, Subparts C and D,[13] often occurs as co-contaminants with TRU waste from defense-related operations, resulting in "TRU mixed waste." The BIR[9] estimates the quantities of Resource Conservation and Recovery Act (RCRA) regulated TRU waste to be shipped from each generator site.

However, the BIR[9] does not provide the necessary information on hazardous constituents for use in this safety analysis. Hazardous constituents in TRU mixed wastes to be shipped to the WIPP may exist in both the gaseous and solid/liquid states within the waste containers. For potential accident scenarios involving the breach of waste containers, knowledge of the hazardous materials in the gaseous state is necessary. Information on headspace gas concentrations is taken from the Draft WIPP No Migration Variance Petition (NMVP),[14] for use in analyzing potential waste container breach/puncture scenarios.

Fire scenarios require knowledge of the hazardous materials in the solid/liquid state. Neither the BIR[9] nor NMVP[14] provides the necessary detail to determine the hazardous material inventory for fire related scenarios. The BIR,[9] however, does indicate that the largest volume of existing TRU mixed waste is from the Idaho National Engineering Laboratory (INEL). As such, the INEL Hazardous Stored TRU Waste Source Term for the Radioactive Waste Management Complex Transuranic Storage Area[15] is used to develop the total waste container nonradioactive hazardous material inventory (Table 5.1-2).

Hazardous Constituents

Mixed waste planned to be emplaced in the WIPP may contain small quantities of spent halogenated solvents identified in 40 CFR 261.31[13] by the Environmental Protection Agency (EPA) hazardous waste numbers F001 through F005. These solvents (e.g. methylene chloride and carbon tetrachloride) exist primarily in residual quantities (real or limited) and result from the cleaning of equipment, plastics, and glassware. Nonhalogenated organic compounds (prevalent by methanol, and n-butanol) occur in TRU mixed waste in much smaller quantities than halogenated organic compounds. Presence of these compounds has been confirmed by analytical results of headspace gas sampling of retrievable stored TRU waste. (Headspace is the void surrounding the waste). Analytical data on the concentrations of

29 Volatile Organic Compounds (VOCs) in the headspace gases has been calculated and is summarized in the NMVP.[14] The most prevalent VOCs observed in the headspace gases are methylene chloride, and carbon tetrachloride. Therefore, they were selected for consideration for accidental releases involving the release of headspace gases (Table 5.1-3). The data represent all Waste Matrix Code Groups excluding soil and unknown waste forms, which is less than two percent of the inventory. The average concentration of these VOCs has been observed in a range between 100 parts per million volume (ppmv) and 1,000 ppmv after being weighted to reflect estimated proportions of Waste Matrix Code Groups within the DOE complex.

Other mixed waste planned for disposal in the WIPP may contain metals for which EPA toxicity criteria have been established under 40 CFR 261.24[13] (EPA codes D004 through D011). Lead and other metals are known to be present in the waste, based on knowledge of waste-generating processes and some analytical results. Lead is a hazardous constituent in TRU mixed waste, present predominantly in the form of shielding, glove box parts, and leaded rubber gloves and aprons. Other metals (e.g., cadmium, beryllium, and mercury) are also present in some of the mixed waste (e.g., sludges) but in much smaller quantities. Lead, because of its radiation-shielding applications, is the most prevalent toxic metal present.

The WIPP WAC[7] restrict wastes for disposal that exhibit the characteristics of spontaneous ignition, chemical reaction, or accelerated corrosion. The DOE ensures, through administrative and operational procedures at the generator sites, TRU mixed waste received at the WIPP facility excludes materials with these characteristics. These characteristics are generally associated with liquid wastes or specific waste forms that may react violently. The WAC,[7] therefore, prohibit free liquids, explosives, compressed gases, oxidizers, and pyrophorics.

The WIPP facility is designed to manage only compatible waste. A compatibility analysis was performed for wastes originally reported by generators as eligible for WIPP disposal. Results of this analysis are presented in the WIPP RCRA Part B Permit Application,[16] Appendix C-1. Wastes were assigned TRUPACT II Content Codes (TRUCON) based on their chemical content and physical waste form using the TRUCON codes reported for each waste stream. No wastes were found to be incompatible either with each other or with the waste containers.

5.1.3 CH Hazard Categorization

The hazard categorization for the CH TRU Waste Handling Process was developed based on the methodology and requirements in DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.[2] The Standard requires that a nonreactor nuclear facility be placed in a hazard category based on the unmitigated release of material from the facility. The material then is compared against Threshold Quantities (TQs) identified in Attachment 1 of the Standard.

The material at risk from a single drum susceptible to an unmitigated accidental release (inventory scaled up to 200 FGE) is 80 PE-Ci. Since this quantity exceeds the Hazard Category 3 threshold of 56 Ci for Pu-239 (Attachment 1 of Standard), the WIPP is classified as a Hazard Category 2 facility.

5.1.4 Hazard Evaluation

The WIPP CH TRU handling process was qualitatively evaluated using a HAZOP (Summarized in Appendix C).[4] This systematic approach to hazard analysis was conducted by a leader knowledgeable in the HAZOP methodology and consisted of personnel from various disciplines familiar with the design and operation of the WIPP (HAZOP Team). The HAZOP Team identified deviations from the intended design and operation of the waste handling system that could: (1) result in process slowdown or shutdown, (2) result in worker injury or fatality, and (3) result in the release of waste container radiological and nonradiological materials. The HAZOP Team assigned a qualitative consequence and likelihood ranking for each deviation as discussed below. A hazard evaluation ranking mechanism utilized the likelihood and the most significant consequences to separate the low risk hazards from high risk hazards that may warrant additional quantitative analysis. Based on this ranking approach a basic set of accidents was chosen for further assessment.

5.1.4.1 HAZOP Methodology

The HAZOP technique, based on a creative systematic interaction of a multi-disciplinary team, evaluated the significance of deviations from the normal waste handling process. The HAZOP Team consisted of experienced personnel from Facility Operations, Maintenance Operations, (including previously certified waste handlers experienced in TRUPACT and drum handling activities), industrial and nuclear safety, engineering, and regulatory compliance.

The HAZOP process started with the receipt of a CH TRU waste transporter at the front gate and ended with CH TRU waste being disposed of in the underground. HAZOP nodes (process steps) were selected to define the movement of CH TRU waste through the facility. Deviations were postulated for each node and once the deviation was confirmed to be plausible, the HAZOP Team determined the possible causes for the deviation. The resulting potential consequences were explored without taking into consideration any mitigating features. An evaluation was made to determine if mitigating safeguards were in place to alleviate the consequences. Some of the potential deviation consequences or concerns identified by the HAZOP Team are:

- Worker injury or fatality,
- Process slowdown or shutdown,
- Internal and external conditions may result in breach/rupture of waste containers resulting in the airborne release of radiological or nonradiological hazardous materials (loss of primary confinement),
- External waste container surface contamination and need for decontamination,
- Worker and public exposure to radiation and airborne radiological and nonradiological hazardous materials,
- Potential for receipt of damaged waste containers and need for overpack operations.

The HAZOP deviation ranking process used a two-number system, consisting of a qualitative severity classification and a qualitative likelihood classification. The qualitative severity (consequence) classification was ranked without consideration for mitigation. The qualitative likelihood was ranked taking into consideration the probability of failure of identified safeguards and mitigation for that deviation. The HAZOP Team concluded that:

- Substantial safeguards currently exist at the WIPP to prevent or reduce the likelihood of such deviations from occurring. Identified safeguards include facility and equipment design, procedures, training, preventative maintenance and inspection, and administrative controls including the WIPP WAC[7] (see Table 5.1-7, and Appendix C).

- Substantial mitigation exists to reduce the consequences of any postulated deviation to acceptable levels. Identified mitigation includes confinement/ventilation systems and associated HEPA filtration systems (see Table 5.1-7, and Appendix C).

As qualitatively concluded from this HAZOP, the design of the WIPP CH TRU Waste Handling System is sufficient to ensure the safety of the public, workers and the environment. The HAZOP Team identified no substantial recommendations for the WIPP management to consider to reduce the severity or likelihood of any of the postulated deviations.

5.1.4.2 Selection of CH Potential Accidents

The HAZOP[4] provided a list of deviations that were qualitatively ranked by relative consequence and probability using the 'total rank' consequence criteria of Table 5.1-4 and the probability criteria of Table 5.1-6. This resulted in the 'total rank' recorded in Appendix C. As stated in the HAZOP[4], the consequence ranking of each deviation included both the resultant consequence to the worker and the radiological and nonradiological consequence to the offsite public. In most deviations, the possibility of worker fatality resulted in the assignment of the highest possible consequence ranking of 4.

In order to select potential CH accidents for quantitative accident analysis, the total list of hazards was narrowed to focus on risk posed by radiological and nonradiological hazardous material, by using the 'hazard rank' consequence criteria Table 5.1-5. This eliminated occupational deviations exclusive of the hazardous materials involved, providing a subset 'hazard rank' (also recorded in Appendix C).

In order to determine the risk associated with each deviation, the relative probability and hazard consequence ranking were combined. The deviations were then categorized as low, moderate, or high risk based on the Relative Probability and Consequence Ranking Matrix (Figure 5.1-1). Those deviations with a combined 'hazard rank' of less than four were excluded from further quantitative evaluation, with the exceptions of the waste hoist drop (CH5), earthquake (CH6), and aircraft crash (CH8). The waste hoist drop (CH5) was also selected for its significant interest to external organizations, as well as the earthquake (CH6) as a natural event and the aircraft crash (CH8) as an external event as required by DOE-STD-3009-94.[3] A list of the selected deviations for further consideration in the accident analysis is provided in Table 5.1-7.

5.1.5 Prevention of Inadvertent Nuclear Criticality

The intent of a criticality safety program is to prevent the accumulation of fissile and fissionable material and neutron moderating or reflecting materials in quantities and configurations that could result in an accidental nuclear criticality.

To ensure adequate margins of criticality safety for adherence to DOE Order 5480.5,[17] the WIPP facility was designed so that during each operation involving fissile material K_{eff} does not exceed a value of 0.95 (at the 95 percent confidence level) for the most reactive set of conditions considered credibly possible. The calculation of K_{eff} includes the effect of neutron interaction and reflection between fissile elements and dimensional variations resulting from fabrication tolerances and changes due to corrosion and mechanical distortion. As discussed below, these calculations indicate the combination of conditions enabling the K_{eff} limit of 0.95 to be exceeded for the CH waste forms handled at the WIPP facility is incredible.

5.1.5.1 WIPP Nuclear Criticality Safety Provisions

The existing provisions for nuclear criticality safety at the WIPP consists of mass limits control, TRU waste disposal configuration control, and analytical verification of subcriticality.

Mass Limits Control

The WIPP WAC[7] limits the fissile or fissionable radionuclide content of CH TRU waste, including allowance for measurement errors, to 200 Fissile-Gram Equivalent (FGE) for a 55-gallon drum and 325 FGE for a SWB. Further, the WAC limits the TRUPACT II payload, including error allowance, to 325 grams of FGE total.

TRU Waste Disposal Configuration Control

In addition to the mass limits control, geometry controls are required for the emplacement and/or in-transit handling disposal configurations. Drum arrays shall not exceed 16 drums wide or 3 drums high. Box arrays shall not exceed 7 boxes wide or 3 boxes high. Drum or box arrays may be of any length.

CH TRU Nuclear Criticality Safety Analysis

In compliance with DOE Order 5480.5,[17] a criticality analysis[18] was performed to ensure that no credible criticality accident could occur at the WIPP. The analysis was based on the mass limit control and geometry control discussed above with additional conservative assumptions in terms of; isotopic content, density and configuration modeling, moderation, and reflection. Further, for the CH waste analysis, it was assumed that the waste package storage array is infinitely long.

The results of the WIPP CH TRU criticality analysis[18] indicate that, for each of the conditions analyzed, the calculated effective multiplication factor, K_{eff}, is less than 0.95 including uncertainties at 95% probability at 95% confidence level. Accordingly, no credible criticality hazard exists at the WIPP for CH TRU operations.

DOE Order 5480.24[19] requires additional analyses of nuclear criticality safety. The WIPP CH TRU criticality analysis[18] was examined for compliance with the order and all the applicable requirements for the order performance of criticality analyses were complied within the analysis.

5.1.5.2 Compliance with Mandatory ANSI/ANS Standards

The existing WIPP nuclear criticality safety provisions were reviewed to ensure compliance with the six mandatory American Nuclear Society's ANSI/ANS nuclear criticality safety standards as the Order requires. The six mandatory standards are: ANSI/ANS-8.1,[20] 8.3,[21] 8.5,[22] 8.7,[23] 8.15,[24] and 8.19.[25]

The WIPP provisions are found to be in compliance with the requirements of ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors,[20] and ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements,[24] in regard to: mass control, geometry control, and performance of criticality analyses.

The criticality-related administrative control provisions were determined to be in compliance with ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety.[25]

Since it has been established by analyses[18] that a criticality accident is incredible at the WIPP as discussed in 3.3.5.1.3, ANSI/ANS-8.3,[21] a Criticality Accident Alarm System is not applicable as called for in the Order.

The two facility-specific standards, ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material,[22] and ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials,[23] are not applicable to the WIPP.

The existing WIPP nuclear criticality safety provisions are therefore in compliance with the Order-required mandatory criticality safety standards.

5.1.6 Defense In Depth

Although the HAZOP[4] qualitatively concludes that the WIPP is inherently safe with regard to its operational phase activities and operations as discussed in the above sections, a defense-in-depth philosophy is employed in its approach to enhancing the safety of the facility in conjunction with its design and operations. The WIPP defense-in-depth safety approach provides layers of defense: (1) against release of radiological and nonradiological hazardous waste container materials and the resultant consequences to the public and the environment, and (2) for protection of the worker against accidents. The WIPP approach provides three layers of defense against releases. Each successive layer provides an additional measure of the combined defense strategy.

The ultimate safety objective of the first, or primary layer of WIPP defense in depth is **accident prevention**. The reduction of risk (as the product of frequency and consequence) to both workers and the public from WIPP CH TRU waste handling and emplacement operations is primarily achieved by reducing the frequency of occurrence of postulated abnormal events or accidents. The conservative design of the facility's structures, systems and components (SSCs), with operations conducted by trained/certified personnel to the standards set forth in approved procedures, provides the first layer. Specific preventative measures are identified in Appendix C for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis.

The occurrence frequency for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis is primarily derived from process inherent events, equipment failure and human error. To reduce the probability of equipment failure, the facility design, fabrication, and construction were undertaken in accordance with applicable codes and standards, based on the design classification of SSCs established in Chapter 4. Extensive pre-operational tests were conducted to verify SSCs perform their design function. This is followed up presently by in-service and pre-operational checks and inspections, and preventive maintenance and quality assurance programs. The WIPP employs configuration management change control and modification retest to ensure quality throughout facility life. Technical Safety Requirement (TSR) Administrative Controls (ACs) are derived in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) to ensure that the high level of design is maintained throughout the facility lifetime.

Additionally, as identified in the HAZOP, accident prevention for process inherent events such as spontaneous ignition, is achieved administratively through the WAC[7] which restricts waste elements (such as the presence of pyrophorics) which may be initiating events for accidents.

Prevention of human error as an initiating event is achieved by the extensive training and certification programs, operational procedures, and conduct of operations programs. TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) to ensure that these programs are maintained, and operations continue to be conducted with highly qualified and trained personnel using current approved procedures.

The second layer of defense in depth provides protection against anticipated and unlikely operational events that might occur in spite of the protection afforded by the first layer of defense. The second defense layer is characterized by detection and protection systems, and controls that: (1) indicate component, system, or process performance degradation created by compromises of the first layer, and (2) provide adequate mitigation and accommodation of the consequences of those operational accidents which may occur.

Specific mitigative features are identified in Appendix C for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis. In general, the WHB and underground radiation and effluent monitoring systems and HEPA filtration systems, and the WIPP emergency management program[27] provide this layer of defense in depth. In addition, the WIPP Human Factors Evaluation,[28] determined that well established policies and procedures are in place ensuring normal and emergency procedures are implemented, adequate directions have been provided to shift personnel concerning actions to be taken in a potential accident environment, and adequate procedures are available for follow up response. TSR ACs are assigned in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) supporting the second level of defense in depth. Programs supporting defense in depth as required by the TSRs, are discussed in detail in Chapters 7, 8, and 9.

The third layer of defense in depth supplements the first two layers by providing protection against extremely unlikely operational, natural phenomenon, and external events. These events represent extreme cases of failures and are analyzed in Chapter 5 using conservative assumptions and calculations to assess the radiological and nonradiological effects of such accidents on the public to verify that a conservative design bases has been established.

5.1.7 Protection of Workers from Accidents

The HAZOP[4] for the CH TRU Waste Handling System identified a number of waste handling process hazards that could potentially lead to events resulting in worker injury or fatality, or exposure to radiological and nonradiological hazardous materials. The Total Rank (or risk) for each postulated deviation as identified in Appendix C, is the qualitative product of the likelihood of the event and the potential consequences. As shown in Appendix C, the consequences of the postulated deviations were dominated by the assumption that a worker fatality may result without safeguards in place, regardless of dose or dosage received.

Consistent with the defense-in-depth philosophy, and the philosophy of Process Safety Management (PSM), as published in 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals;[26] reduction of the risk to workers from accidents is accomplished at the WIPP by identifying controls to prevent the event from happening. Total risk is therefore lowered by reducing the likelihood of the event, as opposed to focusing on post accident consequence mitigation through the performance of quantitative consequence calculations for workers.

As discussed in Section 5.1.4.1, the HAZOP Team identified a significant number of existing preventative safeguards that lower the likelihood of occurrence of each deviation, substantially reducing the risk of injury or fatality to workers. The HAZOP Team concluded, consistent with the first layer of defense in depth, substantial safeguards currently exist at the WIPP to prevent or reduce the likelihood of such deviations from occurring. Identified preventative safeguards as shown in Appendix C, and Table 5.1-7 generally include the following:

- Facility and equipment design, application of appropriate design classification and applicable design codes and standards,
- Programs relating to configuration and document control, quality assurance, and preventative maintenance and inspection,
- Administrative controls including the WIPP WAC,[7] waste handling procedures and training, and the WIPP Emergency Plan[27] and associated procedures.

Due to the importance of these preventative features in WIPP defense in depth and worker protection from accidents, TSR ACs are assigned in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR).

References for Section 5.1

1. DOE Order 5480.23, Nuclear Safety Analysis Reports, April 1992.

2. DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, 1992.

3. DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports, July 1994.

4. WCAP 14312, Hazard and Operability Study for CH TRU Waste Handling System, Waste Isolation Pilot Plant, Westinghouse Waste Isolation Division, April, 1995.

5. DOE/EIS-0026, Final Environmental Impact Statement, Waste Isolation Pilot Plant, 2 Vols, U.S. Department of Energy, Carlsbad, N.M., 1980.

6. DOE/EIS-0026-FS, Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant, U.S. Department of Energy, Carlsbad, N.M., 1990.

7. WIPP-DOE-069, Rev. 4, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, December 1991.

8. Public Law 102-579, WIPP Land Withdrawal Act, October 30, 1992.

9. DOE/CAO-94-1005, U.S. Department of Energy Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report, Revision 0, May 1994.

10. Public Law 102-386, Federal Facility Compliance Act, U.S. Congress, 1992.

11. DOE/WIPP 91-058, Radionuclide Inventory for the Waste Isolation Pilot Plant, Rev. 0.

12. DOE Order 5480.22, Unreviewed Safety Questions, December 1991.

13. CFR (Code of Federal Regulations) 40, Part 261, Identification and Listing of Hazardous Waste.

14. DOE/CAO-2043, Waste Isolation Pilot Plant No Migration Variance Petition, Draft.

15. ENV-003, Hazardous Stored TRU Waste Source Terms for the RWMC's TSA, 1990

16. Waste Isolation Pilot Plant RCRA Part B Permit Application, U.S. Department of Energy, Carlsbad, N.M., May 1994.

17. DOE Order 5480.5, Safety of Nuclear Facilities, September 23, 1986.

18. DOE-WIPP 88-014, Criticality Safety Analysis for Contact Handled Waste at the Waste Isolation Pilot Plant, Westinghouse Electric Corporation, June 1988.

19. DOE Order 5480.24, Nuclear Criticality Safety, August 12, 1992.

20. ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.
21. ANSI/ANS-8.3, Criticality Accident Alarm System.

22. ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material.

23. ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials.

24. ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements.

25. ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety.

26. 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals.

27. WP 12-9, WIPP Emergency Plan and Administrative Procedures.

28. PLG-1004, Waste Isolation Pilot Plant Human Factors Evaluation, July, 1994.

Relative Probability				
4	4	8	12	16
3	3	CH2 CH3 CH4 6 CH9 CH11	CH1 CH7 9	12
2	2	CH2 CH10 CH11 4	6	8
1	1	CH6 2	CH5 CH8 3	4
	1	2	3	4

Severity of Consequences

Reference Table 5.1-7 for descriptions of accidents CH1 through CH11.

Combinations of conclusions from risk analysis that identify situations of high risk or major concern

Combinations that identify situations of moderate risk or concern

Combinations that identify situations of low risk

Figure 5.1-1, Relative Probability and Consequence Ranking Matrix for Hazard Evaluation

Table 5.1-1, Hazardous Material Inventory by Facility Location

Hazard Type	Material Form	Location (Facility Process)	Inventory		Basis for Number of Drums/SWBs
			Number of Drums	or SWBs	
WASTE HANDLING BUILDING					
Radioactive/ Nonradioactive Material	CH TRU Waste	Inventory/ Preparation	56	16	(4 TRUPACTs) 2 TRUPACTs/ TRUDOCK
		Shielded Holding	28	4	1 facility pallet
		Overpack and Repair Room	14	2	Capacity of TRUPACT-II
		Conveyance Loading Room	28	4	1 facility pallet
UNDERGROUND HORIZON					
Radioactive/ Non radioactive Material	CH TRU Waste	Waste Shaft Station	28	4	1 facility pallet
		Disposal panel	83,373	9,450	Total waste capacity/panel divided by waste container volume

Table 5.1-2, Hazardous Material Concentrations Used in Fire Scenarios (CH1 and CH7)

Chemical	Average[1] Weight Fraction	Inventory (mg)[2] (Based on 243 lbs/drum)
Asbestos	2.7E-03	3.0E+05
Beryllium	2.1E-04	2.3E+04
Cadmium	3.0E-06	3.3E+02
Lead	8.3E-03	9.1E+05
Butyl Alcohol	3.0E-03	3.3E+05
Carbon Tetrachloride	6.3E-03	6.9E+05
Mercury	3.5E-03	3.9E+05
Methyl Alcohol	8.0E-06	8.8E+02
Methylene Chloride	4.0E-04	4.4E+04
Polychlorinated Biphenyl (PCB)	8.5E-03	9.0E+05
Trichlorethylene	3.9E-03	4.3E+05

Notes:

1. Data from Reference 15, Table 1. Data listed is average weight fraction of each hazardous material of the total drum weight. Sum will not add to unity, as other nonhazardous materials are within each drum.

2. Drum Inventory = (Weight Fraction) x (243 lbs/drum) x (453.592 g/lb) x (1E+03 mg/g)

Table 5.1-3, VOC Concentrations

Chemical	Weighted[1] Average (ppmv) drum	Molecular Weight (g/mole)	Mole Fraction (1.0E-06 mole/ppmv)	Unit Conversion (1.0E+03mg/g)	Drum Inventory[2] (mg)	SWB Inventory[3] (mg)
Methylene Chloride	497.93	84.9	1.0E-06	1.0E+03	42.3	380
Carbon Tetrachloride	408.00	153.8	1.0E-06	1.0E+03	62.8	565

Notes:

1. Data from Reference 14.
2. Drum Inventory = Weighted Average (ppmv) x molecular Weight (g/mole) x mole fraction (1E-06 mole/ppmv) x (1E+03 mg/g)
3. SWB Inventory = (64 ft^3 SWB volume/7.4 ft^3 drum volume) x (Drum Inventory)

Table 5.1-4, Total Rank Qualitative Consequence Classification Table

Consequence Category	Description
1	May cause facility worker injury as a result of an industrial accident or acute exposure from radiological or toxicological material with no lost time. Negligible offsite impact to people or environs. May result in facility contamination with no significant disruption of facility operation.
2	May cause facility worker injury as a result of an industrial accident or acute exposure from radiological or toxicological material with lost time and with no disability. Negligible offsite impact to people or environs. May result in facility contamination, or facility damage with minor disruption of facility operation.
3	May cause severe facility worker injury with disability. Minor offsite impact to people or environs. May result in facility contamination, or facility damage with major disruption of facility operation.
4	May cause deaths to facility workers. Considerable offsite impact to people and environs. Offsite contamination requiring cleanup, or facility destruction.

Table 5.1-5, Hazard Rank Qualitative Consequence Classification Table

Consequence Category	Description
1	May cause facility worker injury as an acute exposure from radiological or toxicological material with no lost time. Negligible offsite impact to people or environs. May result in facility contamination with no significant disruption of facility operation.
2	May cause facility worker injury as an acute exposure from radiological or toxicological material with lost time and with no disability. Negligible offsite impact to people or environs. May result in facility contamination, or facility damage with minor disruption of facility operation.
3	Minor offsite impact to people or environs. May result in facility contamination, or facility damage with major disruption of facility operation.
4	Considerable offsite impact to people and environs. Offsite contamination requiring cleanup, or facility destruction.

Table 5.1-6, Qualitative Relative Probability Classification Table

Relative Probability Category	Estimated Annual Likelihood of Occurrence	Description
1 (Incredible)	$10^{-6} \geq p$	All accidents not included in other categories. Frequency of less than once in a million years.
2 (Extremely Unlikely)	$10^{-4} \geq p > 10^{-6}$	Accidents that will probably not occur during the life cycle of the facility. This class includes the design basis accidents. Frequency between one in 10,000 years and once in 1,000,000 years.
3 (Unlikely)	$10^{-2} \geq p > 10^{-4}$	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this probability class include: Uniform Building code-level earthquake, 100-year flood, maximum wind gust, etc. Frequency between one in 100 years and once in 10,000 operating years.
4 (Anticipated)	$10^{-1} \geq p > 10^{-2}$	Incidents that may occur several times during the lifetime of the facility (incidents that commonly occur). Frequency is one in 100 operating years.

Table 5.1-7, HAZOP Operations Ranking

ACC	Scenario	# Node	Deviation	Consequence	Conseq	Like	Risk	Prevention/Mitigation
CH1	Fire/spontaneous ignition	07 TRUPACT II internal condition	Fire in TRUPACT II	Minor radioactive materials released	3	3	9	Prevention: Type A container, Waste container integrity, QA, Reinstall ICV lid, Building Construction, Stable drum history, TRUPACT II integrity, Vented drums, WAC criteria. Mitigation: Reinstall ICV lid, WHB HEPA filtration and fire suppression systems, Emergency response plan and teams.
CH2	Crane failure/breach	08 Transfer of payload from TRUDOCK to facility pallet	Failure of lifting equipment	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Crane fail safe design, QA, Operator training & certification, PM program, Procedures, Stretch wrapping, WAC criteria, Hoisting & rigging practices, two operators, pre-op checks, waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency response plan and teams.
CH2	Crane failure/breach	08 Transfer of payload from TRUDOCK to facility pallet	Failure to secure load	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Fail safe design, QA, Operator training & certification, Preop checks on equipment, PM program, Procedures, Stretch wrapping, WAC criteria, Hoisting & rigging practices, Two operators, Waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency Response Plan and teams .
CH2	Crane failure/breach	13 Removal of ICV lid, slip sheet, and drums	Failure to remove payload	Negligible radioactive materials released	2	2	4	Prevention: Operator specialized training & certification, TRUPACT II integrity, QA, Two operators, WAC criteria, Hoisting & rigging practices, Pre-op checks, PM program procedures, Waste container integrity. Mitigation: Decon room differential pressure, Dedicated filtered exhaust, Emergency response plan and teams.
CH2	Crane failure/breach	13 Removal of ICV lid, slip sheet, and drums	Moving accident with the ICV lid	Negligible radioactive materials released	2	2	4	Prevention: Operator specialized training and certification, TRUPACT II integrity, QA, Two operators, WAC criteria, Hoisting & rigging practices, Pre-op checks, PM program procedures, Waste container integrity. Mitigation: Decon room differential pressure, Dedicated filtered exhaust, Emergency response plan and teams,
CH3	Fork lift mishap/puncture	09 Transfer facility pallet to conveyance car	Fork lift improper engagement of load	Negligible radioactive materials released	2	3	6	Prevention: Forklift design, QA, Adequate lighting, Operator training & certification, Pre-op checks, PM program, Procedures, Spotters, WAC criteria, Type A container, Drum integrity, Waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency response plan and teams.

Table 5.1-7, HAZOP Operations Ranking

ACC	Scenario	# Node	Deviation	Consequence	Conseq	Like	Risk	Prevention/Mitigation
CH4	Fork lift mishap/breach	09 Transfer facility pallet to conveyance car	Moving accident	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Operator training & certification, PM program, Stretch wrapping, Spotters, Tie-down strapping, WAC criteria, Procedures, Pre-op checks, QA, Drum integrity, Waste container integrity. Mitigation: Building Exhaust HEPA Filtered, Emergency Response Plan and Teams.
CH4	Fork lift mishap/breach	09 Transfer facility pallet to conveyance car	Mislocation on the conveyance car	Negligible radioactive materials released	2	3	6	Prevention: Type A container, QA, Air lock doors interlocked, Local alarms, Operator training & certification, Restricted access, Robust doors & walls, Stretch wrapping, Spotters, WAC criteria, Procedures, Tie-down strapping, Waste container integrity, PM program, Pre-op checks. Mitigation: HEPA filtration, Emergency response plan and teams.
CH4	Car/breach	10 Transfer conveyance car load onto the waste cage	Moving accident	Negligible radioactive materials released	2	3	6	Prevention: Type A container, QA, Operator training & certification, Procedures, Stretch wrapping, Spotters, Strapped containers, WAC criteria, Waste container integrity, PM program, Pre-op checks. Mitigation: HEPA filtration, Emergency response plan and teams.
CH4	Fork lift mishap/breach	12 Overpack and repair room	Transfer failure from TRUDOCK to OP&RR	Negligible radioactive materials released	2	3	6	Prevention: Forklift design, QA, Operator training & certification, Preoperational checks, PM program, Procedures, Spotters, WAC criteria, Type A containers, TRUPACT II integrity, PM program, Pre-op checks. Mitigation: HEPA filtration, Emergency Response plan and teams.
CH4	Fork lift mishap/breach	13 Removal of ICV lid, slip sheet, and drums	Moving accident with payload	Negligible radioactive materials released	2	3	6	Prevention: Operator training & certification, Specialized training, Two operators, WAC criteria, Hoisting & rigging practices, Type A containers, Procedures, Waste container integrity, Pre-op checks, PM program. Mitigation: Decon room differential pressure, Dedicated filtered room exhaust, Emergency response plan and teams.

Table 5.1-7, HAZOP Operations Ranking

ACC	Scenario	# Node	Deviation	Consequence	Conseq	Like	Risk	Prevention/Mitigation
CH5	Hoist failure/breach	11 Waste hoist	Waste hoist drop	Minor radioactive materials released	3	1	3	Prevention: Brake testing, Cable NDT exams, Acoustics exam for failed parts, Control system has elevation check mechanisms, Four independent valve failures required to fail brakes, Brakes checked with full power and max load and speed, Catch gear, Cage fails up, Maintenance procedures & program, Mine rescue equipment, MSHA inspections, Preoperational checks, Qualified personnel, Redundant brakes & controls, Sump under shaft, Six hoist ropes each capable of holding load, inspections, Training and certification, Weekly inspections, annual vendor inspection, visual inspection of structural steel assemblies, QA. Mitigation: HEPA filtration, Plateout and depletion in mine, Emergency response plan and teams.
CH6	Seismic	15 Natural events	Seismic event	Negligible radioactive materials released	2	1	2	Prevention: Drum integrity, DBE qualified Class II and IIIA SSCs, TRUPACT II integrity, WAC criteria, Type A containers, QA. Mitigation: Shutdown procedure, Emergency response plan and teams.
CH7	Spontaneous ignition	27 Drum fire	Drum fire	Minor radioactive materials released	3	3	9	Prevention: Type A container, Waste container integrity, Reinstall ICV lid, Building Construction, Stable drum history, TRUPACT II integrity, Vented drums, WAC criteria. Mitigation: HEPA filtration, depletion and plateout in mine, Emergency response plan and teams.
CH8	Crash/fire/breach	16 External events	Aircraft crashes into WHB	Minor radioactive materials released	3	1	3	Prevention: Flight patterns, Remote location. Mitigation: Emergency response plan and teams.
CH9	Fork lift mishap/breach	23 Life of facility	Floor distortion	Negligible radioactive materials released	2	3	6	Prevention: Drift inspections, Floor surveys, MSHA inspections, Forklift design, Type A containers, Procedures, Training. Mitigation: Ventilation flow, Emergency response plan and teams, HEPA filtration, depletion and plateout in mine.
CH10	Tornado	15 Natural events	Tornado	Negligible radioactive materials released	2	2	4	Prevention: CMR monitors weather conditions, Drum integrity, Procedural guidance for personnel protection, TRUPACT II integrity, WAC criteria, Type A containers. Mitigation: Emergency response plan and teams.

Table 5.1-7, HAZOP Operations Ranking **Page 4 of 3**

ACC	Scenario	# Node	Deviation	Consequence	Conseq	Like	Risk	Prevention/Mitigation
CH11	Roof fall/breach	22 Storage room	Roof collapse during emplacement	Negligible radioactive materials released	2	3	6	Prevention: Inspections & assessments, Ground control, Mine instrumented and monitored, MSHA inspections, Predictive monitoring, Pre-emplacement checks, Type A containers, WAC, procedures, training. Mitigation: Emergency response plan and teams, HEPA filtration.
CH11	Roof fall	23 Life of facility	Roof collapse in life of facility area	Negligible radioactive materials released	2	2	4	Prevention: Floor surveys, MSHA inspections, Shift inspections, WAC criteria, Instrumentation and monitoring, Ground control, Bi-monthly visual and instrument inspections, Procedures, Training. Mitigation: Ventilation during emplacement, HEPA filtration, Emergency response plan and teams.

NOTE: **Accidents CH5, CH6 and CH8 were retained in the safety analysis due to being an external event, a natural event, or an event of significant interest.**

5.2 CH TRU Accident Analysis

The postulated accident scenarios analyzed in this section were selected as discussed in Section 5.1.4. The models and assumptions used in the analysis for determining the amount of radioactivity released to the environment and the extent of exposure to the public are provided in the following sections. Activity releases to the environment are given for each postulated accident. Committed Effective Dose Equivalents (50 yr CEDE) were calculated for what are considered to be hypothetical individuals located at the WIPP Exclusive Use Area boundary and the site boundary (16 Section Boundary). The meteorological conditions under which these doses are evaluated are discussed in Section 5.2.1.

All radioactive material at the WIPP facility that has the potential to be released to the off-site environment (except contamination on the container surface) is contained within the waste container (drum or standard waste box). Physical properties and assumptions for waste container inventories used in this analysis are presented in Section 5.1.2.

In evaluating hypothetical accidents, conservative assumptions are made to provide bounding consequences which result in postulated releases that are overestimated rather than underestimated.

Operational, Natural and External initiating events that require further evaluation as determined by the hazard analysis are listed below:

1. Operational Events
   - CH1 Spontaneous Ignition (Drum) in the WHB
   - CH2 Crane Failure in the WHB
   - CH3 Puncture and Drop of Waste Containers by Forklift in the WHB
   - CH4 Drop of Waste Containers by Forklift in the WHB
   - CH5 Waste Hoist Failure
   - CH7 Spontaneous Ignition (Drum) in the Underground
   - CH9 Drop of Waste Containers by Forklift in the Underground
2. Natural Events
   - CH6 Seismic Event
   - CH10 Tornado Event
   - CH11 Underground Roof Fall
3. External Events
   - CH8 Aircraft Crash

5.2.1 Accident Assessment Methodology

Receptors

A hypothetical maximally exposed off-site individual (MOI) located at the off-limits area (Figure 5.2-1) was selected for the accident-related consequence assessment. Although prevailing winds are towards the northwest at the WIPP Site, the closest distance to the off-limits area (without regard to direction) from the exhaust shaft vent and the WHB vent was used in the dose assessment calculations. The closest distance to the off-limits area boundary from the exhaust shaft vent lies south at approximately 300 meters and the closest distance to the off-limits area boundary from the WHB lies southeast at approximately 350 meters (Figure 5.2-2). The WIPP off-limits area, chosen for MOI consequence assessments and comparison with acceptance criteria, differs from the location chosen for previous analyses. Review of the WIPP Land Management Plan[1] indicates that public access to the WIPP 16-section area up to the "Off-limits Area" shown in Figure 5.2-1 is allowed for grazing purposes, and up to the DOE "Exclusive Use Area" for recreational purposes. Although analyses are traditionally conducted for an MOI at a facility site boundary, in accordance with DOE Order 6430.1A, Section 1300-3.2,[2] the MOI chosen for this analysis is located at the "closest point of public access," or the DOE "Off-limits Area." Calculations are also performed at the site boundary for reference purposes.

Source Term Methodology

The source term Material at Risk (MAR) used in the analyses is based on the waste container inventories (drum and SWB) developed in Section 5.1. Since accidents for the CH TRU waste operations may result in more than one container involved in a postulated accident, each waste container is assumed to contain the maximum radionuclide inventory. As described in Section 5.1, the maximum drum MAR is 80.0 PE-Ci (200 FGE drum) and the SWB MAR at the 325 FGE limit is 130 PE-Ci.

The nonradiological source term (MAR) process for events which involve a breach of a waste container is simplified by assuming the 100% of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-3. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Solid and liquid chemical concentrations that would be expected to be within a waste container during a spontaneous ignition of a waste container are listed in Table 5.1-2. Radiological and chemical source terms (chemical solids/liquids used in the CH1 and CH7 scenarios) developed for specific accidents are estimated using Equation 5-1.

Specific source terms for the postulated accident scenarios described in the accident analysis represent the total amount of respirable radioactive material released to the air from a postulated accident. The Leak Path Factor (LPF) for WIPP accident scenarios is that fraction of the airborne material which is filtered by the WHB or underground exhaust HEPA filtration systems. Bounding values for the Airborne Release Fractions and the Respirable Fractions were utilized based on DOE Handbook, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities.[3]

The following equation reflects the calculation for source term:

$$Q = MAR * DR * ARF * RF * LPF \quad (5\text{-}1)$$

where:

Q = The Source Term (Ci or mg)
MAR = Material At Risk - The maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (Ci or mg).
DR = Damage Ratio - The DR is that fraction of the MAR actually impacted by the accident condition.
ARF = Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF = Respirable Fraction - Fraction of the airborne radioactive particles that are in the respirable size range, i.e. less than 10 μm in aerodynamic equivalent diameter.
LPF = Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident.

Dispersion Modeling Methodology

Nuclear Regulatory Guide (NRG) 1.145,[4] "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1, November 1982, was used to model the accidental releases from the WIPP underground exhaust shaft and the Waste Handling Building. NRG 1.145[4] provides an NRC acceptable methodology to determine site-specific relative concentrations, χ/Qs, as a result of accidents. The model reflects experimental data on diffusion from releases at ground level at open sites and from releases at various locations on reactor facility buildings during stable atmospheric conditions with low wind speeds.

Two type of release models are provided in NRG 1.145:[4] (1) releases through vents or other building penetrations; and (2) stack releases. All release points or areas that are effectively lower than 2.5 times the height of adjacent solid structures are considered nonstack releases. Release points that are at levels 2.5 times the height of adjacent solid structures or higher are considered stack, or elevated releases. Therefore, applying this criteria to the WIPP exhaust shaft and the Waste Handling Building the releases are considered as nonstack releases.

Although the criteria provided in the NRG 1.145[4] suggest a nonstack release, both stack and vent (nonstack) models were evaluated to determine the differences in the dispersion coefficients. The Atmospheric Dispersion Code, GXQ 3.1, described in "Westinghouse Hanford Corporation Support Document," WHC-SD-GN-SWD-30002, Revision 0, June 8, 1993,[5] incorporates the equations used in NRG 1.145[4] and was utilized to evaluate the different models and how they affected the dispersion coefficients. Multiple variations of the models for stack and ground level releases were analyzed with GXQ using various wind speeds and stabilities. However, a ground level release considering a constant wind speed of 1.5 m/s and stability F resulted in larger dispersion coefficients to the receptors of concern which would represent a vent release. These conditions were assumed to prevail for the duration of the accidental release. Therefore, for determining the consequences from the result of postulated accidental releases from the underground or the Waste Handling Building, the following were utilized:

1. NRG 1.145, Releases through Vents or Other Building Penetrations (NRG 1.145, Section 1.3.1)[4] vent release models

2. Pasquill-Gifford-Turner horizontal and vertical diffusion coefficients (GXQ Manual Section 3.1)[5]

3. Atmospheric Conditions:

   - Stability F, 1.5 m/s (wind speed and stability are assumed to remain constant in the direction of the receptor)

4. Dimensions (smallest cross section) of the filter building and the Waste Handling Building:

   - Filter Building - 7 meters high, 27 meters wide

   - Waste Handling Building - 19.2 meters high, 47.8 meters wide

As recommended by the NRG 1.145 Guide,[4] χ/Q values were calculated using equations 5-2, 5-3, and 5-4 below. The values from equations 5-2 and 5-3 were compared and the higher value selected. This value was compared with the value from equation 5-4, and the lower value of these two was selected as the appropriate χ/Q value. Examples and a detailed explanation of the rational for determining the controlling conditions are given in Appendix A of the NRG 1.145 Guide.[4]

Equation
$$\frac{\chi}{Q} = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + \frac{A}{2})} \tag{5-2}$$

Equation
$$\frac{\chi}{Q} = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)} \tag{5-3}$$

Equation
$$\frac{\chi}{Q} = \frac{1}{U_{10}\pi\Sigma_y\sigma_z} \tag{5-4}$$

where:

χ/Q	is relative concentration, in sec/m^3. χ/Q (300 m)=7.7E-04, χ/Q (350 m)=5.96E-04.
π	is 3.14159
U_{10}	is wind speed at 10 meters above plant grade, in m/sec. (assumed 1.5 m/sec.)
σ_y	is lateral plume spread, in meters, a function of atmospheric stability and distance (class F stability). σ_y (300 m)=12.5 σ_y (350 m)=14.3 σ_y(800 m)=30.2
σ_z	is vertical plume spread, in meters, a function of atmospheric stability and distance (class F stability). σ_z (300 m)=5.5 σ_z (350 m)=6.2
Σ_y	is the lateral plume spread with meander and building wake affects, in meters, as a function of atmospheric stability, wind speed U_{10}, and distance (for distances of 800 meters or less), $\Sigma_y = M\sigma_y$, for distances greater than 800 meters, $\Sigma_y=(M-1)\sigma_{y\,800m}+\sigma_y$, where M=4 determined from Figure 3 of NRG 1.145.[4]
A	is the smallest vertical-plane cross sectional area of building, in m^2.

Appendix A of NRG 1.145[4] contains a rationale section which indicates that the equations used in NRG 1.145[4] provide an assessment of atmospheric diffusion, including the effects of building wake mixing that occur during moderate wind speed conditions (>3 m/sec). The equations have been found to provide estimates of ground-level concentrations that are consistently too high during light wind and stable or neutral atmospheric conditions for 1-hour release durations. Consequently the use of these equations in the modelling of the effluent under light wind (1.5 m/sec) and stable atmospheric conditions (F-Class) provides built-in conservatism.

Consequence Methodology

Consequence assessment calculations are determined for the MOI located at the Exclusive Use Area boundary for releases from the WHB vent and the exhaust shaft vent. Radiological dose consequences are calculated assuming the inhalation pathway in CEDE and are calculated using Equation 5-5. External dose calculations were not performed due to there minimal contribution to the Total Effective Dose Equivalent (TEDE), therefore CEDE will be reported as the dose consequences for each of the accidents evaluated. The calculated dose in CEDE is then compared to the off-site radiological acceptance criteria developed in Section 5.2.2 (Table 5.2-1). For nonradiological consequence calculations, the chemical concentration at the MOI in mg/m^3 is calculated using Equation 5-6 for comparison with the nonradiological acceptance criteria developed in Section 5.2.2 (Table 5.2-2). Detailed spreadsheets for the source term and consequence calculations for each postulated accident are found in Appendix E and summarized in Tables 5.2-3 and 5.2-4. To assess the potential releases of radiological and nonradiological material the following equations were utilized:

Radiological Releases

$$D = Q * \chi/Q * BR * DCF \qquad (5\text{-}5)$$

where:

D = Radiological dose (Committed Effective Dose Equivalent (CEDE)) (rem)
Q = Radiological Source Term (Ci) (Appendix E)
χ/Q = Atmospheric dispersion coefficients calculated for specific distances (s/m^3).
χ/Q (300 m)=7.7E-4s/m^3 χ/Q (350 m)=5.96E-04 s/m^3
BR = Breathing rate (standard man) (m^3/s) International Commission on Radiological Protection (ICRP) No.23[6] (Light activity 20.0 liters/min or 3.33 E-04 m^3/s)
DCF = Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public[7] (Pu-239 Class W CEDE Inhalation 5.1E+02 rem/uCi or 5.10E+08 rem/Ci)

Chemical Releases

$$C = (Q * \chi/Q)/RR \quad (5\text{-}6)$$

where:

C = Concentration (mg/m^3)
Q = Chemical Source Term (mg) (Section 5.1.2 and Tables 5.1-2 and 5.1-3)
RR = Release Rate [VOC releases assumed an instantaneous (1 sec) fire within a drum assumed release duration (900 sec)]
χ/Q = Atmospheric dispersion coefficients calculated for specific distances (s/m^3).

Frequency Determination Methodology

The methodology for verifying the occurrence frequencies, qualitatively estimated in the HAZOP, of operational initiating events is based on the evaluation of process inherent events (spontaneous ignition, roof failure), equipment failures, and human error. Appendix D contains the detailed assessment of occurrence frequencies of the accidents evaluated in this section. The occurrence frequencies for process events are estimated based on existing references and engineering judgement. The occurrence frequencies for equipment failures and human errors are based on information from other DOE sites with similar operations, and from generic industry data bases when available, applicable and appropriate.

Equipment failure rates and human error probabilities were combined with WIPP specific operational data to obtain WIPP specific initiating event occurrence frequencies. To determine the occurrence frequencies, logic models were used to describe combinations of failures that can produce a specific failure of interest (TOP event). Basic Events provide specific component failure or human error data which provide input to the logic model to determine the probability of the TOP event. Logical AND (*) or OR (+) functions (gates) are used to show how events can combine to cause the TOP event.

For conservatism, the failure probabilities for accident sequence associated mitigating systems, primarily the failure of above and underground ventilation and HEPA filters, were assumed to be unity (p=1.0).

5.2.2 Off-site Radiological/Nonradiological Acceptance Criteria

Radiological

Off-site radiological dose criteria for accident analyses have been well established by national standards through the licensing process of nuclear facilities regulated by the Nuclear Regulatory Commission (NRC). These criteria are based on the probabilities of occurrence of the accidents or events hypothesized for the accident analysis. For nuclear power plants, the operational accidents or events are classified as Plant Conditions (PC) in accordance with the estimated probability of occurrence.[8,9] This established scheme (ANSI/ANS-51.1)[8] has also been adopted by the WIPP to compare accidental releases from postulated events to dose limits based on estimated likelihood of occurrence. Table 5.2-1 summarizes the acceptance criteria for the assessment of off-site radiological exposures.

Nonradiological

A unique set of approved nonradiological criteria is not found in existing DOE orders. Proposed criteria for application to WIPP is based on Emergency Response Planning Guidelines (ERPG) published by the American Industrial Hygiene Association (AIHA).

Other commonly used guidelines that have been considered in the development of acceptance criteria for the accident analysis include the following:

- Threshold limit-time-weighted average (TLV-TWA)
- Threshold limit value-Short-term exposure limit (TLV-STEL)
- Threshold limit value-Ceiling (TLV-C)
- Permissible exposure limits (PEL)
- Immediately dangerous to life or health (IDLH)
- Emergency response planning guidelines (ERPGs)
- Emergency exposure guidance level (EEGL)
- Short-term public exposure guidance level (SPEGL)

Currently, ERPGs do not exist for most of the nonradiological materials found in TRU mixed waste. Chemicals without established ERPG values will use the following alternate criteria to derive a substitute ERPG assignment:[10]

ERPG-1 (designated TOX-1): Alternate criteria:

- PEL-STEL
- TLV-STEL
- TLV-TWA x 3

ERPG-2 (designated TOX-2): Alternate criteria:

- EEGL (60 minute) or
- PEL-C
- TLV-C
- TLV-TWA x 5

ERPG-3 (designated TOX-3): Alternate criteria:

- EEGL (30 minute)
- IDLH

The derived toxicological limits from the ERPG and alternate criteria are labeled as TOX-1, TOX-2, and TOX-3. The TOXs correspond to ERPG-1, ERPG-2, and ERPG-3, respectively. The compilation of the basis limits for derivation of alternate ERPG limits is provided in Table 5.2-2.[11,12,13]

5.2.3 Accident Analysis

5.2.3.1 CH1 Spontaneous Ignition (Drum) in the WHB

Scenario Description - The spontaneous ignition within a drum in the WHB represents an internal initiated operational accident due to failure of the waste acceptance criteria which prohibits pyrophorics and limits liquids in a waste container. The HAZOP[14] for CH TRU Waste Handling System postulated a spontaneous ignition within a drum occurring while opening the TRUPACT-II. However, it is possible the internal drum fire could occur outside the TRUPACT-II anywhere in the WHB.

For this scenario, after removal of the TRUPACT-II inner containment vessel (ICV) lid a spontaneous ignition of the contents in a single CH drum is postulated. The accident scenario requires that for a sustained waste container fire, spontaneous ignition must occur, and sufficient oxidant and heat of combustion must be available. Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the WHB it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment and continuously high efficiency particulate air (HEPA) filters which filter exhaust air. As analyzed in DOE/WIPP 87-005,[15] Waste Drum Fire Propagation at the WIPP, the fire is postulated to impact a single drum only.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features are assumed to fail or are not in place.

For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage HEPA.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). However, based on a quantitative evaluation using conservative assumptions documented in Appendix D, the frequency of spontaneous ignition is 1.47E-2/yr, and the probability of a sustained drum fire is 6.2E-5/yr. Therefore, for the purposes of evaluating the consequences in terms of frequency of occurrence, the spontaneous ignition is considered extremely unlikely ($10^{-4} \geq p > 10^{-6}$).

Source Term Development

Material at Risk-Radiological - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in a single drum. As discussed in Section 5.1.2, a single drum inventory has been established as 80.0 PE-Ci which provides the MAR for a spontaneous ignition within a drum.

Material at Risk-Nonradiological - As discussed in Section 5.1.2, the solid and liquid chemical compound concentrations that would be expected to be within a waste container (Table 5.1-2) are used as the nonradiological MAR.

Damage Ratio - The accident scenario involves a spontaneous ignition in a drum, therefore it is necessary to discuss the amount of material that will burn (combustible fraction) and the amount of material that will be subjected to thermal stress (heating without ignition) (noncombustible fraction) in order to determine the amount of material that could be released to receptors of concern. The waste form within a drum (combustibles vs noncombustibles) is estimated based on information provided in the Project Technical Baseline (PTB)[16] (Chapter 4, Waste Description). Combustible waste is defined as consisting of paper, kimwipes, and cloth (dry and damp); various plastics such as polyethylene and polyvinyl chloride; wood; and filters contaminated with trace quantities of halogenated organic solvents.

The combustible waste distribution was calculated using the volume percentages expected of each waste form. Forty percent is conservatively used in anticipation that newly generated waste resulting from cleanup operations may result in a greater combustible fraction. The remainder of the material in the drum (60%) is assumed to be noncombustible (sludges, filters, asphalt, soil, glass, metal, other). The radioisotopes within the drum are assumed to be evenly distributed throughout the waste in the drum, therefore 40% of the radioactivity is assumed to be combustible material at risk and 60% of the radioactivity is assumed to be noncombustible material at risk.

Airborne Release Fraction - The ARF for combustible materials in a drum is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03. These values represent bounding airborne release fractions for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Respirable Fraction -The bounding RFs for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Leakpath Factor - The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[17] Based on the handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case, and 1.0 for the unmitigated case.

Estimated Consequences and Comparison to Acceptance Criteria - Based on these calculations using the assumptions presented above, the consequences of the Spontaneous Ignition (Drum) in the WHB (CH1) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

- Waste Handling Building (Structure) - Design Class II (Provide physical confinement)
- Waste Handling Building Exhaust System HV01 (BLDG 411, CH HVAC) - Design Class IIIA (Design Class Interface provides filtration and maintain differential pressure)
- HEPA Filters - Design Class II (Provides the control of radioactive effluent)

5.2.3.2 CH2 Crane Failure in the WHB

Scenario Description - The possibility of a crane accident in the WHB was identified in the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during crane handling. Table 5.1-7 lists four crane failure/breach events which result from 1) failure of lifting equipment , 2) failure to secure load, 3) failure to remove payload, and 4) moving accident with the ICV lid in the OP&RR. As determined in the HAZOP each of the events involve negligible release of radioactive and nonradioactive materials and all occur within the WHB. The failure of lifting equipment during TRUDOCK crane operations bounds all other crane handling accidents in the WHB due to height of lift and total waste containers involved.

A typical TRUPACT II contains fourteen 55-gallon drums that are stretch wrapped or banded together into seven packs or the TRUPACT II may contain up to two SWBs in place of the 55-gallon drums. For this scenario, during TRUPACT unloading, the TRUDOCK crane is assumed to drop the load at the point at which the load is at its greatest height, just over the TRUDOCK railing, crushing the bottom waste containers (7 drums or 1 SWB). Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the WHB it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment and continuously HEPA filters exhaust air.

Also, waste handlers are trained and certified in safe and proper equipment operation (following accepted hoisting and rigging practices) and preoperational inspections. Additionally, the crane design provides for fail safe condition during loss of power (brake set during loss of power). Nevertheless, a release of radiological and nonradiological material is assumed to occur as a result of waste containers falling in excess of 4 ft due to equipment or human (operator) error.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, these preventive/mitigative features are assumed to fail or are not in place.

For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage HEPA.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of a crane dropping the load to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). This estimated frequency has also been verified in Appendix D.

Source Term Development

Material at Risk - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in seven drums or one SWB. The material at risk for the drums and the SWB is determined by multiplying the drum inventory (80.0 PE-Ci) by the number of drums breached (7) and multiplying the SWB inventory (130.0 PE-Ci) by the number of SWBs breached (1).

Damage Ratio - A bounding damage ratio of 0.25 for dropped drums is assumed. The damage ratio for dropped SWBs is assumed to be 0.1 based on the robust construction and bolted lid design making the SWB less susceptible to damage during handling operations (DWG NO. 165-F-001-W REV F[18] and ANSI MH2-1991[19]).

Airborne Release Fraction -The ARF for materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Respirable Fraction - The bounding RF applied to airborne material released due to impact is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Leakpath Factor - The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in the ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[17] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore, the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case and for the unmitigated case an LPF of 1.0 is assumed.

Estimated Consequences and Comparison to Acceptance Criteria - Based on the calculations presented above, the consequences of the Crane Drop in the WHB (CH2) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

- Waste Handling Building - Design Class II (Provides physical confinement)
- Waste Handling Building Exhaust System HV01 (BLDG 411, CH HVAC) - Design Class IIIA (Design Class Interface provides filtration and maintains differential pressure)
- HEPA Filters - Design Class II (Provides the control of radioactive effluent)
- TRUDOCK crane - Design Class IIIA (Failure could cause waste container release)

5.2.3.3 CH3 Puncture and Drop of Waste Containers by Forklift in the WHB

Scenario Description - The possibility of a puncture and a drop of waste containers by a forklift in the WHB was identified in the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste handling. Table 5.1-7 lists one forklift mishap event which results from forklift improper engagement of the load. This scenario bounds all other puncture and drop events involving forklift operations in the WHB due to the total number of waste containers handled during these operations.

After the facility pallet is loaded (contents of two TRUPACT IIs, 28 drums stretch wrapped or banded together in seven packs or 4 SWBs), a forklift equipped with standard tines is used to transport the facility pallet. In preparation of this process, the operator is assumed to improperly engage the fork lift tines in the facility pallet resulting in puncturing the waste containers. The impact from the forklift tines is assumed to puncture two drums or two SWBs on the bottom layer of the stacks on the facility pallet. Each stack on the facility pallet consists of seven drums per layer stacked two layers high, or two SWBs, one SWB per layer. Operating procedures caution the operator not to disengage the forklift once the drums have been punctured, but it is assumed that the forklift tines are disengaged from the drums causing material to be released. Although the waste containers are Type A packages certified through design and testing to withstand a fall from four feet without releasing the contents this analysis also assumes two drums (or two SWBs) are knocked off the stacks during impact breaching their containers in order to provide bounding consequences.

Safe operation of forklifts at the WIPP is accomplished through; 1) qualified and fully trained drivers , 2) qualified drivers that are responsible for the care and operating condition of their equipment, 3) operation of the forklifts at slow speeds within the WHB and 4) stopping operation and reporting mechanical difficulties with the equipment. Waste handlers are trained and certified in safe and proper equipment operation and preoperational inspections. Nevertheless, a release of radiological and nonradiological material is assumed to occur as a result of two drums (or two SWBs) that are punctured and two drums (or two SWBs) that are dropped as a result of equipment or human (operator) error.

Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the WHB it is not expected to result in loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment and continuously HEPA filters exhaust air.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features are assumed to fail or are not in place.

For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage high efficiency particulate filters (HEPA).

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of a puncture and drop of waste containers to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). This estimated frequency has also been verified in Appendix D to be in the same range. Therefore, for the purpose of evaluating the consequences in terms of frequency of occurrence, this scenario is considered unlikely.

Source Term Development

Material at Risk - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in four drums or two SWBs. The material at risk for the drums and the SWB is determined by multiplying the drum inventory (80.0 PE-Ci) by the number of drums breached (4) and multiplying the SWB inventory (130.0 PE-Ci) by the number of SWBs breached (2).

Damage Ratio - A bounding damage ratio of 0.25 for the drums that are dropped and 0.1 for the drums that are punctured is assumed. The damage ratio for the SWBs (for drop or puncture) is assumed to be 0.1 based on the construction of the standard waste box which utilizes material that is 10-gauge steel (0.1285 in minimum) and a bolted lid design making the SWB less susceptible to damage during handling operations (DWG NO. 165-F-001-W REV F[18] and ANSI MH2-1991[19]).

Airborne Release Fraction - The ARF for materials which are subjected to puncture and impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Respirable Fraction -The bounding RF applied to the airborne material released due to puncture or impact is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Leakpath Factor - The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[17] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore, the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case and for the unmitigated case a LPF of 1.0 is assumed.

Estimated Consequences and *Comparison to Acceptance Criteria* - Based on the calculations presented above, the consequences of the Puncture and Drop of Waste Containers in the WHB (CH3) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and at the site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

- Waste Handling Building - Design Class II (Provides physical confinement)
- Waste Handling Building Exhaust System HV01 (BLDG 411, CH HVAC) - Design Class IIIA (Design Class Interface provides filtration and maintains differential pressure)
- HEPA Filters - Design Class II (Provides the control of radioactive effluent)

5.2.3.4 CH4 Drop of Waste Containers by Forklift in the WHB

Scenario Description - The possibility of waste container breaches due to drops in the WHB was identified in the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste handling. For this type of event Table 5.1-7 lists four failure/breach events which result from 1) mislocation on the conveyance car , 2) moving accident, 3) transfer failure from TRUDOCK to OP&RR, and 4) moving accident with payload. As determined in the HAZOP each of the events involve negligible release of radioactive and nonradioactive materials and all occur within the WHB. The drop of waste containers from a forklift during waste handling operations in the WHB bounds all other moving or forklift drops due to the total number of waste containers involved during these operations.

Once the waste containers are loaded onto the facility pallet (contents of two TRUPACT IIs, 28 drums or 4 SWBs), a forklift equipped with standard tines is used to transport the facility pallet. The facility pallet can be transported to the conveyance loading room or the shielded storage room. Overpacked waste containers are also transferred from the OP&RR to the facility pallet loading area. Although the waste containers are Type A packages certified through design and testing to withstand a fall from four feet without releasing the contents it is assumed during the transport of waste containers within the WHB that waste containers are dropped and breached.

Safe operation of forklifts at the WIPP is accomplished through; 1) only qualified and fully trained drivers are permitted to operate forklifts, 2) qualified drivers will be responsible for the care and operating condition of their equipment, 3) qualified drivers complete preoperational inspections, 4) forklifts shall be operated at slow speeds within the WHB and 5) in the case of mechanical difficulties the driver is responsible to stop the equipment and report the problem. Nevertheless, a release of radiological and nonradiological material is assumed to occur as a result of four drums (or two SWBs) dropped from the facility pallet causing a breach of the waste containers due to equipment or human (operator) error.

As stated in previous scenarios in the WHB, although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the WHB it is not expected there is loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features are assumed to fail or are not in place.

For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage high efficiency particulate filters (HEPA).

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of a drop of waste containers to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). However, this estimated frequency has been determined to be in the anticipated range ($1 \geq p > 10^{-2}$) as documented in Appendix D. Therefore, for the purposes of evaluating the consequences in terms of frequency of occurrence this scenario is considered anticipated.

Source Term Development

Material at Risk - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in four drums or two SWBs. The material at risk for the drums and the SWB is determined by multiplying the drum inventory (80.0 PE-Ci) by the number of drums breached (4) and multiplying the SWB inventory (130.0 PE-Ci) by the number of SWBs breached (2).

Damage Ratio - A bounding damage ratio of 0.25 for the drums that are dropped is assumed. The damage ratio for the SWBs (for drop or puncture) is assumed to be 0.1 based on the construction of the standard waste box which utilizes material that is 10-gauge steel (0.1285 in minimum) and a bolted lid design making the SWB less susceptible to damage during handling operations (DWG NO. 165-F-001-W REV F[18] and ANSI MH2-1991[19]).

Airborne Release Fraction - The ARF for materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Respirable Fraction - The bounding RF applied to the airborne material released from each of the waste containers that are breached is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Leakpath Factor - The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[17] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case, and for the unmitigated case a LPF of 1.0 is assumed.

Estimated Consequences and Comparison to Criteria - Based on the calculations presented above, the consequences of the Drop of Waste Containers by forklift in the WHB (CH4) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and at the site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

- Waste Handling Building - Design Class II (Provides physical confinement)
- Waste Handling Building Exhaust System HV01 (BLDG 411, CH HVAC) - Design Class IIIA (Design Class Interface provides filtration and maintains differential pressure)
- HEPA Filters - Design Class II (Provides the control of radioactive effluent)

5.2.3.5 CH5 Waste Hoist Failure

Scenario Description - The possibility of a waste hoist failure has been identified as part of the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which may involve a breach of waste container(s) during a waste hoist failure. Table 5.1-7 lists one waste hoist drop event which results from hoist failure.

The waste hoist is a counterbalanced multi-rope friction hoist that operates a single conveyance in the waste shaft. It is used primarily to transport waste from the surface facilities to the underground repository and secondarily to transport personnel and machinery.

During transportation to the underground, it is postulated that a simultaneous break of the hoisting cables (six) or loss of power event occurs and, a failure in the hoist braking system.

Preventive and Mitigative Features - General preventive and mitigative measures were identified in the HAZOP process for this specific scenario and are listed in Table 5.1-7. These measures should be reviewed to comprehend the amount of features that are in place that either prevent and/or mitigate against this accident.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of a hoist failure to be incredible (incredible $10^{-6} \geq p$). This estimated frequency of occurrence has also been verified in Appendix D.

Source term Development - The probability of the accident scenario is incredible, therefore source term development is not required.

Estimated Consequences and Comparison to Acceptance Criteria - The probability of the accident scenario is incredible, therefore consequence analysis is not required.

Verification of Design Classification - The consequence of the waste hoist failure was not evaluated because the probability of failure was defined as incredible. Therefore, a comparison of the consequences to the acceptance criteria which would provide a basis for design classification verification was not performed. Instead, the waste hoist was evaluated against the Design Class definitions identified in the SAR Chapter 3, Principal Design and Safety Criteria. When compared to the definitions the waste hoist system is correctly categorized as a Design Class IIIA. The following Design Class IIIA selection criteria were used to make this evaluation:

- Where failure could cause a major sustained stoppage of waste handling and disposal operations.

- Design and fabrication complexity or uniqueness.
- Equipment with unique subassemblies that require replacement subassemblies to be identical in terms of function, form, and fit.
- Potential for contamination due to component failure
- Equipment failure could be of special significance to the health and safety of operating personnel

5.2.3.6 CH6 Seismic Event

Scenario Description - The possibility of a seismic event has been identified as part of the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents a natural phenomena induced accident which may involve the potential breach of waste containers.

As discussed in Chapters 2 and 3 of this SAR, the Design Basis Earthquake (DBE) is the most severe credible earthquake expected to occur at the WIPP Site. The DBE is based on a 1000-year return interval established through a site specific study. The maximum ground acceleration for the DBE is 0.1 g in both the horizontal and vertical directions, with 10 maximum stress cycles.

It is expected that as a result of the DBE, internal events within the Waste Handling Building (WHB) may cause the loss of primary confinement (e.g. process/equipment disruption resulting in waste container drops/falls and breaches) and release airborne radiological or nonradiological hazardous materials. The above ground WHB CH waste handling process was reviewed to determine the process step (1) most vulnerable to the DBE, and (2) bounding in terms of potential to release airborne hazardous materials.

The processes of TRUPACT unloading and movement of waste containers on the facility pallet to the conveyance loading room are considered as the most vulnerable to DBE movement, and bounding in terms of number of waste containers involved (28 drums on facility pallet or 4 SWBs). However, as discussed in Chapter 4, the 5-ton TRUDOCK cranes are designed to hold their loads in the event of the DBE. Therefore, no resultant release of hazardous materials can be postulated during TRUPACT unloading.

Additionally, the main lateral force resisting members of the Support Building and Building 412 are DBE designed to protect the WHB from their structural failure.

The original design for WIPP used the 1982 Uniform Building Code and predated both DOE 6430.1A[2] and UCRL-15910.[20] An updated assessment of the DBE was performed in 1990 by Bechtel.[22] The assessment showed that the design classifications shown in the original design for WIPP either met or exceeded the newer standards for DBE for nonreactor facilities.

It can be postulated that drum fall/drops and breaches may occur as a result of the DBE while moving waste containers on the facility pallet to the conveyance loading room. This process step is discussed in detail in Chapter 4, however, as a result of the existing process design (Type A container design, facility pallet and tiedown and lateral straps, etc.), procedures, operator training, etc., no credible release scenario can be postulated.

As discussed in Section 4.4, the WHB secondary confinement is designed to remain functional (following DBEs) to the extent that the guidelines in DOE 6430.1A, Section 1300-1.4.2, Accidental Releases,[2] are not violated. Design Class II DBE SSCs (see Table 4.1-1) are designed to withstand a free-field horizontal and vertical ground acceleration of 0.1 g, based on a 1000-year recurrence period, and retain their safety function. The WHB structure and structural components, including tornado doors are designed to withstand the DBE.

Therefore, no credible release scenario could be postulated for loss of primary confinement (waste container breach) as a result of the DBE. In conclusion, there are no consequences to the off-site public as a result of the WIPP DBE aboveground.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. These measures should be reviewed to comprehend the amount of features that are in place that either prevent and/or mitigate against this accident.

Estimated Likelihood - The DBE is based on a 1000-year return interval.

Source Term Development - No hazardous material is postulated to be released during the DBE, therefore, no source term is developed.

Estimated Consequences and Comparison to Acceptance Criteria - No hazardous material is postulated to be released during the DBE, therefore, no consequence analysis is developed.

Verification of Design Classification - No hazardous material is postulated to be released during the DBE, and verification of design classification is not required. DBE SSCs are assumed to function as designed during the DBE. No change in design classification or design is required.

5.2.3.7 CH7 Spontaneous Ignition (Drum) in the Underground

Scenario Description - The HAZOP for CH TRU Waste Handling System postulates a spontaneous ignition within a drum in route to or within the waste disposal panel. Based on DOE/WIPP 87-005,[15] Waste Drum Fire Propagation at the WIPP, the fire is not postulated to propagate to additional drums.

The spontaneous ignition within a drum in the underground represents an internal initiated operational accident due to failure of the waste acceptance criteria which prohibits pyrophorics and limits liquids in a waste container. The accident scenario requires that for a sustained waste container fire, spontaneous ignition must occur, and sufficient oxidant and heat of combustion must be available. Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the underground it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the Central monitoring room (CMR) operator, or automatically due to a continuous air monitor (CAM) alarm logic sequence.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features fail or are not in place.

For the mitigated case, credit is taken for automatic or manual shift of the underground ventilation system to the HEPA filtration mode.

Estimated Likelihood - As part of the HAZOP[14], the team qualitatively estimated the frequency of occurrence of each event. Based on this study, the frequency of occurrence of a spontaneous ignition has been estimated to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). However, based on a quantitative evaluation using conservative assumptions documented in Appendix D the frequency of spontaneous ignition is 1.47E-2/yr, and the probability of a sustained drum fire is 6.2E-5/yr. Therefore, for the purposes of evaluating the consequences in terms of frequency of occurrence the spontaneous ignition is considered extremely unlikely ($10^{-4} \geq p > 10^{-6}$).

Source Term Development

Airborne Release Fraction - The ARF for combustible materials in a drum is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03. These values represent bounding airborne release fractions for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Respirable Fraction - The bounding RFs for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Damage Ratio - The accident scenario involves a spontaneous ignition in a drum, therefore it is necessary to discuss the amount of material that will burn (combustible fraction) and the amount of material that will be subjected to thermal stress (heating without ignition) (noncombustible fraction) in order to determine the amount of material that could be released to receptors of concern. The waste form within a drum (combustibles vs noncombustibles) is estimated based on information provided in the PTB[16] document (Chapter 4, Waste Description). Combustible waste is defined as consisting of paper, kimwipes, and cloth (dry and damp); various plastics such as polyethylene and polyvinyl chloride; wood; and filters contaminated with trace quantities of halogenated organic solvents.

The combustible waste distribution was calculated using the volume percentages expected of each waste form. Forty percent is conservatively used in anticipation that newly generated waste resulting from cleanup operations may result in a greater combustible fraction. The remainder of the material in the drum (60%) is assumed to be noncombustible (sludges, filters, asphalt, dirt, glass, metal, other). The radioisotopes within the drum are assumed to be evenly distributed throughout the waste in the drum, therefore 40% of the radioactivity is assumed to be combustible material at risk and 60% of the radioactivity is assumed to be noncombustible material at risk.

Airborne Release Fraction - The airborne release fraction for combustible materials in a drum is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03 (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Respirable Fraction - The bounding respirable fractions for combustible and noncombustible are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[3]

Leakpath Factor - Based on the Final Environmental Impact Statement[21] (FEIS), it is assumed that fifty percent of the particulates will be depleted from the release by fallout in the drifts and will not reach the environment. In addition, the amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[17] Based on the handbook, a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore, the total DF used in this analysis for both stages of filtration is 1.0E+06. When 0.5 (depletion) is combined with 1.0E-06 (HEPA efficiency), the leakpath factor is 5.0E-07 for the mitigated case, and 1.0 for unmitigated case.

Estimated Consequences and Comparison to Acceptance Criteria - Based on the calculations presented above, the consequences of a spontaneous ignition in the Underground (CH7) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and the site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Table 4.1-1, identifies those Design Class SSCs, Table 3.1-2 identifies the applicable design code requirements. Detailed design information may be found in the respective System Design Description.

Design Class SSCs from Table 4.1-1 applicable to this accident scenario are the:

1. Underground Ventilation System
   - HEPA Filters - Design Class II (Provide Control of Radioactive Effluent)
   - Exhaust Fans for the Filtration Mode-Design Class II [Design Class Interface Channels Exhaust air through the Exhaust Filter Building (EFB)]
2. Station A Effluent Monitoring Shed - Design Class II [Design Class Interface (Houses Station A)]
3. Effluent Monitoring Rooms A and B - Design Class II [Design Class Interface (Houses Local Processing Units collecting data from Stations A and B)]
4. Station B Effluent Monitoring Instrument Shed - Design Class IIIA [Design Class Interface (Houses monitoring equipment for the Exhaust Filter Building duct)]
5. Radiation Monitoring System Station A units A1 and A2 - Design Class II (Monitors and Controls radioactive effluent)
6. Exhaust Filter Building - Design Class IIIA [Design Class Interface (Houses Exhaust Filtration System)]

5.2.3.8 CH8 Aircraft Crash

Scenario Description - The possibility of an aircraft crash into the WHB has been identified as part of the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an external accident which may involve the potential breach of waste containers. It is postulated that a military or civilian aircraft crashes into the WHB. For the development of the frequency of aircraft crashes, the U.S. Nuclear Regulatory Commission Standard Review Plan (SRP) NUREG-0800[23] is used. This SRP provides criteria for the development of frequencies of aircraft accidents to be used in analyses for nuclear power plants. The SRP provides criteria for crash frequency contributions associated with airport operations (takeoffs and landings), and federal airway activity (overflights).

As described in Chapter 2 of this SAR, two federal ten-mile wide airways (one jet route and one low-altitude route) pass within five miles of the WIPP. Traffic data show that the combined traffic is about 28 instrument flight rule flights per day.

There are no airports or approaches within a five-mile radius of the WIPP. The nearest airstrip, 12 miles north of the site, and privately owned by Transwestern (TW) Pipeline Co. is no longer in use and TW filed for abandonment in 1990 with the Federal Aviation Administration. The nearest commercial airport is in Carlsbad (28 miles to the west).

There are no military facilities within a five mile radius of the WIPP, however, some military installations in New Mexico and Texas have operations that might affect the WIPP (the closest is Holloman Air Force Base, 138 miles NW of the site).

Using NUREG-800[23], the total aircraft hazard probability (combined airway, and airport) at the WIPP site is 1.03E-07/yr.

Preventive and Mitigative Features - Air space above facility not part of normal flight patterns and WIPP is in a remote location.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of an aircraft crash to be incredible (incredible $10^{-6} \geq p$). This estimated frequency of occurrence has also been verified in Appendix D using NUREG-0800[23], considering the total aircraft hazard probability (combined airway, airport, and military designated airspace operations probability of an aircraft crash).

Source term Development - The probability of the accident scenario is incredible therefore, source term development is unnecessary.

Estimated Consequences and Comparison to Acceptance Criteria - The probability of the accident scenario is incredible therefore, consequence analysis is unnecessary.

Verification of Design Classification - This scenario is considered incredible and no hazardous material is postulated to be released during this scenario, therefore, no verification of design classification is developed, nor change in design classification or design is required.

5.2.3.9 CH9 Drop of Waste Containers by Forklift in the Underground

Scenario Description - The possibility of waste container breaches due to drops in the underground was identified in the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste emplacement. For this type of event Table 5.1-7 lists one forklift mishap/breach event which results from the operator not observing the floor distortion which causes the forklift to tip and result in dropping of the load. Floor surveys and MSHA inspections are conducted to preclude this type of event, however it is assumed the drop could also occur not only from human error but also from equipment failure. The drop of waste containers from a forklift during waste emplacement operations in the underground bounds all other forklift drops due to the total number of waste containers involved during these operations.

Once the waste containers are at the bottom of the waste shaft, the pallet locking pins are removed and the facility pallet is pulled from the hoist to the transporter with a hydraulic driven screw hook latch. The transporter then carries the pallet to the emplacement area.

In the emplacement room, the tie-down and lateral straps are removed and a fork lift is used to place the waste containers in their final location. The fork lift uses a solid platform with a hydraulic push-pull device to handle the seven-drum arrays or a vertical tanged lifting device to engage the standard waste box lifting slots. The operator, aided by a spotter and the transporter driver, places the waste containers in the desired emplacement position (7-drum arrays stacked 3 layers high or single SWBs stacked three layers high).

During emplacement of a 7-or 14-drum array or one or two SWBs, the operator is assumed to improperly disengage the forklift and the waste containers drop from a height of greater than 4 feet causing a breach of seven drums or a single SWB.

Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the underground it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the CMR, or automatically due to a CAM alarm logic sequence.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features are assumed to fail or are not in place.

For the mitigated case, credit is taken for automatic or manual shift of the underground ventilation system to the HEPA filtration mode. It is assumed for this scenario, that the waste handler initiates the manual shift of the underground ventilation system to filtration.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of a drop of waste containers to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$). This estimated frequency has been determined to be in the same range in Appendix D. Therefore for the purposes of evaluating the consequences in terms of frequency of occurrence this scenario is considered unlikely.

Source Term Development

Material at Risk - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in seven drums or one SWB. The material at risk for the drums and the SWB is determined by multiplying the drum inventory (80.0 PE-Ci) by the number of drums breached (7) and multiplying the SWB inventory (130.0 PE-Ci) by the number of SWBs breached (1).

Damage Ratio - A bounding damage ratio of 0.25 for the dropped drums is assumed. The damage ratio for the dropped SWB is assumed to be 0.1, based on the robust construction and bolted lid design making the SWB less susceptible to damage during handling operations (DWG NO. 165-F-001-W REV F[18] and ANSI MH2-1991[19]).

Airborne Release Fraction - The ARF for materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Respirable Fraction - The bounding RF applied to the airborne material released from each of the waste containers that are breached is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Leakpath Factor - Based on the 1980 Final Environmental Impact Statement[21] (FEIS) it is assumed that fifty percent of the particulates will be depleted from the release by fallout in the drifts and will not reach the environment. In addition, the amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[17] Based on the handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. When 0.5 (depletion) is combined with 1.0E-06 (HEPA efficiency) the leakpath factor is 5.0E-07 for the mitigated case, and 1.0 for unmitigated case.

Estimated Consequences and Comparison to Acceptance Criteria - Based on the calculations presented above, the consequences of a drop of waste containers from a forklift in the underground (CH9) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at the Exclusive Use Area and at the site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

1. Underground Ventilation System

   - HEPA Filters - Design Class II (Provide Control of Radioactive Effluent)

   - Exhaust Fans for the Filtration Mode - Design Class II [Design Class Interface Channels Exhaust air through the Exhaust Filter Building (EFB)]

2. Station A Effluent Monitoring Shed - Design Class II [Design Class Interface (Houses Station A)]

3. Effluent Monitoring Rooms A and B - Design Class II [Design Class Interface (Houses Local Processing Units collecting data from Stations A and B)]

4. Station B Effluent Monitoring Instrument Shed - Design Class IIIA [Design Class Interface (Houses monitoring equipment for the Exhaust Filter Building duct)]

5. Radiation Monitoring System Station A units A1 and A2 - Design Class II (Monitors and Controls radioactive effluent)

6. Exhaust Filter Building - Design Class IIIA [Design Class Interface (Houses Exhaust Filtration System)]

5.2.3.10 CH10 Tornado Event

Scenario Description - The possibility of a tornado event has been identified as part of the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents a natural phenomena induced accident which may involve the potential breach of waste containers.

As discussed in Chapters 2 and 3 of this SAR the Design Basis Tornado (DBT) is the most severe credible tornado that could occur at the WIPP Site. The DBT used for the WIPP has a maximum wind speed of 183 mi/hr (including effects of suction vortices), translational velocity of 41 mi/hr, tangential velocity of 124 mi/hr, a 325 ft radius of maximum wind, pressure drop of 0.5 lb/in^2, and rate of pressure drop of 0.09 lb/in^2/sec, with a mean recurrence interval of 1,000,000 years.

No internal events within the WHB can be postulated to cause the loss of primary confinement (e.g. process/equipment disruption resulting in waste container drops/falls and breaches) and release airborne radiological or nonradiological hazardous materials as a result of the DBT.

As discussed in Section 4.4, the WHB secondary confinement is designed to remain functional (following DBAs) to the extent that the guidelines in DOE 6430.1A,[2] Section 1300-1.4.2, Accidental Releases, are not violated. Design Class II DBT SSCs (see Table 4.1-1) are designed to withstand winds generated by this tornado (183 mi/h), based on a 1,000,000-year recurrence period, and retain their safety function. The WHB structure and structural components, including tornado doors and tornado dampers are designed to withstand the DBT.

With regard to the effects of missiles generated by the DBT, the WIPP is designed on a single failure basis. It is considered incredible that two or more failure events can occur simultaneously, therefore, the effects of missiles are not evaluated.

Table 4.1-1, identifies those Design Class II and IIIA DBT SSCs, Table 3.1-2 identifies the applicable design code requirements, and Section 3.2 identifies the applicable DBT structural design criteria for WIPP DBT SSCs. Detailed design information may be found in the respective System Design Description.

Design Class II and IIIA SSCs from Table 4.1-1 applicable to the DBT aboveground are the:

- WHB structure and structural components including tornado doors - Design Class II (Provides physical confinement)
- WHB tornado dampers - Design Class II (Controls radioactive effluent)

Additionally, the main lateral force resisting members of the support building and building 412 are DBT designed to protect the WHB from their structural failure.

As shown in Table 3.1-2, Design Class I, II, and IIIA structures and supports necessary for the confinement of radioactivity (secondary confinement) are DBT designed. Therefore, no releases of hazardous materials are postulated as a result of the WIPP DBT designed mitigative/preventative secondary confinement SSCs.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7.

Estimated Likelihood - The Design Basis Tornado (DBT) is the most severe credible tornado (183 mi/hr) that could occur at the WIPP site, based on a 1,000,000-year recurrence period.

The DBT was developed by a site specific study SMRP No. 155, "A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico," Department of Geophysical Sciences, T. Fujita, University of Chicago, February 1978 and its Supplement of August 1978.[24]

Source Term Development - No hazardous material is postulated to be released as a result of the DBT, therefore, the source term development is not required.

Estimated Consequences and Comparison to Acceptance Criteria - No hazardous material is postulated to be released as a result of the DBT, therefore, consequence analysis is not required.

Verification of Design Classification - No hazardous material is postulated to be released during the DBT, and verification of design classification is not required. DBT SSCs are assumed to function as designed during the DBT, therefore, no change in design classification or design is required.

5.2.3.11 CH11 Underground Roof Fall

Scenario Description - The possibility of waste container breaches due to a roof fall in the underground was identified in the HAZOP[14] performed for the CH TRU Waste Handling system. This scenario represents a natural event which involves a breach of waste container(s) during waste handling or emplacement. For this type of event Table 5.1-7 lists two roof fall events which occur in the storage room and the life of facility area. As determined in the HAZOP each of the events involve negligible release of radioactive and nonradioactive materials and all occur within the underground. The roof fall event during emplacement operations in the underground bounds all other roof falls due to the total number of waste containers in the area during these operations.

Based on the throughput described in Chapter 4 and the two years required to mine a panel, panels two through eight will be open for approximately 4.5 years. Room 1 in the Site and Preliminary Design Validation (SPDV) was eight years old when the roof fall occurred in 1991 (DOE/WIPP 93-033).[26]

A roof (back) collapse in panels two through eight is considered to be incredible ($\leq 10^{-6}$) because the panels will be mined, filled with waste, and closed before a roof fall in these panels becomes a concern. Because panel one has been open since 1986, it is postulated that an underground roof (back) collapse may occur during waste emplacement causing 21 drums or 5 SWBs to fall from the top of the stack resulting in a breach of the drums and SWBs, although the roof life has been extended by the supplementary roof support system.[25] A roof fall similar to the roof fall that occurred in the Site and Preliminary Design Validation (SPDV) Room 1 on February 4, 1991 (DOE/WIPP 93-033)[26] is assumed. The section that fell was approximately 33 feet wide by seven feet high by 180 feet long and weighed 700 tons. The surface area of the roof fall was 5,940 square feet. The roof fall is expected to produce a force generally in the vertical direction.

Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the underground it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the central monitoring room (CMR) operator, or automatically due to a CAM alarm logic sequence.

Drums

The number of drums that can be placed under this predicted roof fall, stacked 3 layers high (longest dimension vertical) in seven pack configuration, is 3,843. The maximum drum weight allowed by the WIPP WAC[28] is 1,000 pounds. Assuming the top two layers of drums in the waste stack are loaded to the maximum weight of 1,000 pounds, a loading of 2,562,000 pounds would be applied to the bottom drums. With the added weight of the roof fall material, a total weight of 3,962,000 pounds would be applied to the bottom drums or a load of 3,100 pounds per drum.

Sandia report SAND80-2517[27], Analysis, Scale Modeling, and Full-Scale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments, concluded that in order to crush a drum 12 inches in the axial direction a load of about 15,000 to 80,000 pounds was required. The lid did not separate from the drum and the drum did not breach during the test. Deformation of the drum began at a load of about 15,000 pounds.

Test and Evaluation Document for DOT Specification 7A Type A Packaging[29] performed compression tests on the DOT-7A drum in the axial direction. A test weight of 5,100 pounds was used. The drum passed the test with no damage detected.

Even if some of the drums are breached, the material falling is expected to encapsulate the waste and the material available to be released will be minimal. Therefore, no release of radiological or nonradiological hazardous materials is expected from the loading of drums due to added weight of roof fall material. However, for conservatism it is postulated that 21 drums in the waste stack face will be displaced from the waste stack due to the vertical force of the waste fall material and breached.

Standard Waste Box (SWB)

The number of SWBs that can be placed under the predicted roof fall, stacked 3 high and 5 wide (longest dimension horizontal), is 555. The maximum SWB weight allowed by the WAC[28] is 4,000 pounds. Assuming the top two layers of SWBs in the waste stack are loaded to the maximum weight of 4,000 pounds, a loading of 1,480,000 pounds would be applied to the bottom drums. With the added weight of the roof fall material a total weight of 2,880,000 pounds would be applied to the bottom SWBs, or a load of 15,600 pounds per SWB.

Test and Evaluation Document for DOT Specification 7A Type A Packaging[29] performed compression test on the SWB from the top of the bottom. A test weight of 21,105 pounds was used. The SWB passed the test with no damage detected.

Even if some of the SWBs are breached, the material falling is expected to encapsulate the waste and the material available to be released will be minimal. Therefore, no release of radiological or nonradiological hazardous materials is expected from the loading of drums due to the added weight of roof fall material. However, for conservatism it is postulated that five SWBs in the waste stack face will be displaced by the roof fall from the waste stack and breached.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the unmitigated case, mitigative features fail or are not in place. For the mitigated case, credit is taken for automatic or manual shift of the underground ventilation system to the HEPA filtration mode.

Estimated Likelihood - The HAZOP team qualitatively estimated the frequency of occurrence of this scenario to be in the unlikely range (unlikely $10^{-2} \geq p > 10^{-4}$).

Source Term Development

Material at Risk - Based on the postulated scenario, the material at risk for this accident has been determined to be the inventory contained in twenty one drums or five SWBs. The material at risk for the drums and the SWB is determined by multiplying the drum inventory (80.0 PE-Ci) by the number of drums breached (21) and multiplying the SWB inventory (130.0 PE-Ci) by the number of SWBs breached (5).

Damage Ratio - A bounding damage ratio of 0.25 for the dropped drums is assumed. The damage ratio for the dropped SWB is assumed to be 0.1, based on the robust construction and bolted lid design making the SWB less susceptible to damage during handling operations (DWG NO. 165-F-001-W REV F[18] and ANSI MH2-1991[19]).

Airborne Release Fraction - The ARF for materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Respirable Fraction - The bounding RF applied to the airborne material released from each of the waste containers that are breached is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[3]

Leakpath Factor - Based on the Final Environmental Impact Statement[21] (FEIS) it is assumed that fifty percent of the particulates will be depleted from the release by fallout in the drifts and will not reach the environment. In addition, the amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[17] Based on the handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. When 0.5 (depletion) is combined with 1.0E-06 (HEPA efficiency) the leakpath factor is 5.0E-07 for the mitigated case and 1.0 for the unmitigated case.

Estimated Consequences and Comparison to Acceptance Criteria - Based on the calculations presented above, the consequences of a roof fall in the underground (CH11) are well within the radiological and nonradiological acceptance criteria for both the mitigated and the unmitigated cases (Table 5.2-3, 5.2-4) at both the Exclusive Use Area and the site boundary.

Verification of Design Classification - Based on the estimated unmitigated consequences and comparison to the acceptance criteria, Design Class I SSCs are not required.

Design Class II and IIIA SSCs from Table 4.1-1 which are applicable to this scenario have been verified per the criteria provided in Chapter 3 and have been determined to be assigned correctly as follows:

1. Underground Ventilation System
   - HEPA Filters - Design Class II (Provide Control of Radioactive Effluent)
   - Exhaust Fans for the Filtration Mode - Design Class II [Design Class Interface Channels Exhaust air through the Exhaust Filter Building (EFB)]
2. Station A Effluent Monitoring Shed - Design Class II [Design Class Interface (Houses Station A)]
3. Effluent Monitoring Rooms A and B - Design Class II [Design Class Interface (Houses Local Processing Units collecting data from Stations A and B)]
4. Station B Effluent Monitoring Instrument Shed - Design Class IIIA [Design Class Interface (Houses monitoring equipment for the Exhaust Filter Building duct)]
5. Radiation Monitoring System Station A units A1 and A2 - Design Class II (Monitors and Controls radioactive effluent)
6. Exhaust Filter Building - Design Class IIIA [Design Class Interface (Houses Exhaust Filtration System)]

References for Section 5.2

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2. DOE Order, 6430.1A, U.S. Department of Energy, General Design Criteria, 1989.

3. DOE-HDBK-3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, December 1994.

4. Nuclear Regulatory Commission Regulatory Guide 1.145, Rev 1, Atmospheric Dispersion Models for the Potential Accident Consequence Assessments at Nuclear Power Plants, United States Nuclear Regulatory Commission, Washington, DC, November 1982.

5. WHC-SD-GN-SWD-30002, GXQ Users Guide, Westinghouse Hanford Company, Rev 0., June 8, 1993.

6. ICRP Report No. 23, Report of the Task Group on Reference Man, International Commission on Radiological Protection, Pergamon Press, NY, 1974.

7. DOE/EH-0071, Internal Dose Conversion Factors for Calculation of Dose to the Public, July 1988.

8. ANSI/ANS-51.1-1983, American National Standards Institute, Standard Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants.

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10. Craig, DK et al., Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for the use in DOE Facilities, May 1993.

11. American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances, ACGIH, Cincinnati, Ohio, ISBN:1-882417-06-2, 1994.

12. Federal Emergency Management Agency, Handbook of Chemical Hazards Analysis Procedures, 1989.

13. American Conference of Government Industrial Hygienists, Guide to Occupational Exposures Values-1993, ISBN:1-882417-07-0, 1994.

14. WCAP 14312, Hazard and Operability Study for CH TRU Waste Handling System, Waste Isolation Pilot Plant, Westinghouse Waste Isolation Division, April, 1995

15. DOE\WIPP 87-005, Waste Drum Fire Propagation at the WIPP, April 1987.

16. WIPP-CAO-95-1014, Project Technical Baseline for Regulatory Compliance, Revision 0, April 20, 1995.

17. ERDA 76-21, Energy Research and Development Administration, Nuclear Air Cleaning Handbook.

18. TRUPACT II Standard Waste Assembly, DWG No. 165 F 001 W, Rev F.

19. ANSI MH2-1991, (3.4), American National Standard for 55-Gallon (208-Liter) Tight-Head Steel (Double-Seam Chime) Drums (DOT-17C).

20. UCRL-15910, Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards, June 1990.

21. DOE/EIS-0026, Final Environmental Impact Statement, October 1980

22. Bechtel Interoffice Memorandum, J.J. Litehiser to H.G. Taylor, DOE Order 6430.1A Review of the WIPP Site, Job No. 20585-001, September 27, 1990.

23. NUREG-0800, U.S. Nuclear Regulatory Commission. Standard Review Plan, 3.5.1.6, Aircraft Hazards, Rev 2, July, 1981.

24. SMRP No. 155, A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico, Department of Geophysical Sciences, T. Fujita, University of Chicago, February 1978 and its Supplement of August 1978.

25. DOE/WIPP 91-057, WIPP Supplementary Roof Support System Underground Storage Area Panel One Room, November 1991.

26. DOE/WIPP 93-033, The Current Basis for Roof Fall Prediction at WIPP and the Preliminary Prediction for SPDV Room II, August 1993.

27. SAND80-2517, Analysis, Scale Modeling, and Full-Scale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments.

28. WIPP-DOE-069, Rev. 4, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, December 1991.

29. WHC-EP-0558, UC-600, Test and Evaluation Document for DOT Specification 7A Type A Packaging, June 1992.

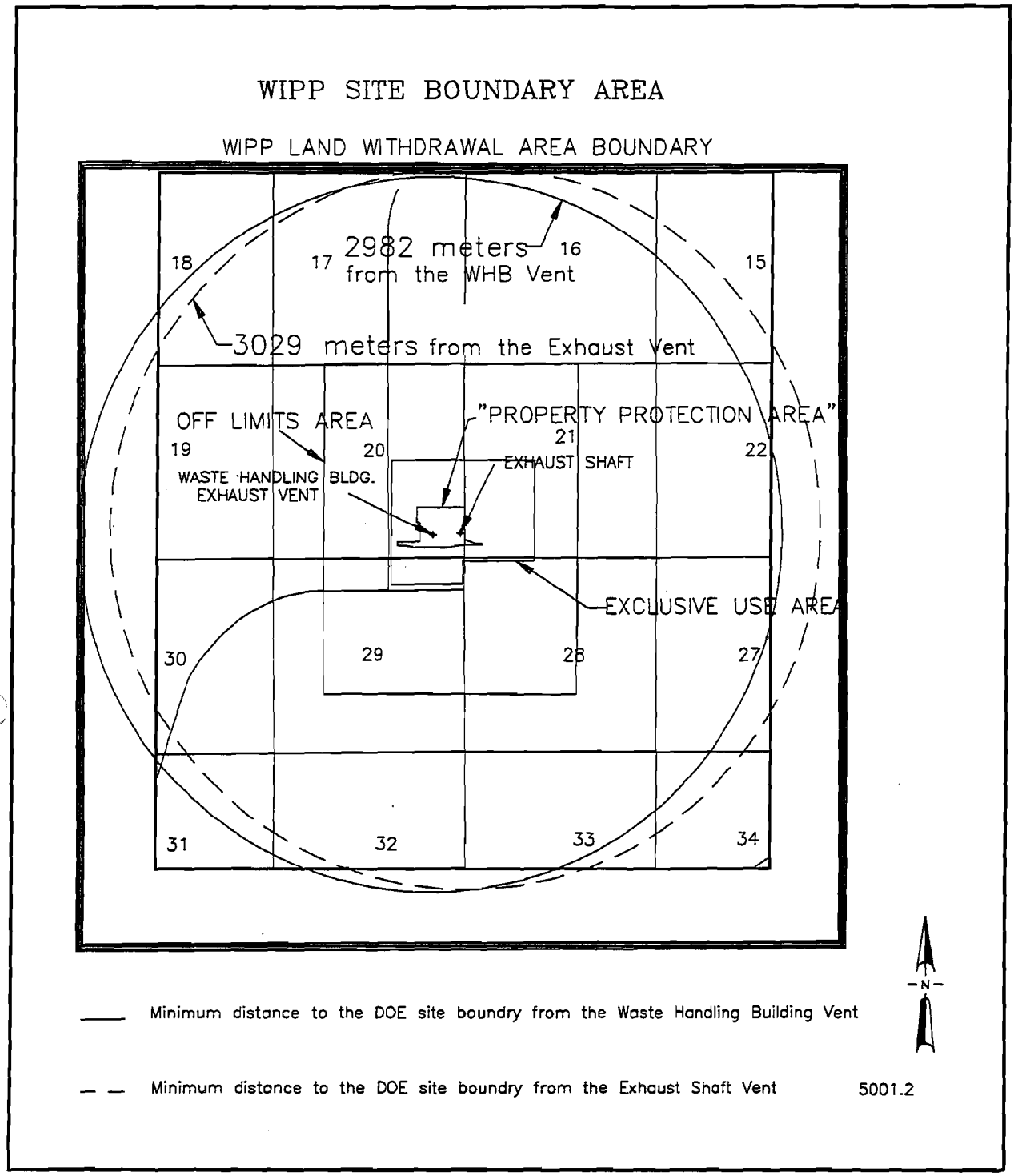

Figure 5.2-1, WIPP Site Boundary Area

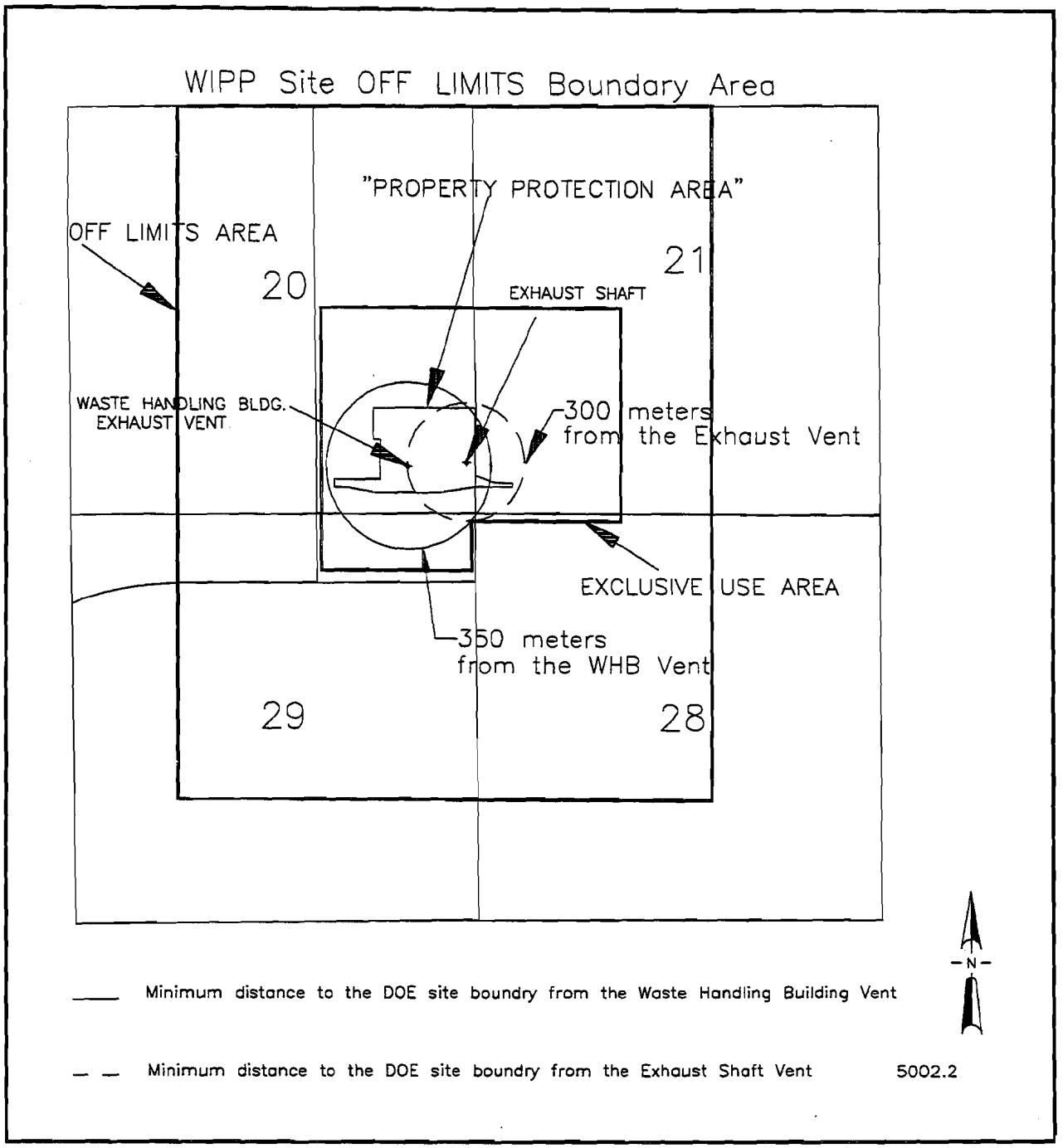

Figure 5.2-2, WIPP Site Off-Limits Boundary Area

Table 5.2-1, Off-site Acceptance Criteria

Description	Estimated Annual Likelihood of Occurrence	Description	Radiological Criteria	Nonradiological Criteria
Normal operations	$1 \geq p\ 10^{-1}$			
Anticipated	$10^{-1} \geq p \geq 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)	≤ 2.5 rem	≤ PEL-TWA or TLV-TWA
Unlikely	$10^{-2} \geq p > 10^{-4}$	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this probability class include: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc.	≤ 6.5 rem	≤ TOX-1(1)
Extremely Unlikely	$10^{-4} \geq p > 10^{-6}$	Accidents that will probably not occur during the life cycle of the facility.	≤ 25 rem	≤ TOX-2(2)
Incredible	$10^{-6} \geq p$	All other accidents.		

(1) TOX-1 Alternative Criteria
ERPG1
PEL-STEL
TLV-STEL
TLV-TWA*3

(2) TOX-2 Alternative Criteria
ERPG2
EEGL (60 min.)
PEL-C
TLV-C
TLV-TWA*5

Table 5.2-2, Toxicological Criteria for Derivation of TOXs

Substance	TLV - TWA (mg/m^3)	TLV - STEL/C (mg/m^3)	PEL - TWA (mg/m^3)	PEL - STEL/C (mg/m^3)	IDLH (mg/m^3)	EEGL (mg/m^3)	ERPG 1 - 2 - 3 (mg/m^3)
Asbestos	2 f/cc	n/a	.2 f/cc	1 f/cc (30min)	n/a	n/a	n/a
Beryllium	0.002	n/a	0.002	C0.005	10	n/a	1 - 0.005 2 - 25 3 - 100
Cadmium	0.002	n/a	0.005	n/a	50	n/a	n/a
Lead	0.15	n/a	0.05	n/a	700	n/a	n/a
Butyl Alcohol	n/a	C152	300	C150	24,640	n/a	n/a
Carbon Tetrachloride	31	63	12.6	n/a	1,917	n/a	1 - 95 2 - 159 3 - 1917
Mercury	0.025	n/a	0.05	C0.1	28	.2 (24 hour)	1 - 0.15 2 - 0.2 3 - 28
Methyl Alcohol	262	328	260	310	33,250	266	1 - 266 2 - 266 3 - 532
Methylene Chloride	174	n/a	500	C1,000	21,000	n/a	n/a
Polychlorinated Biphenyl (PCB)	0.5	n/a	0.5	n/a	10	n/a	n/a

Notes to Table 5.2-2:

EEGL is a concentration of a substance in air that has been judged by the Department of Defense to be acceptable for the performance of specific tasks by military personnel during emergency conditions lasting 1 to 24 hours. EEGL dosages may produce transient central nervous system effects and eye or respiratory irritation, but nothing serious enough to prevent response to emergency conditions.

Threshold limit values (TLVs) have been defined to include various levels of exposure to worker populations. TLVs are published by the American Conference of Governmental Industrial Hygienists (ACGIHs).

TLV-TWA: Threshold limit value-Time-weighted average for a specific substance defines the limit of acceptable concentration to which most workers can be exposed for up to a normal eight-hour day and a 40-hour week without adverse effect. As with other TLV values, the population that comprises the general public differs from the population defined for TLVs in that the general public includes additional groups such as children, elderly persons, and hospitalized patients.

TLV-STEL: Threshold limit value-Short-term exposure limit is a time weighted average concentration to which workers should not be exposed for longer than 15 minutes and which should not be repeated more than four times per day, with at least 60 minutes between successive exposures. Whereas the TLV-TWA is useful for chronic exposure effects, the TLV-STEL addresses effects of Short-term, high-level exposures. As with other TLV values, the population that comprises the general public differs from the population defined for TLVs in that the general population includes additional groups such as children, elderly persons, and hospitalized patients.

Table 5.2-2, Toxicological Criteria for Derivation of TOXs

TLV-C: Threshold Limit Value-Ceiling is the concentration in air that should not be exceeded during any part of the working exposure, for the work population. Ceiling limits may be used with other TLVs or independently. As for other TLV values, the population that comprises the general public differs from the working population since it includes additional groups such as children, elderly persons, and hospitalized patients.

PELs have been developed by the Occupational Safety and Health Administration (OSHA) as a measure for safe and healthful working conditions for men and women employed in any business engaged in commerce in the United States. As with other exposure limits developed for industrial applications, limitations exist with respect to applicability to the general population. PEL is an exposure limit established by OSHA. PEL-C is the concentration that shall not be exceeded during any part of the workday exposure.

SPEGL-Short-term Public Emergency Guidance Level is an acceptable ceiling concentration for a single, unpredicted short-term exposure to the public. The exposure period is usually calculated to be one hour or less and never more than 24 hours. Five SPEGLs have been developed by the USNRC Committee on Toxicology and are generally set at between 0.1 and 0.5 of EEGL values.

IDLH levels have been developed to define concentrations of materials from which workers should evacuate within 30 minutes without escape-impairing symptoms or any irreversible health effect. As IDLH values were developed by the National Institute for Occupational Safety & Health (NIOSH) for industrial application, their usefulness for application to the general population is limited. IDLH is a NIOSH definition.

ERPGs are published by the AIHA These are intended to provide airborne concentration levels to which most individuals (in a community) could be exposed for periods up to one hour without experiencing adverse effects as defined by the ERPG level. These guidelines are intended for emergency response applications. ERPG designations are:

ERPG-3: The maximum airborne concentration below which, it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

ERPG-2: The maximum airborne concentration below which, it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible adverse health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-1: The maximum airborne concentration to which nearly all individuals could be exposed for up to one hour without experiencing or developing health effects (i.e., more severe than sensory perception or mild irritation, if relevant).

a. There is no IDLH identified for asbestos. TLV for asbestos is set by the number of asbestos fibers. The TLV-TWA (per OSHA permissible exposure limits) is 0.2 fibers longer than 5 micrometers and with a length to diameter ratio of at least 3:1.

b. Conversion to fibers/cc and calculation of fraction of TLV: The asbestos release is assumed to be chrysotile, the most common form of asbestos. The density of chrysotileis 1.55 gm/cc (or 1.55E+09 mg/m^3). Fibers of respirable size would be approximately 10 microns long by 3.3 microns in diameter. Using the expression that volume equals (π/4)x(diameter squared) x (length), the volume of a fiber is then 8.5E-17 m^3. The volume multiplied by the density gives the mass as 1.3E-07 mg per fiber. Using the concentration in mg/m^3 at each receptor and converting to fibers/cc will allow a comparison of the asbestos released to the appropriate TLV.

   Fibers/cc = (Asbestos concentration mg/m^3)(1 fiber/1.3 x 10^{-7}mg)(1m^3/1.0 x 10^{6}cc)

c. C denotes ceiling value.

Table 5.2-3, Summary of Estimated Radiological Dose and Comparison to Criteria

Summary of Radiological Consequences for Postulated Accidents for the CH TRU Waste Handling Operations							
Accident	Estimated Frequency/yr	Type of Release	Total Released (PE-Ci)	Receptor Doses (CEDE-Rem)		Offsite Dose Criteria (CEDE-rem)	% of Dose Criteria [(Dose/Criteria)*100]
				Exclusive Use Area Boundary	Site Boundary		Exclusive Use Area Boundary
CH1	Extremely Unlikely						
WHB Spont. Ign		Drums/mitigated	1.9E-08	1.9E-06	1.3E-07	≤ 25	<1.0%
		Drums/unmitigated	1.9E-02	1.9E+00	1.3E-01	≤ 25	7.6%
CH2	Unlikely						
Crane Drop		Drums/mitigated	1.4E-08	1.4E-06	9.6E-08	≤ 6.5	<1.0%
		Drums/unmitigated	1.4E-02	1.4E+00	9.6E-02	≤ 6.5	21.8%
		SWBs/mitigated	1.3E-09	1.3E-07	8.9E-09	≤ 6.5	<1.0%
		SWBs/unmitigated	1.3E-03	1.3E-01	8.9E-03	≤ 6.5	2.0%
CH3	Unlikely						
WHB Punct/Drop		Drums/mitigated	5.6E-09	5.7E-07	3.9E-08	≤ 6.5	<1.0%
		Drums/unmitigated	5.6E-03	5.7E-01	3.9E-02	≤ 6.5	8.7%
		SWBs/mitigated	2.6E-09	2.6E-07	1.8E-08	≤ 6.5	<1.0%
		SWBs/unmitigated	2.6E-03	2.6E-01	1.8E-02	≤ 6.5	4.0%
CH4	Anticipated						
WHB Drop		Drums/mitigated	8.0E-09	8.1E-07	5.5E-08	≤ 2.5	<1.0%
		Drums/unmitigated	8.0E-03	8.1E-01	5.5E-02	≤ 2.5	32.4%
		SWBs/mitigated	2.6E-09	2.6E-07	1.8E-08	≤ 2.5	<1.0%
		SWBs/unmitigated	2.6E-03	2.6E-01	1.8E-02	≤ 2.5	10.5%
CH5	Incredible	no release					
Hoist Failure			-	-	-	-	
CH6	Incredible	no release					
DBE			-	-	-	-	

Table 5.2-3, Summary of Estimated Radiological Dose and Comparison to Criteria

Summary of Radiological Consequences for Postulated Accidents for the CH TRU Waste Handling Operations							
Accident	Estimated Frequency/yr	Type of Release	Total Released (PE-Ci)	Receptor Doses (CEDE-Rem)		Offsite Dose Criteria (CEDE-rem)	% of Dose Criteria [(Dose/Criteria)*100]
				Exclusive Use Area Boundary	Site Boundary		Exclusive Use Area Boundary
CH7	Extremely Unlikely						
U/G Spont. Ign		Drums/mitigated	9.4E-09	1.2E-06	6.4E-08	≤ 25	<1.0%
		Drums/unmitigated	9.4E-03	1.2E+00	6.4E-02	≤ 25	5.0%
CH8	Incredible	no release					
WHB Aircraft Crash			-	-	-	-	-
CH9	Unlikely						
U/G Drop		Drums/mitigated	7.0E-09	9.2E-07	4.7E-08	≤ 2.5	<1.0%
		Drums/unmitigated	7.0E-03	9.2E-01	4.7E-02	≤ 2.5	36.8%
		SWBs/mitigated	6.5E-10	8.5E-08	4.4E-09	≤ 2.5	<1.0%
		SWBs/unmitigated	6.5E-04	8.5E-02	4.4E-03	≤ 2.5	3.4%
CH10	Incredible	no release					
DBT							
CH11	Unlikely						
U/G Roof Fall		Drums/mitigated	2.1E-08	2.8E-06	1.4E-07	≤ 6.5	<1.0%
		Drums/unmitigated	2.1E-02	2.8E+00	1.4E-01	≤ 6.5	42.4%
		SWBs/mitigated	3.3E-09	4.3E-07	2.2E-08	≤ 6.5	<1.0%
		SWBs/unmitigated	3.3E-03	4.3E-01	2.2E-02	≤ 6.5	6.6%

Table 5.2-4, Summary of Estimated Toxicological Concentrations and Comparison to Criteria

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria (Table 5-5)	Exclusive Use Area Boundary
CH1	Extremely Unlikely							
WHB Spont. Ign.		Drums/unmitigated						
			Asbestos	7.1E+01	3.6E-04 f/cc	2.5E-05 f/cc	TLV-TWA	<1.0%
			Beryllium	5.5E+00	3.6E-06	2.5E-07	TLV-TWA	<1.0%
			Cadmium	7.8E-02	5.2E-08	3.5E-09	TLV-TWA	<1.0%
			Lead	2.1E+02	1.4E-04	9.7E-06	TLV-TWA	<1.0%
			Butyl Alcohol	7.8E+01	5.2E-05	3.5E-06	PEL C	<1.0%
			Carbon Tetrachloride	1.6E+02	1.1E-04	7.3E-06	TLV-TWA	<1.0%
			Mercury	9.2+01	6.1E-05	4.1E-06	PEL C	<1.0%
			Methyl Alcohol	2.1E-01	1.4E-07	9.4E-09	EEGL	<1.0%
			Methyl Chloride	1.0E+01	6.9E-06	4.7E-07	TLV-TWA	<1.0%
			Polychlorinated Biphenyl (PCB)	2.2E+02	1.5E-04	1.0E-05	TLV-TWA	<1.0%
			Trichloroethylene	1.0E+02	6.8E-05	4.6E-06	EEGL	<1.0%

Table 5.2-4, Summary of Estimated Toxicological Concentrations and Comparison to Criteria

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations

Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria (Table 5-5)	Exclusive Use Area Boundary
MCH2	Unlikely							
Crane Drop		Drums/unmitigated						
			Methylene Chloride	295.92	1.8E-01	1.2E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	439.25	2.6E-01	1.8E-02	TLV-STEL	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	380.47	2.3E-01	1.5E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	564.75	3.4E-01	2.3E-02	TLV-STEL	<1.0%
CH3	Unlikely							
WHB Punct/Drop		Drums/unmitigated						
			Methylene Chloride	169.10	1.0E-01	6.8E-03	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	251.00	1.5E-01	1.0E-02	TLV-STEL	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	718.66	4.3E-01	2.9E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	1066.76	6.4E-01	4.3E-02	TLV-STEL	1.0%

Table 5.2-4, Summary of Estimated Toxicological Concentrations and Comparison to Criteria

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations								
Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria (Table 5-5)	Exclusive Use Area Boundary
CH4	Anticipated							
WHB Drop		Drums/unmitigated						
			Methylene Chloride	169.10	1.0E-01	6.8E-03	TLV-TWA	<1.0%
			Carbon Tetrachloride	251.00	1.5E-01	1.0E-02	PEL-TWA	1.2%
		SWBs/unmitigated						
			Methylene Chloride	718.66	4.3E-01	2.9E-02	TLV-TWA	<1.0%
			Carbon Tetrachloride	1066.76	6.4E-01	4.3E-02	PEL-TWA	5.3%
CH5	Incredible							
Hoist Failure				-	-	-	-	-
CH6	Incredible							
DBE				-	-	-	-	-

Table 5.2-4, Summary of Estimated Toxicological Concentrations and Comparison to Criteria

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations

Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria (Table 5-5)	Exclusive Use Area Boundary
CH7								
U/G Spont. Ign	Extremely Unlikely							
		Drums/unmitigated						
			Asbestos	3.6E+01	1.8E-04 f/cc	1.2E-05 f/cc	TLV-TWA	<1.0%
			Beryllium	2.7E+00	1.8E-06	1.2E-07	TLV-TWA	<1.0%
			Cadmium	3.9E-02	2.6E-08	1.8E-09	TLV-TWA	<1.0%
			Lead	1.1E+02	7.1E-05	4.8E-06	TLV-TWA	<1.0%
			Butyl Alcohol	3.9E+01	2.6E-05	1.8E-06	PEL C	<1.0%
			Carbon Tetrachloride	8.2E+01	5.4E-05	3.7E-06	TLV-TWA	<1.0%
			Mercury	4.6E+01	3.1E-05	2.1E-06	PEL C	<1.0%
			Methyl Alcohol	1.0E-01	6.9E-08	4.7E-09	EEGL	<1.0%
			Methyl Chloride	5.2E+00	3.5E-06	2.3E-07	TLV-TWA	<1.0%
			Polychlorinated Biphenyl (PCB)	1.1E+02	7.4E-05	5.0E-06	TLV-TWA	<1.0%
			Trichloroethylene	5.1E+01	3.4E-05	2.3E-06	EEGL	<1.0%
CH8	Incredible							
Aircraft Crash				-	-	-	-	-

Table 5.2-4, Summary of Estimated Toxicological Concentrations and Comparison to Criteria

Summary of Chemical Consequences for Postulated Accidents for the CH TRU Waste Handling Operations

Accident	Estimated Freq./yr	Type of Release	Compound	Total Released (mg)	Concentrations (mg/m3)			% of Dose Criteria [(Dose/Criteria)*100]
					Exclusive Use Area Boundary	Site Boundary	Limiting Off-site Toxicological Criteria (Table 5-5)	Exclusive Use Area Boundary
CH9	Unlikely							
U/G Drop		Drums/unmitigated						
			Methylene Chloride	295.92	2.3E-01	1.2E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	439.25	3.4E-01	1.8E-02	TLV-STEL	<1.0%
		SWBs/unmitigated						
			Methylene Chloride	380.47	2.9E-01	1.5E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	564.75	4.4E-01	2.3E-02	TLV-STEL	<1.0%
CH10	Incredible	no release						
DBT				-	-	-	-	-
CH11	Unlikely							
UG Roof Fall		Drums/unmitigated						
			Methylene Chloride	887.76	6.9E-01	3.5E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	1317.76	1.0E+00	5.3E-02	TLV-STEL	1.6%
		SWBs/unmitigated						
			Methylene Chloride	1817.79	1.4E+00	7.3E-02	TLV-TWA*3	<1.0%
			Carbon Tetrachloride	2698.27	2.1E+00	1.1E-01	TLV-STEL	3.3%

NOTE: No credit is taken for mitigation of solid, liquid chemicals or VOCs by HEPA filtration.

5.3 RH TBD

5.4 Long-Term Waste Isolation Assessment

Applicable regulations require the DOE to assess the capability of the WIPP repository to isolate TRU & TRU mixed wastes for a 10,000-year period (40 CFR 191[1], 40 CFR 268.6[2]). The DOE is required to demonstrate, through this long-term assessment, that the repository can reasonably be expected to contain the wastes such that established quantitative release limits for both radionuclides and hazardous constituents are not exceeded for the 10,000-year performance period. The DOE's Performance Assessment (PA) is a probabilistic risk assessment tool designed to evaluate the long-term performance of the repository.

The PA process requires three (3) general types of information. These include: 1) those future events and processes that could occur, 2) the relative probabilities that such events and processes will occur, and 3) the consequences of such events and processes, should they occur.

Once a comprehensive set of such Features, Events and Processes (FEPs) are identified, a screening process is initiated. FEPs that are specifically excluded by regulation, are determined physically not reasonable, are of low probability, or are of low consequence are screened from the PA analysis. All FEPs that remain are treated in the PA through either incorporation in the modeling system or through modeling assumptions.

Consequence analyses are conducted using the applicable quantitative measures of performance from the driving regulations. The results are used to develop probabilistic distributions of calculated releases. These distributions will be used to display results in the form of a Complimentary Cumulative Distribution Function (CCDF). This CCDF will allow direct measure of calculated performance to the applicable release limits.

Uncertainty and sensitivity analyses will be conducted as appropriate. These efforts will differ in that the compliance assessment for hazardous chemicals will be deterministic in nature. Uncertainty analysis for this assessment will consist of a qualitative pre-modeling process where reasonable, discreet values are estimated for parametric input in instances where variables are imprecisely known. The compliance assessment for radionuclides is probabilistic in that imprecisely known variables are expressed in terms of ranges for parametric input and are randomly sampled across the range during the modeling process. The uncertainty analyses will be performed as a post-modeling process and will be both qualitative and quantitative.

Sensitivity analysis will identify those portions of the disposal system that drive the largest change in calculated result with their variation. Results of sensitivity analysis will be important for such activities as developing long-term monitoring concepts and other qualitative assurances, which will complement the expected performance of the natural disposal system.

Applicable regulatory agencies will determine the DOE's compliance with the regulations. The PA analysis will be presented in the Compliance Certification Application (40 CFR 191[1]) and the No-Migration Variance Petition (40 CFR 268.6[2]).

References for Section 5.4

1. 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, Subpart A, Environmental Standards for Management and Storage.

2. 40 CFR 268.6, Petition to Allow Land Disposal of A Waste Prohibited of Subpart C of part 268.

5.5 Conclusions

The analyses in this chapter provided a detailed review of the potential hazards associated with CH TRU waste handling operations. The methodologies used in this process included a qualitative hazard analysis and a quantitative evaluation of the potential consequences of postulated accidents. The hazard analysis process indicated that eleven potential accident scenarios required further review and quantitative evaluation. Based on bounding container inventory and release estimates, the calculated accident consequences were compared to accident acceptance criteria for the public and found to be significantly below the acceptance criteria.

Additionally, (1) the analysis indicated Design Class I SSCs are not required for the WIPP to mitigate any accident radiological and nonradiological consequence to acceptance levels, and (2) per the discussion in Section 4.4.1, secondary confinement is not required. Design Class II and IIIA SSCs while not required to prevent or to mitigate the consequences of an accident from exceeding the acceptance criteria support the WIPP defense-in-depth philosophy.

DERIVATION OF TECHNICAL SAFETY REQUIREMENTS
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DERIVATION OF TECHNICAL SAFETY REQUIREMENTS

This section provides the bases for deriving the WIPP Technical Safety Requirements (TSRs) in accordance with the requirements of DOE Order 5480.22, *Technical Safety Requirements*.[1] DOE Order 5480.22[1] provides detailed criteria for the selection of TSR Safety Limits (SLs), Limiting Control Settings (LCSs), Limiting Conditions for Operations (LCOs), Surveillance Requirements (SRs), and Administrative Controls (ACs).

The Chapter 5 Hazards and Accident Analyses indicate that SLs, LCSs, LCOs, and SRs are not required for the WIPP facility as derived below. As discussed in Chapter 5, Design Class I Systems, Structures or Components (SSCs) are not required for the WIPP to mitigate any accidental radiological and nonradiological consequence to acceptable levels. WIPP TSRs in the form of ACs are derived in this chapter. These ACs provide TSRs covering the WIPP defense-in-depth approach developed in Chapter 5.

6.1 Requirements

Requirements for the derivation of TSRs are specified in DOE 5480.22.[1]

6.2 TSR Coverage

ACs impose administrative requirements necessary to control operation of the facility such that all TSR requirements are met. Since no SLs, LCSs, LCOs, SRs are defined for the WIPP, WIPP specific ACs impose administrative requirements necessary to ensure safe operation of the facility. These requirements are defined in Section 6.4.5.

6.3 Derivation of Facility Modes

Operations at the WIPP consist mainly of waste handling, in-process storage, and disposal operations. The following description of the operational modes provides a definition of the varying levels of operations. Prior to receiving waste, the facility is required to be in one of the modes of operation.

6.3.1 Waste Handling Mode

The facility or sections of the facility are operating in their intended function (waste handling, in-process storage and/or disposal operations are being conducted). The Waste Handling Building (WHB) and/or the Underground is configured for waste handling, in-process storage and/or disposal, and all applicable TSR ACs for the appropriate areas have been met. The activities that directly support the mission of the facility include waste handling, in-process storage, and disposal. Maintenance, repair activities and inspections are allowed as long as they do not violate the conditions of Waste Handling Mode.

6.3.2 Waste Storage/Disposal Mode

Waste handling operations are not being conducted in the WHB or in the Underground. WHB and/or the Underground is configured for waste in-process storage or disposal, and all applicable TSR ACs for the appropriate areas have been met. After receipt of waste, the facility retains its inventory of radioactive and hazardous material. The facility will always be in the Waste Storage/Disposal Mode or Waste Handling Mode. No waste handling operations are allowed during Waste Storage/Disposal Mode. Maintenance, and repair activities and inspections are allowed provided the conditions for Waste Storage/Disposal Mode remain in effect. The ventilation system for an area may be completely shut down provided no waste handling operations are in progress.

6.4 Derivation of WIPP TSRs

6.4.1 Safety Limits (SLs)

As defined in DOE Order 5480.22,[1] Technical Safety Requirements, SLs are limits on process variables associated with those physical barriers, generally passive, that are necessary for the intended facility function and that are found to be required to guard against the uncontrolled release of radioactivity and other hazardous material. "Process Variables" refers to observable, measurable parameters such as temperature and pressure. "Passive physical barriers" refers to those barriers that constitute the primary process material boundary.

Based on the analysis presented in Chapter 5, no SLs are identified for the WIPP facility.

6.4.2 Limiting Control Settings (LCSs)

As defined in DOE Order 5480.22,[1] LCSs are settings on safety systems that control process variables to prevent exceeding SLs. More precisely, an LCS is the set point for an instrument or device monitoring a process variable that, if exceeded, initiates actions to prevent exceeding an SL.

The WIPP facility has no SLs identified, therefore, no LCSs are required.

6.4.3 Limiting Conditions for Operations (LCOs)

DOE Order 5480.22,[1] Attachment 1, Section II.2.3.h, provides that "LCOs should be written only for systems and equipment which meet one (or more) of the following descriptions," and prescribes five selection criteria, h.(1) through h.(5). The order also emphasizes that "Maintaining the LCOs at the minimum number necessary will emphasize the importance of the LCOs and better ensure the compliance with them." All five criteria clearly tie the LCOs to the facility accident or transient analyses.

The LCO selection criteria interpretations define TSR content based on key nuclear safety analysis requirements. Specifically, three of the five TSR LCO selection criteria are understood to restrict TSR LCOs to only those requirements that are under the direct control of the facility's operators and are of primary importance for; **prevention** (Criterion h.(1)), **mitigation** (Criterion h.(2)) and **initial conditions** (Criterion h.(3)) of credible, unmitigated accident scenarios. Additionally, Criterion h.(4) involves the application of criteria h.(1), h.(2), and h.(3) to experiments and experimental facilities, and Criterion h.(5) to systems and equipment that are used for handling fissile material.

The specifics of each criterion as applied to the WIPP facility are as follows:

Criterion h.(1) - Prevention:

A basic concept in the protection of the public is the prevention of accidents that have the potential for an uncontrolled release of radioactive material. Criterion h.(1) is intended to ensure that TSRs be selected to identify instrumentation that is used to detect, and to indicate in the control room or other control location, a significant degradation of the physical barriers which prevent the uncontrolled release of radioactive or other hazardous materials. For example, instrumentation installed to detect significant degradation of a reactor coolant pressure boundary enables the operator to correct the degraded condition prior to accident initiation or to place the facility in a condition that reduces the likelihood of the accident.

Instrumentation at the WIPP, such as the Continuous Air Monitors (CAMs), Effluent Monitors, Area Radiation Monitors (ARMs), and installed instrumentation to control differential pressure, is not required to prevent accidents as analyzed in the SAR from occurring, or to facilitate the Central Monitoring Room (CMR) operator placing the facility in a condition reducing the likelihood of an accident from occurring. Therefore, Criterion h.(1) has no application to the WIPP.

Criterion h.(2) - Mitigation:

Criterion h.(2) provides that "Structures, systems, and components that are relied upon in the Safety Analyses to function or actuate to prevent or mitigate accidents, or transients that either involve the assumed failure of, or present a challenge to, the integrity of a physical barrier that prevents the uncontrolled release of radioactive materials ... intended to include only those structures, systems, and components that are part of the primary success path of a safety sequence analysis and those support and actuation systems necessary for them to function successfully."

The "primary success path of a safety sequence analysis" is defined as "the sequence of events assumed by the Safety Analyses, which leads to the conclusion of a transient or accident with consequences that are acceptable. Hence, any structure, system, or component in that assumed sequence should be included in the LCO."

Consistent with the primary intent of DOE Order 5480.22[1] establishing requirements for the protection of the public, the existing practice is: 1) to evaluate the unmitigated radiological and non-radiological consequences to members of the off-site public as the result of an accident, 2) to compare the radiological and non-radiological consequences to established accident acceptance criteria, and 3) if the consequences of the accident exceed the established accident consequence acceptance criteria, to define SSCs and associated TSR LCOs mitigating or reducing those consequences to acceptable levels below the established criteria.

The unmitigated off-site radiological and non-radiological consequences and acceptance criteria, as documented in Chapter 5, Tables 5.2-3, and 5.2-4. are used as the basis for applying this criterion.

Application of DOE Order 5480.22[1] TSR LCO Selection Criterion h.(2) to the WIPP:

The WIPP SSCs that are assumed to function in the SAR accident analysis mitigating an accident's radiological and non-radiological consequences to acceptable levels (to within the accident acceptance criteria) satisfy Criterion h.(2).

The unmitigated radiological and non-radiological accident consequences were estimated and compared to the acceptance criteria in Chapter 5. The unmitigated radiological and non-radiological accident consequences are below the consequence acceptance criteria therefore; 1) mitigating SSCs are not required, and 2) TSR LCOs are not required.

Tables 5.2-3 and 5.2-4 of Chapter 5 of the SAR list the analyzed accidents and the mitigated and unmitigated off-site radiological consequences. All of the radiological and non-radiological accident consequences are well below the off-site acceptance criteria.

Criterion h.(3) - Initial Condition:

Process variables as initial conditions of accidents or transients that are monitored and controlled during operations so the parameter remains within the analysis bounds satisfy this selection criterion. The WIPP is not a process facility, therefore process variables are not considered in the SAR accident analysis as initial conditions for accidents. Thus, Criterion h.(3) is not applicable to the WIPP.

Criterion h.(4)

Criterion h.(4) involves applying criteria h.(1), h.(2), and h.(3) to experimental activities involving radioactive or other hazardous materials. There are currently no planned experimental or test activities at the WIPP. Therefore, Criterion h.(4) is not applicable to the WIPP.

Criterion h.(5)

Criterion h.(5) applies to fissile material handling facilities and is only related to inadvertent criticality protection. Inadvertent criticality is not a credible hazard at the WIPP. Inadvertent criticality is controlled through the ACs Criticality Program in conjunction with the Waste Characteristics program which conforms to the WIPP Waste Acceptance Criteria (WAC).[2] Therefore, Criterion h.(5) is not applicable to the WIPP.

6.4.4 Surveillance Requirements (SRs)

As defined in DOE Order 5480.22,[1] SRs relate to testing, channel calibration, channel operational testing, or inspection to maintain the operability, quality, and safety of SSCs and their support systems. SRs are defined as the requirements necessary to maintain facility operation within the SLs, LCSs, and LCOs. Selection criteria for SRs are defined in DOE Order 5480.22.[1]

Without SLs, LCSs, and LCOs for the WIPP facility, SRs are not required.

6.4.5 Administrative Controls

As discussed in Section 2.4 of Attachment 1 of DOE Order 5480.22[1], ACs impose necessary requirements controlling operation of the facility to meet all TSR requirements. Without SLs, LCSs, LCOs, and SRs, WIPP specific ACs impose administrative and operational requirements supporting the WIPP defense-in-depth concept. Basic elements and requirements defined for TSR AC programs are enforced by the associated implementing WIPP procedures.

Supporting the first layer of defense in depth (the prevention of accidents) as defined in Section 5.1.6, WIPP TSR ACs are established as follows:

- To maintain the design, quality, testability, inspectability, operability, maintainability, and accessibility of the facility, TSR ACs are required relating to: (1) configuration and document control, (2) maintenance, and (3) quality assurance.

- To ensure that the facility operations are conducted by trained/certified personnel, TSR ACs are required relating to: (1) facility operations chain of command and responsibilities, (2) facility staffing requirements, (3) procedures, (4) staff qualifications, (5) conduct of operations, and (6) training.

- To ensure the administrative accident prevention measures are maintained, TSR ACs are required relating to: (1) waste characteristics (Waste Acceptance Criteria), (2) waste container integrity, and (3) criticality safety.

Supporting the second and third layers of defense in depth, WIPP TSR ACs are identified which establish programs for radiation protection (including radiation monitoring equipment and airborne radioactivity monitoring), and emergency management.

6.5 Design Features

The Design Features of the WIPP Facility are described in Chapter 4 of the SAR.

6.6 Interface TSRs

The WIPP Facility does not have interfacing TSRs from other facilities.

References for Chapter 6

1. DOE Order 5480.22, Technical Safety Requirements, September 15, 1992.

2. WIPP-DOE-069, Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 4, December 1991.

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RADIOLOGICAL AND HAZARDOUS MATERIAL PROTECTION

7.1 Radiological Protection

This section discusses (1) the radiological hazards to the worker and off-site public as a result of normal (routine) CH and RH TRU waste handling and emplacement activities, (2) the WIPP radiological control program and organization, and (3) the WIPP "As Low As Reasonably Achievable" (ALARA) policy and program. Waste containers accepted for disposal at the WIPP are expected to meet the DOE Radiological Control (RadCon) Manual[1] and 10 CFR 835[2] external contamination limits since the containers are surveyed prior to release from the generator sites. Waste containers are thus considered contamination free. Therefore, WIPP normal operations do not involve or entail any planned or expected releases of airborne radioactive materials to the workplace or the environment.

The radiological control philosophy at the WIPP is "Start Clean - Stay Clean," which emphasizes the prevention of radioactive contamination. This philosophy dictates the immediate securing of any radiological work when radioactive contamination above established levels is found, or a release of radioactive contamination is known or suspected. Normal work will not resume until the area, including personnel and equipment, has been released in accordance with contamination control procedures, and approval from the Radiation Safety Manager has been obtained.

As part of normal operations activities, the waste containers, although having met the DOE RadCon Manual[1] and 10 CFR 835[2] limits prior to shipping, are closely inspected for damage and surveyed for radiation and radioactive contamination prior to unloading and transfer to the underground for disposal. Decontamination or overpack will be undertaken, if required, and as approved by management. Decontamination and operations involving overpack and repair of damaged containers are considered abnormal activities, and the risk to workers and the public is addressed qualitatively through the hazards analysis process in Chapter 5.

7.1.1 Radiological Control Program and Organization

7.1.1.1 Radiological Control Program Objectives

The objective of the radiological control program is to ensure the exposure of employees and the general public to radiation and radioactive materials is within the guidelines of 10 CFR 835[2]; 40 CFR Part 191, Subpart A[3]; 40 CFR 61, Subpart H[4]; DOE Orders 5400.5[5], and 6430.1A[6] and the DOE RadCon Manual[1] respectively, and that such exposures are kept ALARA. These objectives are met by ensuring that:

- Shipments of radioactive material are handled in accordance with WIPP Waste Acceptance Criteria (WAC)[7] limitations, DOT regulations[8] and internal operating procedures.
- Shielding, posting, and access control may be employed to reduce direct radiation exposures.
- Engineering controls are designed to reduce exposures during normal operations.
- Areas where the radioactive waste is unloaded are continuously monitored for airborne radioactivity with alarm capabilities.
- Personnel receive a level of radiation protection training appropriate to their assignments.

- Appropriate access/egress control techniques and radiological surveys of personnel and equipment are used to prevent the spread of external contamination.

- A source control program is in place to minimize the potential for the spread of contamination, unnecessary exposure to personnel, loss, theft, sabotage, or improper disposal of radioactive sources.

- A respiratory protection program is in place, and respiratory protective equipment will be used during abnormal activities (Decontamination and overpack and repair operations).

- Instruments and equipment are properly calibrated so that accurate radiation, contamination, and airborne radioactivity surveys can be performed.

- Radiological work procedures and instructions provide for an ALARA review prior to commencement of work for jobs in which radiation and/or radioactive contamination are expected to exceed trigger levels established by the WP 12-5 WIPP Radiological Control (RadCon) Manual.[9]

- Appropriate personnel dosimetry devices are supplied, and a radiation exposure record system is maintained.

- An internal dose-assessment program (whole-body counting and bioassay) is in place.

- Radiological Protection management is notified of any unusual or unexpected radiological conditions.

- Every radiological worker is given the authority to stop radiological work if there is evidence that radiological controls are being compromised.

- An effluent and environmental monitoring program is in place to monitor releases to the environment to verify that facility releases are maintained at a minimum.

- The radiological control program is conducted in accordance with written and approved procedures.

7.1.1.2 Administrative Organization

Radiation Safety is a functional part of the Environment, Safety and Health (ESH) Department. The divisions of the ESH Department are Industrial Safety, Monitoring and Analysis and Compliance and Permitting. The management organization described in the following paragraphs implements the radiological control program.

Environment, Safety and Health (ESH) - The Manager for ESH has responsibility for all activities concerning industrial safety and radiation protection of employees and the general public. With regard to Radiation Safety, the ESH Manager is responsible for the training of radiation workers and health physics technicians, emergency planning, and the ALARA program. The ESH Manager is also responsible for coordinating these activities with cognizant governmental agencies. Within the organization of the Management and Operating Contractor, the Radiation Safety Manager reports to the Manager of Monitoring and Analysis, who reports to the Manager of ESH. The ESH Manager approves Radiation Safety procedures.

Radiation Safety - The Radiation Safety Manager is responsible for maintaining radiological safety of the plant by regularly evaluating and assessing surface contamination, radiation levels, and airborne radioactivity concentrations in radiological work areas with respect to approved limits.

The Radiation Safety Manager is also responsible for directing operational health physics activities; performing surveillance of routine and special WIPP facility operations; establishing training programs for qualification and requalification of radiological control technicians; and approving other radiological training programs consistent with 10 CFR 835[2] and applicable DOE Orders. The Radiation Safety Manager is required to review radiological control procedures annually to determine their adequacy.

The Radiation Safety Manager and designees have the authority to stop operations when an actual or impending loss of radiological safety control is identified. In addition, because of the importance of radiation safety, the Radiation Safety Manager has a direct line of communication to the General Manager in matters of radiation safety.

Minimum qualifications for radiological control program personnel are in accordance with applicable DOE Orders and Guidance.

Dosimetry - The Manager of Monitoring and Analysis is responsible for operating and maintaining a personnel dosimetry program to determine radiation exposure to employees and visitors. In addition, the Manager of Monitoring and Analysis is responsible for implementing and operating the internal dosimetry program. The Radiation Safety Manager has the authority to remove from further exposure, upon notification then from the Monitoring and Analysis Manager, employees who have either exceeded the established administrative radiation exposure limits or not demonstrated their continuing understanding of or compliance with the WIPP radiological control program.

7.1.2 ALARA Policy and Program

7.1.2.1 Policy Considerations

It is the firm commitment of the WIPP management that occupational radiological exposures are kept ALARA. This policy, as reflected in administrative programs and procedures established in accordance with 10 CFR 835[2], DOE/EV/1830-T5[10], and DOE RadCon Manual[1], ensures that the design basis of the WIPP facility will maintain individual occupational radiation exposures to an ALARA level of less than 1 rem per year per person. A site-specific administrative control level may be established at less than 1 rem per year per person in accordance with WP 12-5, WIPP RadCon Manual.[9]

7.1.2.2 Design Considerations

The ALARA techniques applied to the WIPP facility design were based on DOE Order 5480.11,[11] as well as DOE exposure guide DOE EV/1830-T5,[10] as appropriate for this first-of-a-kind facility. Future design modifications will be in accordance with 10 CFR 835,[2] DOE Order 6430.1A,[6] and other codes, standards, and orders applicable at the time of modification. Chapter 4 presents details of plant design and operations.

The ALARA criteria were applied during the design of the plant through a series of design reviews by nuclear and health physics specialists from the responsible Architect-Engineer organization. During the operational disposal-phase, the responsibility for ensuring that exposures are kept ALARA is the responsibility of all levels of management. Operationally, the manager responsible for waste handling will develop and implement procedures and operation of equipment to ensure waste handler exposures are maintained ALARA.

7.1.2.3 Operational Considerations

Radiological exposure to plant personnel will be kept ALARA by continued review of operations and training. The WIPP ALARA Program is described in the WIPP ALARA Manual, WP 12-2.[12]

The Manager of ESH, or designees, will monitor performance of the waste handling operations by reviewing exposures, procedures, and incident reports and recommending corrective action, when required. The DOE and the Management and Operating Contractor (MOC) will supplement this program through periodic audits of exposure records and procedures, as well as investigations of all incidents.

7.1.3 Radiological Exposure Control

7.1.3.1 Radiological Protection Design Features

7.1.3.1.1 Plant Arrangement Designs for Keeping Exposures ALARA

Facility Arrangement - For radiological control purposes, the areas in the WIPP facility to which access is managed to protect individuals from exposure to radiation and/or radioactive materials are identified as Controlled Areas and are administrated in accordance with the WIPP RadCon Manual.[9] The Controlled Areas are segregated from other operating areas by physical barriers (e.g., fences, walls, bulkheads). The Controlled Areas on the surface are primarily located in and around the Waste Handling Building (WHB) and are separated from other areas by a fence and walls (Figure 4.1-2). Personnel contamination monitoring stations are located at the exits from the Radiological Buffer Areas (RBAs), which are inside the Controlled Area in the WHB. A High Radiation Shielded Holding Area is located inside the Controlled Area of the Waste Handling Building to provide temporary holding of CH TRU waste packages with surface dose rates greater than 100 mrem/h.

A Controlled Area will be established in the underground disposal area during disposal operations. Engineering control features are incorporated in the arrangement of the underground disposal area. The disposal area is isolated from the construction area by physical barriers and separate ventilation flow paths. The disposal areas are normally excavated in groups of rooms called panels as indicated in Figure 4.1-3. The sequence and manner in which the disposal rooms are filled are consistent with the ventilation requirements discussed in Section 7.1.3.1.4.

Access control and personnel traffic patterns are considered in the plant layout to minimize the potential for spreading contamination and to minimize personnel radiation exposure.

Waste Handling Building - General Arrangement - A Controlled Area will be established in the WHB as required to support Waste Handling operations. Personnel access into the operating areas of the building is through a controlled access corridor from the Support Building. Within the building, there are control points at all locations with normal access to areas outside the Controlled Area.

Air locks are located between areas with either different levels of contamination potential or large pressure differentials. The ventilation system and air locks act to mitigate the spread of contamination by maintaining pressure differentials between radiological areas. This is done to ensure that any leakage is directed into areas with higher potentials for contamination.

CH TRU Waste Handling Area Arrangement - The surface waste handling equipment and facilities in the CH TRU waste handling area are arranged so that waste handling flow patterns are as direct as possible from TRUPACT II unloading to hoist loading.

The Overpack and Repair Room is designed and located such that damaged containers can be transferred with minimum potential for spreading contamination.

RH TRU Waste Handling Area Arrangement - The RH waste handling area is arranged for efficient handling of shielded road casks and waste canisters and includes an area for shielded road cask preparation and decontamination, as required. The enclosed Cask Unloading Room is located below the hot cell. Here a ventilation barrier provided by an inflatable seal between the cask and hot cell floor provides the means for controlling the potential spread of contamination during cask unloading. The hot cell is arranged to allow inspection and, if required, over packing of the canisters before they are lowered into the canister transfer cell and subsequently transferred to the Facility Cask.

A Crane Maintenance Room and a Manipulator Repair Room are provided next to the hot cell, behind shielding, to allow removing hot cell equipment to areas with a lower radiation background for repair. This reduces the need to enter the hot cell.

Personnel access into the hot cell is through air locks from the main operating gallery. A room below the hot cell operating gallery houses the hot cell HEPA filters.

Radiation sources and shield penetrations are arranged to prevent radiation streaming and to reduce radiation levels in accessible areas.

7.1.3.1.2 Equipment and Component Designs for Keeping Exposures ALARA

This section summarizes the design features used for general classes of equipment and major components. These classes of equipment are common to many of the plant systems. Therefore, the features employed to maintain exposures ALARA for each system are similar.

Waste Handling Equipment - Features to facilitate decontamination, such as smooth cleanable surfaces and the elimination of square corners and crevices, are incorporated in the handling equipment design, where practicable. Mechanical handling equipment is designed for easy replacement for decontamination and/or repair.

Remote handling equipment in the hot cell includes the hot cell crane and the master/slave manipulators. The hot cell crane can be moved into the Crane Maintenance Room using manual override, if crane failure occurs in the hot cell. This allows maintenance in a separate area and minimizes the need for access into the hot cell. The master/slave manipulators can be removed from the operating gallery side of the hot cell for maintenance and brought into the manipulator repair room, an area with a lower radiation background.

Forklifts and transporters are designed to expedite the loading and unloading of waste packages while minimizing the potential for accidents. They also ensure the effective securing of waste packages to minimize waste handling time.

Instruments - Whenever practical, instrumentation and control devices are located in low radiation areas and away from radiation sources.

Instruments, that for functional reasons are located in areas with a relatively high radiation background, are designed for easy removal to areas with a lower radiation background for calibration or repair.

Lighting - Multiple electric lights are provided. Sufficient illumination is provided so that the loss of a single lamp does not require immediate entry and replacement of the defective lamp.

HVAC Equipment - The environmental control systems for areas with a potential for contamination are designed for contamination free replacement of filter elements.

7.1.3.1.3 Radiation Shielding

7.1.3.1.3.1 Design Objectives

The objective of radiation shielding is to minimize the exposure of personnel to the radiation sources described below. Radiation shielding is one of the methods utilized to maintain the exposure of personnel to radiation ALARA.

7.1.3.1.3.2 Direct Radiation Sources

The direct radiation sources that are the bases for shielding design are categorized from CH TRU and RH TRU waste. The direct radiation sources described in this section use maximum expected values and conservative assumptions to ensure a conservative basis for radiation shielding design. The representative characteristics of these radiation sources are described below and summarized in Tables 7.1-1 and 7.1-2.

CH TRU Waste - CH TRU waste will primarily be received in standard waste boxes (SWBs) and 55-gallon drums. Because of higher anticipated activity density, the 55-gallon drum is used as the reference CH TRU waste radiation source for shielding analysis. The CH TRU waste source container used for this analysis is 24 inches in diameter and 35 inches long (the approximate dimensions of a DOT 17C 55-gallon drum). These drums can be stacked in the underground no more than three high due to the limited height of the disposal drift. Some space remains above the stack for airflow over the waste packages during the disposal operations.

Although the CH TRU waste contains alpha and beta emitting nuclides, the primary radiation of interest in shielding calculations is gamma rays. Alpha and beta particles are completely shielded by the waste containers and do not contribute to the external dose with the possible exception of a beta-generated bremsstrahlung contribution to the gamma spectrum. For shielding design calculations, a spectrum representing typical waste containing TRU nuclides and fission products was derived. The gamma spectrum selected as representative of the CH TRU waste is characterized by a RH TRU radionuclide distribution with a reduced photon source. The selected RH TRU spectrum is believed to yield conservative results since the photon energies are greatly skewed to the higher energies. Photon energies for CH TRU radionuclides are typically much lower.

The average and maximum gamma source strengths used in the CH TRU waste shielding calculations are based on a design average CH TRU waste surface exposure rate of 10 mrem/h and the maximum CH TRU waste surface exposure rate of 200 mrem/h. The resultant design basis CH TRU waste gamma source strengths are shown in Table 7.1-1. A few neutron sources have been identified for CH TRU wastes, but the neutron component of the total dose rates for these few identified waste forms is negligible.

RH WASTE - The RH waste handled at the WIPP facility is categorized as RH TRU waste. The radiation source geometries used for shielding design calculations are shown below for RH TRU waste.

	RH TRU Waste Source Geometries		
	Configuration	Diameter (inches)	Length (inches)
RH TRU Waste canister dimensions	Cylindrical	26	121

The allowed neutron dose rate (270 mrem/h maximum) is much smaller than the total allowed dose rate (1000 rem/h maximum). Thus, gamma source strengths are primarily used for shielding calculations but the shielding effectiveness for neutrons is reviewed. As an example, the neutron dose rate assumed for the design of the WIPP facility hot cell is 45 rem/h though RH TRU waste with dose rates of this magnitude are not allowed by the WIPP WAC.[7] The design basis gamma source strengths for RH TRU waste are derived from a similar distribution to that used for the CH TRU waste discussed above and are listed in Table 7.1-2.

7.1.3.1.3.3 Design Description

To meet the shielding design objectives, the following general guidelines are used:

- Radiation shield thicknesses must ensure that the dose rate due to uncollided and scattered radiation through the shield are less than the maximum levels specified for each design radiation zone. Shield wall thicknesses are shown in plant arrangement drawings.

- Principal shielding materials are ordinarily concrete/rebar, lead, steel, or salt. Shielding materials for viewing windows include leaded glass and oil. Temporary shielding, such as lead blankets or bricks or other materials may also be employed, as required, during maintenance or other operations.

- Temporary shielding for openings such as doors, hatches, windows, ventilation ducting, and piping should be designed to prevent radiation streaming. Penetrations through primary shielding are placed so that they do not provide a direct line through the shield wall to the radiation source. Design features such as offset piping connections, stepped doors or hatches, shadow shields, and labyrinths are incorporated in the shielding design, wherever applicable. Shielding for large diameter penetrations is provided by additional concrete or steel around a penetration. Shielding can also be provided by the addition of shield collars or leaded grout around pipes and penetrations.

- Access to potentially high radiation areas involves passage through shield doors or labyrinth walls. This prevents direct radiation streaming into adjacent areas. Labyrinth shielding is designed so that the exposure due to uncollided and scattered radiation is less than the maximum levels specified for the adjacent area.

The CH TRU Waste Handling Area is arranged for efficient handling of the CH TRU waste containers. Traffic flow and adequate space for waste transfer activities are considered in the layout of this area. A separate enclosed area shielded by concrete walls is provided for temporary holding of CH TRU wastes that cannot be immediately emplaced and have surface dose rates greater than 100 mrem/h.

Within the RH TRU Waste Handling Area, RH TRU waste canisters are handled within shielded casks or by remote means within the shielded hot cell enclosure. The primary shielding in the hot cell complex is provided by the shipping cask shields or the hot cell walls. The hot cell complex is designed for a 45 rem/h neutron surface dose rate and a gamma surface dose rate of 400,000 rem/h.

The hot cell is an integral part of the Waste Handling Building. The shield walls are primarily constructed of reinforced concrete. Remote operations using the hot cell crane and master slave manipulators are observed through closed circuit television and shielded viewing windows at hot cell work stations. A shielded pass-through drawer is utilized to introduce supplies into the hot cell, to remove waste materials from the cell, and to transfer swipes. An interlocked shielded door and labyrinth shield walls at the personnel access to the hot cell reduce radiation levels from sources in the cell. The shipping cask unloading room, crane maintenance room, facility cask loading room, manipulator repair room, and canister transfer room are separate functional areas integrated with the hot cell.

A Shielded Room for hot cell crane maintenance is provided next to the hot cell. Normally, personnel are not permitted in the crane maintenance room during hot cell operations. However, in the event of a crane failure requiring maintenance, the crane can be moved into the crane maintenance room where a steel shield gate reduces the dose rates from within the hot cell. Under most conditions, dose rates during these maintenance activities will be less than 0.5 mrem/h in the maintenance room. Under no conditions are personnel allowed in the crane maintenance room when a canister is raised above a position on top of the cask unloading room.

The Facility Cask provides shielding while the RH TRU waste canisters are moved from the canister transfer cell to the disposal locations underground. Figure 4.3-16 shows the facility cask shielding.

The facility cask provides a cylindrical steel and lead shield enclosure around one RH TRU canister and has shield valves at either end. The cask design includes sufficient shielding to reduce gamma radiation levels to less than 200 mrem/h at the surface of the cask for wastes meeting the WIPP WAC. Design and operation of the facility cask will be reviewed should a significant RH TRU neutron contribution be identified.

Within the Underground Disposal Areas, no permanent shielding is required. The facility cask construction provides shielding for operators and helps maintain doses ALARA. When transferring a RH TRU canister from the facility cask to the disposal location in the underground salt, horizontal emplacement and retrieval equipment shielding overlap with the facility cask to minimize radiation streaming paths.

7.1.3.1.3.4 Method of Shielding Analysis

The radiation sources used for shielding design are based on maximum values expected during plant operations. Shielding thicknesses ensure that the sum of the dose rates due to uncollided and scattered radiation through the shield wall during waste canister handling are within the limits of the radiation zone specified for the area.

Shielding analysis was performed by the Architect-Engineer for the WIPP Project by use of the QAD-P5A computer code and input parameters.[13,14] This code is a multigroup, multiregion point kernel, general purpose shielding code for estimating the effects of gamma rays originating in a volume distributed source. The point kernel method utilized by the code involves representing the source volume by a number of point sources and computing the line of sight distance from each point source to the detector point. Using the distance the gamma ray travels through the shielding and the attenuating characteristics of the shielding materials, the geometric attenuation and material attenuation are determined. The point kernel representing the energy transferred by the uncollided photon flux along a line of sight path is combined with an appropriate buildup factor to account for the contribution from the scattered photons.

Gamma scattering calculations are used to estimate dose rates around labyrinth and shadow shielding. The G^3 computer code and input parameters are used for gamma scattering calculations.[15] The code calculates gamma scattering from a point source to a series of point detectors. The code evaluates the uncollided flux at specified scatter points and multiplies it by the product of the differential cross section for scattering toward the detector point and the number of electrons in the elemental volume associated with the scatter point (the center of the elemental volume).

The ANISN computer code with the Cask 40-group neutron/gamma cross section library is used for neutron and secondary gamma calculations to confirm adequate shield thicknesses.[16,17] This code is a multigroup, multiregion, one dimensional, discrete ordinates transport code that solves the Boltzmann transport equation in slab, cylindrical, or spherical geometries for neutron and gamma radiation.

These computer codes are used to calculate dose rates for various shielding thicknesses. The radiation sources in the computer code are modeled as closely as possible to the actual geometries, dimensions, and physical conditions. The RH waste handling area shielding is designed to comply with the design radiation dose rates. In the CH TRU waste handling area, the interim holding area shielding thicknesses are based on storing drums that contain the average gamma source strengths as described in Section 7.1.3.1. The separate shielded holding area shielding is based on the full-capacity holding of drums that contain the maximum gamma source strength.

Shielding Integrity and Verification - The integrity of the shielding and its design features is ensured by the adherence to the requirements and recommended practices described in ANSI N101.6-1972,[18] with the following additional criteria:

- In addition to the applied loads requirements listed in Section 4.3.3 of ANSI N101.6-1972[18], the concrete radiation shield structural analysis also considers steady-state and transient thermal loads.

- Detailed thermal stress analysis in the design of reinforcement for controlling thermal cracking (temperature reinforcement) in specific concrete radiation shields is included in determining variables used in equations for bending moment and tensile stress, as described in Section 6.4 of ANSI N101.6-1972.[18]

- Reinforcing steel or other means are provided for transferring shear and other forces through a construction joint, as described in Section 8.8.7 of ANSI N101.6-1972.[18]

7.1.3.1.4 Ventilation

As ted in Section 7.1, WIPP normal operations do not involve or entail any planned or expected rel es of airborne radioactive materials. However, plant ventilation systems are part of the engineering controls; the second layer in a defense-in-depth program. Ventilation systems control the potential spread of radioactive contamination to ensure that doses to workers and the general public, as a result of airborne radioactive materials, if they occur, are below the limits specified in the appropriate regulatory guidance.[2,3,4,5,6] Plant ventilation systems are described in Chapter 4 and are designed to provide ready access to necessary components and thereby reduce exposure to operations and maintenance personnel during servicing and inspection.

General Design Features To Maintain Radiation Exposures ALARA - Ventilation air flows from areas with less potential for radioactive contamination to areas of progressively greater contamination potential. This direction of airflow is provided by maintaining pressure differentials between the areas.

HEPA filters are provided on ventilation exhausts from areas with a potential for contamination. Except for the HEPA filtration system associated with the underground exhaust ventilation system, sufficient filter capacity is provided to accommodate normal design ventilation airflow. Exhaust ventilation HEPA filters for the underground areas are normally bypassed due to the absence of airborne radioactivity releases during normal operations.

The service of ventilation systems in radioactive materials areas is expedited by providing adequate access space to components to facilitate operations involving minimal operator exposures during maintenance, inspection, and testing. Ductwork is designed with smooth interior surfaces to minimize the buildup of radioactive contamination within the ducts. All systems are designed to allow for periodic testing of the efficiency of ventilation exhaust filtration systems in accordance with ANSI N101.1-1978[19] and ANSI N510-1975.[20]

A locks provide physical barriers to separate areas between which pressure differentials are to be maintained.

A discussion of radiological monitoring of accessible areas and exhaust ventilation is provided in Section 7.1.3.2.6.

Underground Ventilation - The air flows underground are split into four separate systems. One supports waste disposal operations, the second supports construction activities, the third supports experimental activities, and the fourth ventilates the waste shaft and station area. The air flows for disposal and construction separate at W30-S1000 and this separation is maintained until they reach the exhaust shaft. The experimental area is on a separate split of air. Pressure differentials across ventilation barriers and structures between the construction and waste disposal areas ensure that all leakage through these structures flows from construction areas to the waste disposal side. The airflow is eventually directed to the exhaust shaft and surface Exhaust Fans. The underground ventilation system is described in Chapter 4.

Bulkheads and barriers used to maintain the separation of the four ventilation systems are designed to support the maximum pressure differential that can occur. These structures are designed to accommodate ground deformation (salt creep) without impairing their ability to maintain ventilation separation.

The waste disposal area ventilation system is designed so that personnel work stations and egress paths are upstream from stored CH TRU waste. The exhaust air filtration system at the surface is usually bypassed. In the event radioactivity in excess of predetermined setpoints is detected by the underground radiation monitoring system or the Effluent Monitoring System, the exhaust airflow is reduced and redirected through a HEPA filtration system in the Exhaust Filter Building. The HEPA filtration system may also be manually activated if airborne radioactivity from an abnormal event is suspected.

Surface Ventilation - Ventilation air in areas with potential for contamination is segregated from ventilation in other areas and is exhausted through HEPA filtration systems. The ventilation systems in areas with potential for contamination include the RH TRU waste handling area, CH TRU waste handling area, laboratory areas, ventilation exhaust equipment room, site-generated waste areas, and Exhaust Filter Building HVAC systems. These systems are separated from each other, and each system's ventilation air is individually filtered. The final filtration systems consist of one stage of prefilters and two stages of HEPA filters in series. Filtered ventilation air is exhausted from the Waste Handling Building and Exhaust Filter Building through exhaust ducts. Radiological monitoring of stack effluents is discussed in Section 7.1.4.2.1.

In the Waste Handling Building, a separate ventilation subsystem is provided for the hot cell, with redundancy in filtration capacity and exhaust fan capacity. In other areas with potential for contamination, ventilation exhaust is segregated into subsystems consisting of two fans and filters, each with 50 percent capacity. During maintenance or testing of the subsystems, one fan and filter operate (at 50 percent capacity) while maintenance or testing is performed on the other fan or filter. During loss of off-site power the system is initially isolated by the intake dampers, and then the exhaust fans for the CH & RH waste handling areas, the hot cell, and the mechanical room can be manually switched to standby power. This is sufficient to maintain the pressure differentials necessary for confinement.

The ventilation system for the Central Monitoring Room in the Support Building provides a suitable environment for continuous personnel occupancy under both normal and emergency conditions. Standby power can be supplied to this system in the event of a power outage. To protect operators from airborne contamination that may potentially exist in areas outside the Central Monitoring Room during an emergency, a slightly positive indoor air pressure is maintained relative to outdoor conditions, and supply air is directed through a HEPA filter. A redundant air handling unit is provided. The central monitoring room ventilation system is described in Chapter 4.

7.1.3.2 Radiological Practices

7.1.3.2.1 Radiation Safety Training

Radiation safety training is conducted at the WIPP facility to ensure that each worker understands: (1) the general and specific radiological aspects of their assignment, (2) their responsibility to their co-workers and the public for safe handling of radioactive materials, and (3) their responsibility for minimizing their own radiation exposure. The level of training for each employee is commensurate with the requirements of their job category.[9]

7.1.3.2.2 Radiological Control Procedures

The following procedures are established by policy to help ensure that radiation exposures to the general public, operating personnel, and the environment are within regulatory limits and ALARA. These procedures also support the "Start Clean - Stay Clean" philosophy, which emphasizes the prevention of radioactive contamination as well as its movement or spread.

Radiation and Contamination Surveys - Health physics personnel perform routine radiation and contamination surveys of all accessible areas of the facility, surveys of the waste packages upon receipt, and various other types of surveys to detect contamination and its potential spread and expected radiation dose rates. Routine survey areas and frequencies are established in accordance with health physics procedures and manuals, and are based upon the probability of contamination and changes in radiation level and upon personnel occupancy. These surveys consist of measurements for dose rate and contamination, as appropriate, for the specific area. The records of the survey results are retained in a permanent file by the Radiation Safety Section and are reviewed periodically so that trends indicative of problem areas are identified as early as possible. Radiation and contamination surveys and associated records are described in Chapter 5 and Chapter 7 of the WIPP RadCon Manual[9], respectively.

Access Control - Access to radiological areas of the facility is controlled in accordance with 10 CFR 835[2] and the WIPP RadCon Manual.[9] Only personnel who have successfully completed the requirements specified in Chapter 3 of the WIPP RadCon Manual[9] will be allowed unescorted entry to the radiological areas of the site. All other personnel will require an escort. Refer to Figure 7.1-1 for radiological areas and access requirements.

Personnel monitoring will be in accordance with WP 12-3, Dosimetry Program Manual,[21] and Chapter 5 of the WIPP RadCon Manual.[9]

The WIPP policy addressing visitors is described in Chapter 3 of the WIPP RadCon Manual.[9]

Personnel entering a Controlled Area are required to sign an access control log; personnel performing radiological work in a radiological area are also required to sign-in on the access control log in addition to signing in on a Radiological Work Permit (RWP) issued in accordance with Chapter 3 of the WIPP RadCon Manual.[9]

The RWP specifies the controls necessary for the planned entry, and may require additional monitoring devices, protective clothing, respiratory equipment, etc. The necessity for these control items may be based exclusively on radiation level, a combination of surface contamination and radiation level, an area of airborne radioactivity, or the potential for occurrence of any of these conditions. When required, these additional control items will be prescribed, and personnel will be properly equipped prior to entering the work area.

Exposure control is accomplished by identifying areas containing sources of radiation and/or contamination and controlling personnel access into these areas.

Radiological areas are designated and defined in the WIPP RadCon Manual[9] as follows:

- Controlled Area - Any area to which access is controlled in order to protect individuals from exposure to radiation and radioactive materials.

- Radiological Buffer Area (RBA) - A intermediate area established to protect personnel from potential radiation exposure and to prevent the spread of potential radioactive contamination. The area may surround Contamination Areas, High Contamination Areas, Airborne Radioactivity Areas, or be contiguous with Radiation Areas and/or High Radiation Areas.

- Radioactive Material Area (RMA) - An area or structure where radioactive material is used, handled or stored.

- Radiation Area - An area, accessible to personnel, in which the dose rate is greater than 0.005 rem/hr (0.05 mSv/hr), but less than or equal to 0.1 rem/hr (1mSv/hr), at 30 centimeters from the source or from any surface that the radiation penetrates.

- High Radiation Area - An area, accessible to personnel, in which the dose rate is greater than 0.1 rem/hr (1 mSv/hr) at 30 centimeters, but less than or equal to 500 rad/hr (5 Gy/hr), at 100 centimeters from the radiation source or from any surface that the radiation penetrates.

- Very High Radiation Area - An area, accessible to personnel, in which the dose rate is greater than 500 rad/hr (5 Gy/hr) at 100 centimeters from a radiation source or from any surface that the radiation penetrates.

- Contamination Area - Area where contamination levels are greater than the values specified in Chapter 2, Table 2-2, of the WIPP RadCon Manual[9], but less than or equal to 100 times those levels.

- High Contamination Area - Area where contamination levels are greater than 100 times the values specified in Chapter 2, Table 2-2, of the WIPP RadCon Manual.[9]

- Airborne Radioactivity Area - Area where the measured concentration of airborne radioactivity, above natural background, exceeds either:

  1. 10 percent of the Derived Air Concentration (DAC) averaged over 8 hours, or,

  2. A peak concentration of 1 DAC.

  (DAC values are contained in 10 CFR 835[2])

Personnel Monitoring Program - Personnel at the WIPP facility are monitored for both internal and external exposure as described in Section 7.1.3.2.6 .

A routine external exposure monitoring program at the WIPP facility measures the radiation dose received by personnel. The external dose measurement program is described in Chapter 5 of the WIPP RadCon Manual[9] and WP 12-3, Dosimetry Program Manual.[21]

Internal exposure measurement is described in Chapter 5 of the WIPP RadCon Manual[9] and the Dosimetry Program Manual.[21] The WIPP program for internal exposure measurement may use the techniques of in vitro bioassay examination (e.g., urinalysis, and/or fecal analysis) and in vivo bioassay examination (whole-body counting and chest counting). Bioassay will be performed on a routine basis. Baseline bioassay will be performed on workers who handle radioactive materials as a normal function of their job.

Personnel dosimetry records are maintained by Monitoring and Analysis which ensures that occupational exposure records are maintained in a readily retrievable data base to permit ready accounting of employees' accumulated radiation exposure. Maintenance of personnel radiation exposure records is described in WP 12-3, Dosimetry Program Manual.[21]

Airborne Radioactivity Monitoring Program - The airborne radioactivity monitoring program complies with 10 CFR 835[2] and verifies that the survey program described above is detecting contamination con[illegible] problem areas, and those problem areas are corrected before loose surface contamination bec[illegible]es airborne. The equipment used for air sampling and monitoring is described in Section 7.1.[illegible].6. The airborne monitoring program is described in Chapter 5 of the WIPP RadCon Manual.[9]

Respiratory Protection Program - A variety of types of respiratory protection equipment for non-routine operations such as maintenance, emergency use, and mine rescue is available at the WIPP facility.

Only respiratory protection equipment approved for use by the National Institute of Occupational Safety and Health is used at the WIPP facility.

Workers who may be required to wear respiratory protection equipment must attend a training program on the equipment use during abnormal and emergency conditions. They are fitted for the devices they are required to wear and are given a special medical examination to ensure that there is compatibility with wearing the devices.

The respiratory protection program meets the requirements of ANSI Z88.2-1980.[22] Respiratory protection is addressed in Chapter 5 of the WIPP RadCon Manual[9] and WP 12-1, WIPP Safety Manual.[23]

Radioactive Material Control - There are two facets to the control of radioactive material. The first is radioactive source control. Radioactive sources are used to test, calibrate, and check the operation of radiation detection instrumentation. Radioactive sources are also brought on-site by external organizations for testing, radiography, and soil density operations. The radioactive source control program ensures that proper control, including leak testing, inventory, transfer, and disposal, of these sources are maintained at all times to prevent loss/theft, spread of contamination, and other abnormal occurrences involving radioactive sources.

The second facet of the radioactive material control program is the control of radioactive material produced from radiological work processes performed on-site. Any item used in a process that involves known or suspected presence of radioactive contamination or radioactive materials is surveyed prior to release from a radiological area. If the survey indicates the presence of radioactive material on the item, then the item is either decontaminated or disposed of as site-derived waste, as directed by the Radiation Safety Manager.

7.1.3.2.3 Radiological Control Facilities

Control Points - Control points are located at all normal exits from the WHB, which allow exit from a controlled area to an uncontrolled area. The major control points are at the exits from the WHB and at the exits from the CH TRU and RH TRU waste disposal areas underground. All personnel leaving the Controlled Areas are required to sign out of the access control log at the control points. All personnel leaving RBA's, Contamination, High Contamination, and Airborne Radioactivity Areas are required to sign out on the RWP and perform a personnel survey prior to exit.

Personnel Access Control Points - As discussed in Section 7.1.3.2.2 access to the areas at the WIPP facility where radioactive materials are handled is controlled and limited to personnel who have successfully completed the requirements of Chapter 3 of the WIPP RadCon Manual.[9]

Personnel decontamination will be performed in accordance with approved procedures.

Laboratory Facilities - Radiological analysis facilities are located in the Safety and Emergency Services Building and the WHB. The counting equipment located in the laboratories is described in Section 7.1.3.2.6. A sample preparation facility, which is used to prepare samples for analysis, is also located near the Safety and Emergency Services Building. The sample preparation facility has appropriate equipment for radiochemical separation of radionuclides in the samples for counting.

Calibration Facilities - The dose rate instrument calibration facility is located in the Shielded Calibration Room of the Support Building. Contamination survey instruments are calibrated in the area of the health physics office. Calibration equipment is described in Section 7.1.3.2.6 .

Equipment Decontamination Stations - Decontamination or overpacking of major equipment may be carried out in the decon enclosure located in the Overpack & Repair Room. Small area "spot" decontamination can be accomplished in place according to established procedures.

Dosimetry Laboratory - The laboratory is located in the Safety and Emergency Services Building. The TLD equipment in the laboratory is described in Section 7.1.3.2.6. No radioactive materials, other than those used for calibration purposes, are permitted in the Dosimetry Laboratory.

Plant Clothing Facility - Plant clothing will be issued from the clothing issue room in the Support Building. Plant clothing items, which are assumed or have been shown by survey to be contaminated, will be disposed of as site-generated waste.

7.1.3.2.4 Radiological Control Equipment

Various types of protective clothing and equipment are stocked at the WIPP facility to protect personnel from contamination. Protective clothing is provided for body, head, hand, and foot protection.

Contamination control equipment is used to prevent or limit the spread of radioactive contamination and to assist in its removal. The equipment is stored and routinely inventoried in cabinets in or near areas where it is normally used.

7.1.3.2.5 Radiological Posting

When required, areas within the WIPP facility, including the underground disposal area, are posted in accordance with the WIPP RadCon Manual[9] to specify the actual or potential radiological hazard. Posting provides necessary information and access control for minimizing personnel radiation exposures and the potential spread of contamination.

Areas within Controlled Areas where the potential for dose and/or radioactive contamination conditions exist are posted as Radiological Buffer Areas. Areas where actual dose and/or radioactive contamination conditions exist are posted as described in Section 7.1.3.2.2.

7.1.3.2.6 Radiation Protection Instrumentation

The instrumentation used by the health physics personnel can be divided into four categories:

- Fixed radiation counting instruments (laboratory type)
- Portable radiation survey instruments
- Area radiation monitoring instruments
- Airborne radioactivity sampling and monitoring instruments

Instruments are repaired and calibrated by health physics personnel. In some cases, specialized instruments may be returned to the manufacturers for repair and calibration.

Fixed Radiation Counting Instruments - Fixed radiation counting instruments are located in the counting laboratories and are used primarily for analyzing process monitoring samples and environmental samples taken in and around the WIPP facility. The instruments selected for use in the laboratories possess the sensitivities required for performing environmental and operational activities.

These instruments are periodically calibrated with standard sources traceable to the National Institute of Science and Technology (NIST). Instrument background and response to calibrated check sources are determined before each operating day to verify that the instrument background and calibration have not changed.

The instruments in the counting laboratories include gross radioactivity counters and spectrographic systems.

When required, samples are prepared for counting in the sample preparation facility. Sample preparation for counting may include evaporation, ashing, partitioning, grinding, chemical separation, or placing samples in containers that conform the sample to a defined geometry.
Portable Radiation Survey Instruments - The portable radiation detection instruments are used to perform radiation and contamination surveys in the field.

Portable dose rate instruments are normally calibrated in the calibration room using a shielded calibrator and/or other smaller NIST traceable sources and approved procedures. Portable contamination instruments are calibrated in the area of the health physics office with NIST traceable sources and approved procedures. Prior to use, these instruments are checked for response with a check source containing a nominal amount of radioactivity.

Portable instruments include alpha contamination detectors, beta contamination detectors, gamma survey meters, and neutron survey meters.

Personnel Monitoring Instruments and Service - The WIPP facility has a personnel dosimetry program that conforms to the requirements of DOE Order 5480.15[24] (Department of Energy Laboratory Accreditation Program for Personnel Dosimetry), otherwise known as DOELAP. The program is DOELAP certified and will be conducted in accordance with the WP 12-3[21] WIPP Dosimetry Program Manual.

Digital dosimeters are used when a dose rate above background is expected or exists. These dosimeters are used to keep track of exposure in between TLD readouts. The TLD reading is the record of exposure. Personnel monitoring for external contamination is performed using the survey instruments previously discussed or with hand and foot monitors at the exits of radiological areas. Portal Monitors are placed at the WIPP site security gate to monitor personnel for radiation sources.

It is the intent of the radiological control program to qualify all employees who handle waste to perform contamination surveys on their clothing and body. In addition, when special operations are conducted, contamination surveys of personnel are performed by or under the direction of a qualified Health Physics Technician. Bioassay and in-vivo programs will be administrated in accordance with WP 12-3, Dosimetry Program Manual.[21]

A radiation monitoring system supplements the personnel and area radiation survey provisions of the plant radiological control program to ensure that radiation exposures are maintained ALARA. The radiation monitoring system includes area radiation monitors, continuous air monitors for radioactive particulate and fixed air samplers. The radiation monitoring alarms give visual and/or audible signals that annunciate locally and, for select systems, in the Central Monitoring Room. Except for the automatic underground exhaust filtration system operation, these alarms require operator response and corrective actions. Most of the radiation monitoring system instruments are supplied with an Uninterruptible Power Supply (UPS) in the event of a power outage.

Calibration of Radiation Survey Instruments - All calibrations of radiological instruments shall be traceable to NIST or other equivalent recognized standards. The portable dose rate instruments are calibrated with a shielded calibrator that minimizes radiation exposure to the calibration technician. Portable sources are used to calibrate fixed instruments such as the area radiation monitors and continuous air monitors (CAMS). Radiation survey instrument calibration records are maintained for the life of the facility.

Instruments receive periodic electronic calibration using NIST traceable, calibrated electronic sources.

Area Radiation Monitoring - Area radiation monitors are provided, as needed, in normally accessible areas to provide indications of changes in the surrounding operational environment within the plant.

Area radiation monitors continuously monitor gamma radiation. The monitors activate local and remote alarms upon the detection of radiation levels higher than the limits specified for a given work area. Separate alarms are activated by the failure of a monitor.

Each monitor is periodically calibrated using sources certified by or traceable to the NIST. Detector operation is checked using radioactive sources. Instrument failure alarms are provided locally and in the Central Monitoring Room.

Airborne Radioactivity Monitoring - Occupied radiological areas on the surface and underground are monitored, when required, by continuous air monitoring (CAM) equipment. CAMs are located in occupied areas that may have the potential to exceed 10 percent of the DAC of the radionuclides of interest.

The design features of the airborne monitoring equipment depend on their function. The monitors continually collect and measure airborne particulates by pulling air through a filter in proximity to an integral beta-gamma or alpha detector. The airborne radioactivity monitor provides a local and, in some locations, a remote readout and alarm in the central monitoring room (CMR). Meters, audible and visual alarms provide a clear and unambiguous indication of alarm conditions. As appropriate, each monitoring system is set to alarm within acceptable levels of the limits in 10 CFR 835.[2]

Fixed air samplers (FASs) are installed to collect airborne particulates on a fixed filter medium. The fixed air sampler filters are removed and counted periodically to evaluate cumulative radioactive particulate concentrations.

In addition to the above permanently installed equipment, portable CAMs and portable air samplers are provided. The air samplers and portable CAMs are similar to those described above. Portable samplers normally are used for sampling non-routine operations or for emergency air sampling or to temporarily replace inoperable equipment.

The CAMs are calibrated periodically and after repairs, using standards that are traceable to the NIST. The source and detector geometry during calibration are the same as the sample and detector geometry in actual use.

7.1.4 Dose Assessment for Normal Operations

7.1.4.1 On-site Dose Assessment

This section provides a summary of the dose assessments for the primary, occupationally exposed groups involved in waste handling operations at the WIPP facility. The results are representative values, determined by estimating dose rates based on shielding analyses, the characterization of the waste forms (see Chapter 5), time, and motion/manpower studies for the handling of the waste, and the estimated quantities of waste received. The time and motion/manpower information used is based on the current concept of staffing levels and the organization planned for WIPP facility operations. This assessment considers normal waste handling operations only. Abnormal operations, such as decontamination and overpack operations are addressed in Chapter 5, Hazards and Accident Analysis.

Waste containers accepted for disposal at the WIPP are expected to meet the DOE RadCon Manual[1] external contamination limits. Waste containers are thus considered contamination free. Therefore, WIPP normal operations do not involve or entail any planned or expected releases of airborne radioactive materials. As such the projected occupational worker dose from normal operations is a result of direct radiation from waste containers only, with no contribution from internal dose (CEDE) to airborne radiological materials.

Table 7.1-3 provides the estimated annual external exposure to workers during normal CH TRU and RH TRU waste handling operations.

7.1.4.1.1 Radiation and Contamination Zones and Radiological Areas

For design purposes, waste handling and disposal areas were divided into radiation and contamination zones. Each zone was designed to minimize and confine both direct radiation and potential contaminants if they occur using static barriers, such as permanent and temporary walls and shielding, and by the dynamic controls provided by the ventilation systems. The design objective was to provide the ability to operate with an administrative control level of 1.0 rem/year per person or less.

For operational purposes, designated radiological areas (Figure 7.1-1) are dynamic and subject to frequent change depending on activities and radiological conditions in the areas.

7.1.4.1.2 Normal Operations Dose Estimates

Normal operations encompass the transfer of RH waste casks and canisters and CH TRU transporters and containers from the point of receipt to the disposal area without an abnormal occurrence.

The following items are inputs to the analysis of the dose estimates included in Table 7.1-3:

- The average dose rate for a CH TRU waste drum is estimated based on information provided by waste generators to be 14 mrem/h at an assumed distance of 4 inches from the surface and for the standard waste box (SWB) is estimated to be 5 mrem/h. The volumetric ratio of drums to boxes is taken to be about 60/40 for this assessment with an estimated annual throughput of about 230,000 cubic feet (6500 cubic meters). (Analysis to be updated when better data is available)

- The average dose rate for remote handled transuranic (RH TRU) waste transport casks and RH TRU waste facility casks is estimated to be approximately 2.0 mrem/h at 4 inches from the cask surfaces. For the purposes of this assessment, 250 canisters are assumed to be received per year. (Analysis to be updated in the FY-98 Annual Update.)

The number of people who could receive radiation exposure in a given area is based on projected manpower studies for the RH and CH TRU areas both aboveground and underground at the facility. The primary occupationally exposed groups considered in the dose assessment are waste handling personnel and radiation control personnel. Estimated exposure times are based on time and motion analyses of the functional steps constituting the preoperational checkouts. In unshielded areas, estimated exposure rates are based on the exposure rates from waste containers and the expected range of distances between radiation sources and personnel. For shielded areas, e.g., immediately outside the hot cell, the exposure rate is conservatively estimated from shielding analyses that consider shielding effectiveness using experimental waste as the design source. The data used in this analysis is conservative compared to the actual waste handling operation anticipated.

7.1.4.2 Off-site Dose Assessment

As discussed in Section 7.1.4.1, waste containers accepted for disposal at the WIPP are expected to meet the DOE Radiological Control Manual[1] external contamination limits. Waste containers are thus considered contamination free. Therefore, WIPP normal operations <u>do not</u> involve or entail any planned or expected releases of airborne radioactive materials. The WIPP will be operated in compliance with the release standards of 40 CFR 191 Subpart A[3] and 40 CFR 61 Subpart H[4]. Once operations begin, confirmatory measurements will be performed as discussed below.

7.1.4.2.1 Effluent Sampling/Monitoring and Environmental Monitoring

7.1.4.2.1.1 Effluent Sampling Systems

The effluent sampling system consists of fixed air samplers (FASs) for the confirmation of the presence or absence of airborne particulate radioactivity releases.

Samplers are installed near each release point to collect the particulate samples from a representative fraction of the total volume of air being discharged. The samplers consist of a sampling probe, a filter holder, and a vacuum supply.

Other design features are included to improve sampling efficiency.

The fixed air sampler (FAS) filter holder is designed to prevent in leakage of ambient air and to support the filter under the design pressure of the vacuum supply. Furthermore, the holder is designed so that particulate matter is uniformly deposited on the filter.

The data from this FAS provide a method for quantifying total airborne particulate radioactivity discharged. This is done to demonstrate compliance with the mandated regulatory requirements contained in 40 CFR 191, Subpart A[3] and 40 CFR 61, Subpart H.[4] These regulations place stringent requirements on the allowable annual dose equivalent to any member of the public. The sampling period and sample volume are maximized to provide a reasonable lower limit of detection.

7.1.4.2.1.2 Effluent Monitoring Systems

Continuous air monitors (CAMs) are located near the release points in the effluent airstreams. These instruments monitor the extracted air from the effluent ventilation stream for radioactive particulates to provide an alarm in case of a significant accidental release.

The effluent monitoring systems are designed and environmentally qualified to withstand the effects of the Design Basis Earthquake and are installed with backup power to allow monitoring in the event of a power failure.

References for Section 7.1

1. DOE/EH-0256T, Department of Energy, Radiological Control Manual, Revision 1, April, 1994.

2. 10 CFR 835, Occupational Radiation Protection, January, 1993.

3. 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, Subpart A, Environmental Standards for Management and Storage.

4. 40 CFR 61, Environmental Protection Agency Regulations on National Emission Standards for Hazardous Air Pollutants, Subpart H, National Emission Standard for Radionuclide Emissions from Department of Energy (DOE) Facilities.

5. DOE Order 5400.5, Radiation Protection of the Public and the Environment, June, 1990.

6. DOE Order 6430.1A, General Design Criteria Manual, December 12, 1983.

7. WIPP-DOE-069, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 4, December, 1991.

8. U.S. Department of Transportation, Title 49, Code of Federal Regulations.

9. WP 12-5, WIPP Radiological Control Manual, Revision 1, October, 1994.

10. DOE/EV/1830-T5, A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA), April 1984.

11. DOE Order 5480.11, Radiation Protection for Occupational Workers, June 17, 1992.

12. WP 12-2, WIPP ALARA Manual, April, 1993.

13. ORNL-4181, Modifications of the Point-Kernel Code QAD-P5A: Conversion to the IBM-360 Computer and Incorporation of Additional Geometry Routines, July 1968.

14. LA-3573, QAD: A Series of Point - Kernel General-Purpose Shielding Programs, April 1967.

15. LA-5176, G^3: A General Purpose Gamma-Ray Scattering Program, June 1973.

16. Union Carbide Corp., Report No. K-1693, A User's Manual for ANISN: A One Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering, June 1973.

17. ORNL-RSIC-CLC23, Cask-40 Group Coupled Neutron and Gamma-Ray Cross Section Data, Revision D, March 12, 1974.

18. ANSI N101.6-1972, Concrete Radiation Shields.

19. ANSI 101.1-1978, Efficiency Testing of Air Cleaning Systems Containing Devices for Removal of Particles.

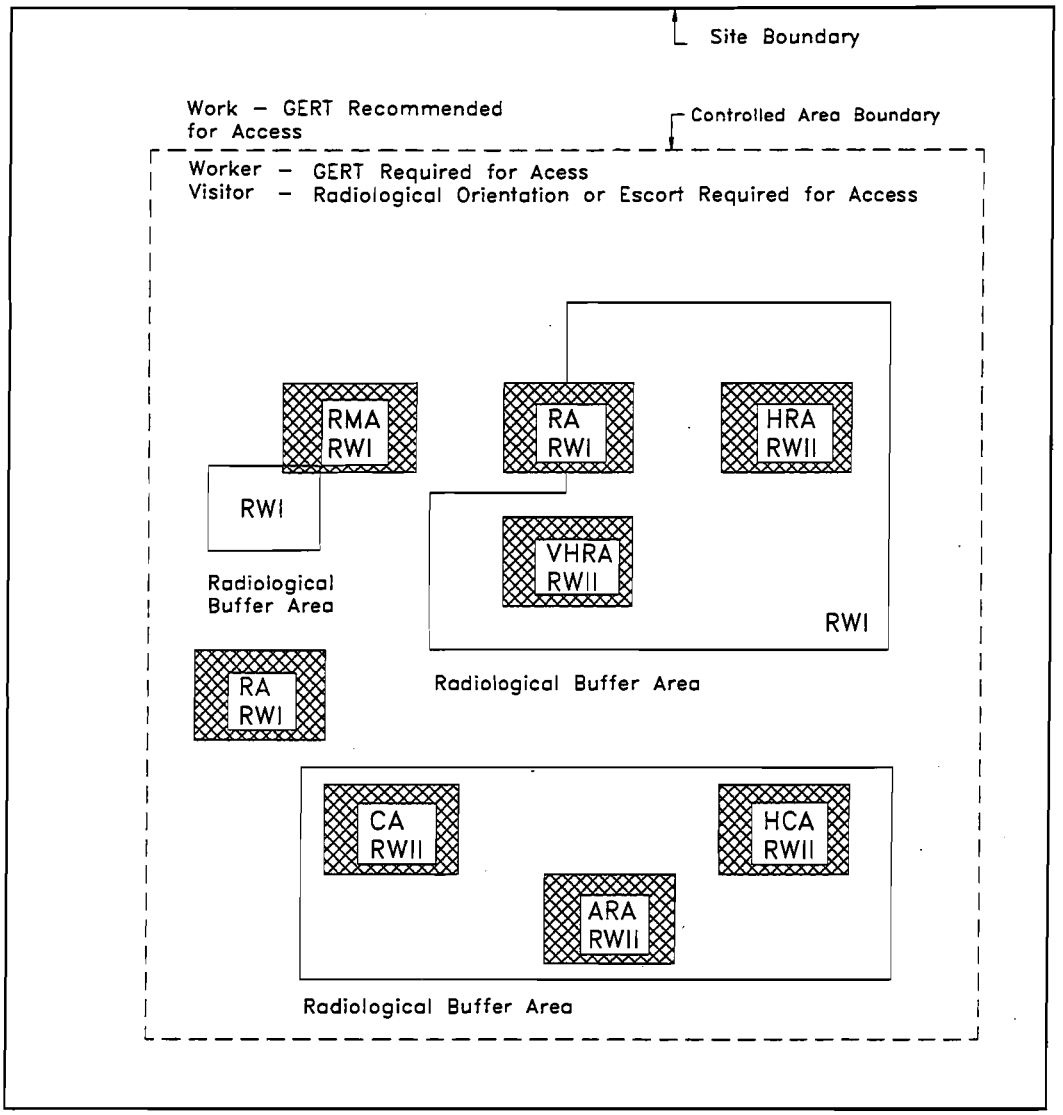
20. ANSI N510-1975, Testing of Nuclear Air-Cleaning Systems.

21. WP 12-3, Dosimetry Program Manual, Revision 4, March, 1995.

22. ANSI Z88.2-1980, Practices for Respiratory Protection.

23. WP 12-1, WIPP Safety Manual, Revision 3, December, 1994.

24. DOE 5480.15, Department of Energy Laboratory Accreditation Program for Personnel Dosimetry, December, 1987.



Legend:
GERT – General Employee Radiological Training
RWI – Radiological Worker I
RWII – Radiological Worker II
RMA – Radioactive Material Area
RA – Radiation Area
HRA – High Radiation Area
VHRA – Very High Radiation Area
CA – Contamination Area
HCA – High Contamination Area
ARA – Airborne Radioactivity Area

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Figure 7.1-1, Radiological Areas and Access Requirements

Table 7.1-1, CH TRU Waste - Gamma Source Strength

Energy (MeV)	Average* Source Strength (MeV/cc-sec)	Maximum** Source Strength (MeV/cc-sec)
0.10	5.33E - 3	1.07E - 1
0.15	9.11E + 0	1.82E + 2
0.30	3.51E + 0	7.02E + 1
0.45	5.48E + 0	1.10E + 2
0.70	7.49E + 1	1.50E + 3
1.00	7.33E + 1	1.47E + 3
1.50	6.12E + 2	1.22E + 4
2.00	5.10E + 0	1.02E + 2

* Calculated exposure rate at surface of drum - 10 mrem/h
** Calculated exposure rate at surface of drum - 200 mrem/h

Table 7.1-2, RH TRU Waste - Gamma Source Strengths

Energy (MeV)	Maximum* Source Strength (MeV/cc-sec)
0.10	7.98E + 2
0.15	1.36E + 6
0.30	5.25E + 5
0.45	8.21E + 5
0.70	1.12E + 7
1.00	1.10E + 7
1.50	9.17E + 7
2.00	7.64E + 5

* Calculated exposure rate at surface of canister - 1000 R/h Standard RH TRU canister filled with waste at a concrete density of 2.35 g/cm^3

Table 7.1-3, Normal CH and RH TRU On-site Annual External Radiation Dose Estimates

Operation	Personnel	Persons*	Total Dose (rem/yr)	Average Individual Dose (rem/person/yr)
CH TRU Waste Handling	Waste Handlers	15	10.5	0.70
	Radiation Control	3	1.8	0.60
RH TRU Waste Handling	Waste Handlers	15	1.42	0.09
	Radiation Control	3	0.75	0.25
Total - All Waste Handling Operations	Waste Handlers	15	11.9	0.79
	Radiation Control	3	2.6	0.87

*Expected staffing level

7.2 Hazardous Material Protection

This section (1) provides an assessment of the potential for occupational and public exposure to nonradiological hazardous materials as a result of normal operations during the WIPP disposal phase, and (2) describes the WIPP programs in place for control of nonradiological hazards and for protection of the worker and the public. An assessment of the potentials for nonradiological exposure as the result of abnormal operations and accidents is included in Chapter 5, Hazards and Accident Analysis.

Hazardous material protection, as implemented by the WIPP Industrial Hygiene Program, is an integral part of the overall WIPP industrial safety program as developed and implemented in the WIPP Safety Manual.[1] The organization responsible for implementation is the WIPP ESH Industrial Safety section. The implementing procedures for the WIPP Industrial Hygiene Program are found in the Industrial Hygiene Procedures Manual.[2] Implementation of the defined program elements will ensure control of occupational health hazards originating from chemical, biological, and physical (excluding ionizing radiation) agents.

Requisition, procurement, use, handling, and storage of non-TRU waste hazardous materials are controlled by the WIPP Nonradioactive Hazardous Materials Environmental Compliance Manual[3] and implementing procedures. Implementation of this program will ensure compliance with the Toxic Substances Control Act[4] (TSCA); the Superfund Amendments and Reauthorization Act[5] (SARA); the Occupational Safety and Health Act[6] (OSHA); the Comprehensive Environmental Response, Compensation, and Liability Act[7] (CERCLA), and the U.S. Code of Federal Regulations (CFR).

7.2.1 Hazardous Material Sources

The primary occupational nonradiological hazard to both the worker and the public during normal operations is from the airborne release of volatile organic compound (VOC) gases from TRU mixed waste containers during waste handling and emplacement operations. Lead and other heavy metals are present in TRU mixed waste, but pose hazards to workers and the public only under accident conditions as discussed in Chapter 5. Exposure assessments for workers and the off-site public in the following sections are based on the releases of the average drum headspace VOC concentrations into the waste handling building and the underground via diffusion through the drum vent filters.

7.2.2 Hazardous Material Exposure Assessment for Normal Operations

The exposure assessments presented in this section are summarized from or based on the environmental impacts analysis provided in the WIPP No-Migration Variance Petition[9] (NMVP).

7.2.2.1 Off-site Exposure Assessment

The potential environmental and public impacts associated with the airborne release of VOCs during normal operations, summarized in this section, are assessed in detail in the WIPP NMVP.[9] Based on the most recent headspace sampling of TRU mixed waste and toxicity data, nine VOCs were identified as the most prevalent and, of these, carbon tetrachloride, methylene chloride, and chloroform are considered potential carcinogens.

The average void volume was used to calculate the total grams of a VOC in the gas phase of each TRU mixed waste drum. The "void volume" or "headspace" is the total volume of a drum occupied by gases. The average void volume within a drum was calculated to be 5.2 cubic feet (147 liters). The average concentrations of the selected VOCs in the drum headspace are given in Table 7.2-1.

The compliance point relevant to air emissions for the NMVP[9] for off-site exposure assessment is the WIPP site boundary. The NMVP[9] assessment uses conservative assumptions, which tend to overestimate the consequences of releases. Table 7.2-1 lists the maximum public exposure concentration at the site boundary from VOC air emissions from both the waste handling building and from the underground calculated assuming a 35-year operational and decommissioning/closure period. As shown in the table, the largest projected health risk to a hypothetical member of the public residing at the WIPP Site boundary would be for carbon tetrachloride, at about 100,000 times below the public exposure health-based levels. The total risk from contributions from all nine emissions is considerably less than the acceptable risk level.

7.2.2.2 On-site Exposure Assessment

The potential occupational exposures associated with the airborne release of VOCs during normal operations, are also shown in Table 7.2-1. The highest occupational exposure concentrations from WHB and underground VOC air emissions are from methylene chloride, which are well below Occupational Safety and Health Administration (OSHA) 29 CFR 1910.1000[10] 8-hour time weighted average (TWA) permissible exposure limits (PELs).

7.2.3 Industrial Hygiene Program

The WIPP Industrial Hygiene Program encompasses the comprehensive aspects of Industrial Hygiene defined by DOE Order 5480.10[11], excluding ionizing radiation, physical safety, fire prevention, medical examinations, and formal training, which are addressed by other programs.

The WIPP Industrial Hygiene Program acts to protect WIPP workers by anticipating, recognizing, evaluating, and controlling chemical, physical, biological, and ergonomic factors and/or stressors in the workplace. The permissible exposure limits used in hazard evaluation shall not exceed those in the mandatory standards of DOE Order 5480.4,[12] Attachment 2.

7.2.3.1 ALARA Policy

The WIPP Industrial Hygiene Program seeks to ensure that employee exposures to hazardous materials are ALARA. The program uses the following controls to meet this goal:

- The use of approved and controlled procedures that provide administrative or engineering controls that minimize or eliminate exposure to hazardous materials.
- Furnishing employees the necessary personal protective equipment.
- Training employees to recognize potential hazards, take safety precautions, understand consequences of an accident, and know the actions to take in case of an accident.
- Monitoring the work environment to obtain personnel and area exposure data.
- Review and approval of all chemical use and storage at the WIPP.

7.2.3.2 Hazard Identification, Evaluation, and Elimination

WIPP Industrial Hygiene identifies, defines, and evaluates controls in the occupational environment for those stresses which could be detrimental to employee health and safety. These stresses, whether chemical (e.g., liquid, particulate, vapor, or gas); physical (e.g., electromagnetic radiation, noise, vibration, extremes of temperature or pressure); biological (e.g., agents of infectious disease); or ergonomic (e.g., body position in relation to task) are recognized by familiarization with the work environment, review of first aid records and hazard control.

Industrial hygiene uses methods available, either by laboratory analysis or instrument monitoring, to define environmental conditions of the workplace. The following activities are included but not limited to: hearing conservation, dust sampling, characterization of mine gases, control of toxic fumes and vapors, sanitation inspections and potable water supply sampling, evaluating OSHA and MSHA compliance for on-site activities, review of proposed project facilities, and evaluation of other hazards by periodic monitoring of work areas. With respect to these activities, assurance of equipment calibration and maintenance and record keeping of inspections are maintained. These methods are outlined in the WIPP Safety Manual.[1]

An on-site industrial hygiene laboratory calibrates and prepares sampling equipment for personnel exposure measurements, to analyze mine atmospheres, water potability, and chemical exposure hazards. Respirator fit testing and maintenance are also an industrial hygiene responsibility.

The WIPP Hazard Communication Program is discussed in detail in the WIPP Safety Manual[1] and WP 12-107, Hazard Communication Program.[13] The program includes material hazard training, MSDS management, inventory/listing of hazardous materials on-site, control of hazardous material purchase requisitions by Industrial Hygiene prior to purchase, material container labeling requirements, on-the-job training requirements, and employee responsibility requirements concerning hazardous materials used in the work area.

The Industrial Hygiene Program is outlined in the WIPP Safety Manual[1] with implementing procedures found in WP 12-8, Industrial Hygiene Procedures Manual.[2]

7.2.3.3 Chemical Management

Management of hazardous materials is implemented by guidance contained in WP 02-EC.04.[14] Guidelines are provided for procurement, receipt, distribution, tracking, storage, transportation, use, recycling, and disposal of hazardous materials.

Each WIPP employee receives as part of the General Employee Training (GET), hazard communication training and hazard recognition training. All employees who work with hazardous materials receive hazard communication training and Resource Conservation and Recovery Act (RCRA) training.

As an overview of site chemical usage purchase requisitions, Material Safety Data Sheet (MSDSs), and Action Requests are reviewed. This minimizes use of hazardous materials by allowing for substitution of materials and maintains an ALARA approach to carcinogens and very toxic materials. During the review availability of appropriate storage, personal protective equipment, and the need for personnel training is also evaluated.

Hazardous Materials are logged into the warehouse upon arrival. Industrial Hygiene receives copies of all MSDS's for materials brought on the site whether by Westinghouse or by subcontractors. Copies of MSDS's are available to all employees during all shifts. Training on the Occupational, Safety and Health Administration (OSHA) Hazard Communication Standard is a requirement of all personnel who work with or enter areas where they are used.

Periodic inspections of work and storage areas are performed to evaluate safe work conditions, proper storage and effectiveness of engineering controls.

7.2.3.4 Air Monitoring

7.2.3.4.1 Nonradioactive Air Contaminants

WP 12-828[15] implements the WIPP Air Quality Monitoring Program. To ensure compliance with American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLV), administrative or engineering controls are determined and implemented whenever possible. When such conditions are not feasible to achieve full compliance, protective equipment and/or other protective measures are used to keep employee exposures to air contaminants within prescribed limits. Any equipment and/or technical measures used must be approved by the WIPP Industrial Hygienist.

Industrial Hygiene monitors or tests the air in areas where hazardous chemicals are stored, and in areas where workers may be exposed to concentrations of airborne fumes, mists, or vapors. All surveys are recorded; records contain the location, time, job description, or occurrences that may be associated with the contaminants, and instruments used. All available inventories, reports and monitoring data are made available to the Health Services Administrator in order to assist the medical monitoring program.

In the WIPP underground, airborne concentrations of mists, fumes, or vapors will be monitored and sampled on a periodic basis, or upon request, by suitable devices such as Draeger pumps or other portable grab sample monitors. If relevant air concentrations are found in excess of the TLVs, immediate corrective actions will be taken as determined by the Industrial Safety Department, and the air will be periodically tested until in compliance.

Air quality monitoring equipment is calibrated per manufacturer's recommendations with an accurate record kept of pre-calibration conditions of the instrument. Functional tests are performed daily. Competency of individuals required to use air monitoring equipment is verified with a qualification card. Functional testing competency requires a formal training program.

7.2.3.4.2 Diesel Emissions

Vehicle emissions of underground equipment are periodically monitored in accordance with procedures in the WIPP Industrial Hygiene Procedures Manual[2], to assure the health and safety of personnel. Incomplete combustion of diesel fuels causes contaminants of carbon monoxide, carbon dioxide, and nitrogen dioxide. The air in the underground is monitored for these contaminants to ensure compliance within TLV limits. Vehicles are checked for carbon monoxide and nitrogen dioxide after preventive maintenance checks and during scheduled overview inspections.

7.2.3.5 Workplace Monitoring

Industrial Hygiene surveys are a means of evaluating and maintaining a safe and healthful workplace. Examples of items surveyed are bioassay; drinking water potability; local exhaust ventilation systems; and chemical, physical, and biological hazards. Sampling of the environment involves calibration of equipment, actual sampling, and recording the results in terms of the actual stress. Surveys are conducted in accordance with procedures in the WIPP Industrial Hygiene Procedures Manual.[2]

7.2.3.6 Occupational Medical Program

The occupational medical site personnel, as defined in the Occupational Medical Program,[16] work in close cooperation and coordination with other departments to optimize the maintenance of a healthful work environment. Pre-employment, periodic, return to work, and termination health examinations are coordinated with the Human Resources Department. Diagnosis and treatment of occupational injuries and illnesses are coordinated with all departments where these incidents may occur. Health maintenance and preventive medical activities are coordinated with the Industrial Safety Section.

The program overview is performed by an occupational medical physician, who works part-time under contract to the WIPP facility. The physician is assisted by an on-site occupational health nurse and emergency service technicians (ESTs). The ESTs provide 24-hour emergency medical coverage on the site.

The occupational medical program is designed to accomplish the following:

- Ensure the health and safety of employees in their work environments, through the application of occupational health principles
- Determine the physical fitness of employees to perform job assignments without undue hazard to themselves, fellow employees, or the public at large
- Ensure the early detection and treatment of employee occupational illness, or injuries, by means of scheduled periodic health evaluations and a wellness awareness program

7.2.4 Environmental Monitoring

The volatile organic compound (VOC) monitoring program activities have focused on the air pathway since 1991. The airborne emission of VOC's is the only credible release pathway from the WIPP facility during disposal operations, and the final closure design basis requires this pathway to be eliminated upon final closure. With over $2^1/_2$ years of data, a credible basis for determining the WIPP's background levels of the targeted VOCs has been established.

In recognition that the volatile hazardous constituent concentrations at the facility boundary, as shown in Table 7.2-1, were predicted using conservative assumptions and show a significant margin of safety below health-based levels, monitoring of VOCs during the continued disposal operations will not be continued.

References for Section 7.2

1. WP 12-1, WIPP Safety Manual, December 1994.

2. WP 12-8, WIPP Industrial Hygiene Procedures Manual, April 1995.

3. WP 02-5, WIPP Nonradioactive Hazardous Materials Environmental Compliance Manual, May 1995.

4. 40 CFR 702-799, Toxic Substance Control Act.

5. 40 CFR 300-399, Superfund Amendments and Reauthorization Act.

6. 29 CFR 1900-1999, Occupational Safety and Health Act.

7. 40 CFR 300-372, Comprehensive Environmental Response, Compensation, and Liability Act.

8. CAO-94-1005, WIPP Transuranic Waste Baseline Inventory Report, Revision 1, February 1995.

9. DOE/CAO-95-2043, WIPP No-Migration Variance Petition, May 31, 1994.

10. 29 CFR 1910.1000, Air Contaminants, July 1993.

11. DOE Order 5480.10, Contractor Industrial Hygiene Program, June 1985.

12. DOE Order 5480.4, Environmental Protection, Safety, and Health Protection Standards, May 1984.

13. WP 12-107, Hazard Communication Program, April 1995.

14. WP 02-EC.04, Hazardous Material Management Plan, September 1995

15. WP 12-828, Air Quality Monitoring Procedure, May 1994.

16. WP 15-3, Occupational Health Manual, April 1992.

Table 7.2-1, Maximum Occupational and Public Exposure Concentrations, and Limit Comparisons of Volatile Organic Compounds

Selected Volatile Organic Compounds	Weighted Average Drum Headspace Concentration (ppmv)	Maximum Occupational Exposure Concentration from Underground Waste Emissions (ppmv)[a]	Maximum Occupational Exposure Concentration in the WHB from Waste Emissions (ppmv)[b]	OSHA 29 CFR 1910.1000 8-hour Time-weighted Average Concentration Permissible Exposure Limit (ppmv)	Maximum Public Exposure Concentration at the LWB from Underground Waste Emissions ($\mu g/m^3$)[c]	Maximum Public Exposure Concentration at the LWB from WHB Waste Emissions ($\mu g/m^3$)[b]	Public Exposure Health-based Levels ($\mu g/m^3$)[d]
Carbon Disulfide	0.13	1.85×10^{-5}	2.09×10^{-8}	20	1.40×10^{-6}	3.21×10^{-10}	10
Carbon Tetrachloride [e]	408	4.34×10^{-2}	5.05×10^{-5}	10	6.91×10^{-3}	1.57×10^{-6}	0.133
Chlorobenzene	7.88	8.04×10^{-4}	9.35×10^{-7}	75	9.38×10^{-5}	2.12×10^{-8}	20
Chloroform [e]	25.21	2.97×10^{-3}	3.46×10^{-6}	50[f]	3.65×10^{-4}	8.32×10^{-8}	0.087
1, 1-Dichloroethene [e]	7.54	9.29×10^{-4}	1.08×10^{-6}	1[g]	9.24×10^{-5}	2.11×10^{-8}	0.4
Methyl Ethyl Ketone	42.42	4.85×10^{-3}	5.64×10^{-6}	200	3.60×10^{-4}	8.20×10^{-8}	1000
Methylene Chloride [e]	497.93	6.49×10^{-2}	7.54×10^{-5}	500	5.64×10^{-3}	1.29×10^{-6}	4.255
1,1,2,2-Tetrachloroethane [e]	5.73	6.10×10^{-4}	7.09×10^{-7}	5	1.06×10^{-4}	2.40×10^{-8}	0.345
Toluene	18.89	1.99×10^{-3}	2.32×10^{-6}	200	1.90×10^{-4}	4.31×10^{-8}	400

a The maximum concentration occurs during the emplacement of the last few drums in a panel (81,000), with ventilation at 47,000 ft^3/min within the panel.
b Based on a maximum of 42 drums (3 TRUPACT-IIs) in the WHB at any one time.
c Maximum at the time when the next-to-the-last panel is closed and waste is being emplaced in the last panel.
d Based on EPA Risk Assessment Guidance for Superfund Sites and RCRA Proposed Subpart S methodology, as explained in the WIPP No-Migration Variance Petition Phase I, DOE/WIPP-95-2043, May 1995.
e Carcinogen
f Ceiling value
g No PEL listed, assumed 1 ppmv

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INSTITUTIONAL PROGRAMS

This chapter discusses additional institutional programs at WID which fulfill the objectives of DOE Order 5480.23, Nuclear Safety Analysis Reports.[1] A description of the requirements and their implementation is provided for the following programs:

- Management, Organization, and Institutional Safety
- Procedures and Training
- Initial Testing, In-Service Surveillance, and Maintenance
- Operational Safety
- Emergency Preparedness Program

8.1 Management, Organization, and Institutional Safety Provisions

8.1.1 Introduction

Westinghouse Electric Corporation (WEC) has managed and operated the Waste Isolation Pilot Plant (WIPP) facility for the U.S. Department of Energy (DOE) since October 1985. Westinghouse, as the Management and Operations Contractor (MOC), provides the management staff, sets the safety culture, issues policies, and implements programs. These MOC actions result in facility operations that are conducted safely, correctly, and efficiently.

8.1.2 Requirements

The requirements and guidelines for developing the WID Management, Organization, and Institutional Safety program are provided in DOE Order 4700.1, Project Management System[2] and DOE/WIPP 103,[3] DOE Management Directives for the WIPP.

8.1.3 Organizational Structure, Responsibilities, and Interfaces

The WIPP facility is managed by Westinghouse Electric Corporation, Government and Environmental Services Company (GESCO), Waste Isolation Division (WID). GESCO includes other Government facilities operated by Westinghouse, and the WID draws on these resources as a result of this arrangement.

Several committees have been formed to integrate information regarding environment, safety, health, and radiation protection activities at the various facilities served by the Business Unit (BU). These committees facilitate the sharing of solutions to common problems and issues. The BU management team is supportive of WID activities by participating in Corporate reviews and audits of WIPP activities, and by providing management attention, as needed.

Additionally, the WID has access to Corporate expertise in several disciplines including waste management, risk assessment, safety analysis, environmental services, technical and analytical services, regulatory compliance, transportation, legal, quality assurance (QA), and others as required.

The corporation periodically reviews GESCO facility operations, including the WIPP, to evaluate compliance with applicable laws and regulations and with Westinghouse corporate directives. Included are audits conducted on engineering and design, construction, quality assurance, testing, operation, and other activities. Westinghouse policy is to conduct all operations so that the health and safety of the employees, the public, and the environment remain protected. This commitment extends to all levels of management and is reflected in the goals and objectives established for operating facilities.

The corporation has no specific authority regarding the engineering and design, construction, QA, testing, operation, and other activities beyond those carried out by the WID, as specified in the contract with the DOE. Corporate resources are available and will be committed, as needed, to ensure that WID activities are conducted safely, correctly and efficiently. Corporate management plays a vital role in providing appropriate direction for WID activities by selecting the WID General Manager (GM).

8.1.3.1 Organizational Structure

Responsibility for operating the WIPP facility has been assigned to the MOC organization. Figure 8.1-1 shows the chain of command by which the Assistant Secretary for Environmental Restoration and Waste Management exercises responsibility for the operational safety of the WIPP.

While responsible for all aspects of the WIPP facility, DOE has contracted these scopes of work to various organizations. The MOC is responsible for managing the current and future construction contracts and to operate the WIPP facility, including all day-to-day operations.

The GM is responsible for the design, operation, maintenance, and modification of the WIPP facility, including the health and safety of employees and the protection of the environment. The GM has issued policies exercising this responsibility to manage these activities directly or by delegation of authority. Management functions are performed according to management policies and requirements defined in the operating contract.

8.1.3.2 Organizational Responsibilities

The GM has delegated specific responsibilities to managers for the following WIPP functions:

1. Radiation safety, industrial safety, environmental protection, and regulatory compliance;

2. Operation, control, and maintenance of all surface structures including the Waste Handling Building and associated equipment; handling and storing radioactive waste on site; transporting hazardous material off-site; transporting salt aboveground; monitoring and operating site utilities including HVAC, power distribution, water and sewer; operating the Central Monitoring System; underground operations including mining, transporting salt underground, hoisting, operating key facility experimental programs; and equipment maintenance;

3. Design of equipment, systems, and facilities for special operations; review designs proposed by other major Project Participants; design new or necessary facilities; resolve technical and operational problems; and maintain design configuration;

4. Identification, development and definition of applicable requirements; assist management in interpreting and implementing QA program elements, provide performance-based and improvement-oriented independent assessment activities specific to quality improvement, review of Federal Registers, review DOE Orders, perform field audits, evaluate audits of other departments, act as the Defense Nuclear Facilities Safety Board (DNFSB) point of contact and develop Agreements-In-Principle (AIP);

5. Planning and scheduling; integration of technical programs, program development and program reporting, strategic planning and long term budget development, programmatic performance, recommend work-scope priorities, and conduct contingency analyses;

6. Financial resources, accounting, computer services, material and property control, document and procedure review, and procurement services;

7. Coordination of all personnel-related functions supporting facility operations, planning and implementing the general employee technical training programs and certifying/qualifying the operating staff;

8. Public information programs, governmental affairs, technical outreach and communications; public displays, handouts and brochures, interaction with the electronic and print media, visitor's program at the WIPP, Speaker's Bureau activities, identification and resolution of issues between the WIPP Project and outside institutions, maintain contacts with individual representatives from outside institutions, public relations efforts, and the States Relations and Training Program (SRTP) aimed at preparing emergency response personnel bordering the WIPP transportation routes.

8.1.3.3 Staffing and Qualifications

The GM has at least a Bachelors degree in science or engineering and at least 10 years experience relating to managing or operating nuclear facilities. At least four years experience is related to nuclear material or nuclear waste management facilities and at least three years experience in supervising technical personnel.

8.1.3.3.1 Managers

The staff managers reporting to the GM have at least:

- A bachelor's degree in a related field and eight years experience or equivalent.
- Five years in a management capacity.

Line managers with Environment, Safety and Health, (ESH) responsibilities have at least:

- A bachelor's degree in a related field <u>or</u> five years equivalent working experience; and
- Five years experience related to environmental, safety or health responsibilities.

8.1.3.3.2 Other Management, Professional, and Nonprofessional Positions

The Westinghouse WID has developed position descriptions for all regular staff positions with the MOC organization at the WIPP facility. These are classified as "management," "exempt," and "nonexempt" positions. Typically, management positions require a college degree or an amount of work experience commensurate with position responsibilities. Exempt positions generally require a degree at entry level or adequate experience and training. Non-exempt positions generally have only skills-related requirements and a high school diploma. All position descriptions are filed with the WID Human Resources Department.

8.1.4 Safety Management Policies and Programs

8.1.4.1 Safety Review and Performance Assessment

Facility safety elements are reviewed annually. The WIPP MOC ensures that applicable environment, safety, and health requirements are met according to DOE Order 5480.23, Nuclear Safety Analysis Reports.[1] The review focuses on the functional areas within the safety program including, industrial safety, fire protection, and hazardous material elements.

WID procedure WP12-AR1001[4] implements the requirements of DOE Order 5480.21, Unreviewed Safety Questions,[5] in determining the existence of an Unreviewed Safety Question (USQ) and provides for the review, determination, and approval of the USQ issue.

8.1.4.2 Configuration and Document Control

The facility is designed to the requirements of DOE Order 6430.1A, General Design Criteria,[6] and design modifications are controlled by the Engineering Change Order (ECO) process as implemented by WP 09-9 Configuration Management Plan.[7] The ECO is used to implement and control changes to approved engineering design documents.

Modifications to operating procedures resulting from an ECO are controlled through the Procedure Change Notice (PCN) process. Procedure changes are implemented through procedure WP 15-PS3003, Procedure Change Process,[8] which specifies the control, review, and approval of any procedure changes.

Temporary or permanent changes proposed to the facility are measured against criteria specified in the Unreviewed Safety Question Determination procedure.[5] USQs are reviewed against the SAR and Technical Safety Requirements (TSR). A safety evaluation documents any change as mandated by DOE Order 5480.21.[5]

8.1.4.3 Occurrence Reporting

The Occurrence Reporting Process at the WID is directed by DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information.[9] The WID occurrence reporting implementing procedure is WP 12-918, Reporting Occurrences In Accordance With DOE Order 5000.3B.[10] This occurrence reporting procedure provides for reporting events to the Facility Manager (FM) or his designee for categorization. Examples of events that should be reported include, but are not limited to the following: events that could endanger or adversely affect operations, personnel safety, or are contrary to DOE requirements. In addition, the procedure requires the event to be investigated to determine the direct cause, root cause and contributing causes, and to develop corrective actions to prevent recurrence.

The WIPP Lessons Learned Program was established as required by DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities[11] and is implemented by WIPP procedure WP 15-MD 3100, Lessons Learned Program.[12] This procedure provides the guidelines for a Lessons Learned Program to ensure a continuing improvement in plant safety and reliability. Lessons learned bulletins are developed from information obtained from DOE Safety Notices, Nuclear Regulatory Commission Bulletins, external occurrence reports, internal occurrence reports, internal investigative reports, and other pertinent industry documents. All lessons learned bulletins are distributed to the WIPP managers for inclusion into their required reading.

8.1.4.4 Safety Culture

A safe working environment is the priority at the WIPP. Individuals responsible for performing work are continually checking the safety of themselves, the environment, and the facility. This philosophy is directed from the top down within the organization.

The Management approach to Occupational Health and Safety at the WIPP emphasizes the integration of safety into all aspects of the facility mission. WIPP management has communicated its expectations of site personnel and subcontractors regarding safety through policies, procedures, programs, and recognition as discussed in the Westinghouse Electric Corporation, WID, Voluntary Protection Program Application, 1994.[13]

Top management is "visibly" involved in safety and health programs by establishing goals, approving management policies, providing accountability mechanisms, implementing site tracking systems, participating in employee communications, reviewing injury/illness trends, reviewing Industrial Safety summaries including inspection trends, and providing resources to perform jobs safely. Management support is evidenced by the Westinghouse Electric Corporation, WID, Voluntary Protection Program Application, 1994.[13]

The DOE Voluntary Protection Program (VPP) Star Status recognition was awarded to the WIPP because of their comprehensive health and safety program. The VPP program encourages recognition of successful leading industry injury and illness prevention programs that result in reducing workplace hazards. The WIPP Safety program elements including training, employee participation, management involvement, and hazard prevention and controls were reviewed. The WIPP Safety program annual reevaluation maintains the appropriate focus on safety to retain VPP Star status.

8.1.4.5 Operational Systems Safety

This aspect of Operational Systems Safety deals with operational controls whose purpose is to detect and control hazards in operational activities. The program is carried out through independent safety review, inspection, and analysis by the Environment, Safety and Health organization. Specific features of Operational Systems Safety include:

- Design review - Formal, documented design reviews of facilities and equipment are attended by staff safety personnel, as required, in addition to construction packages review, and design specifications. Comments generated are formally resolved, with sign off/concurrence required in the issued final package.

- Procedures review - All operations and maintenance procedures are required to be formally reviewed, and approved, by Safety personnel to ensure that hazards inherent in the work are properly controlled. In the process, proper personal protective equipment and other precautions are specified.

- Operational readiness analysis - As part of the formal startup process for new facilities and components, Safety participates in formal readiness analysis to ensure that safety-related personnel (qualifications and training), equipment, and procedures are in place prior to initial operations.

- Procurement and subcontract reviews - Safety reviews of all purchase orders are performed to ensure that purchases of hazardous/toxic substances are known to safety personnel, and to ensure that no prohibited materials are purchased. These reviews are also performed to ensure that any necessary use precautions are issued to the user when the materials are brought on the site. Subcontract reviews are performed to ensure that the DOE and other safety regulations are specified as contract requirements.

- Inspections and audits - Actual compliance with safety requirements is periodically evaluated through scheduled and unannounced inspections of the workplace by safety personnel.

References for Section 8.1

1. DOE Order 5480.23, Nuclear Safety Analysis Reports, April 10, 1992.

2. DOE Order 4700.1, Project Management Systems, March 6, 1987.

3. DOE/WIPP 103, DOE Management Directives for WIPP.

4. WP 12-AR1001, Unreviewed Safety Question Determination, June 1, 1995.

5. DOE Order 5480.21, Unreviewed Safety Questions, December 24, 1991.

6. DOE Order 6430.1A, General Design Criteria.

7. WP 09-9, Configuration Management Plan, Rev. 2, August 31, 1993.

8. WP 15-PS3003, Procedure Change Process, October 29, 1993.

9. DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information, January 19, 1993.

10. WP 12-918, Reporting Occurrences in Accordance with DOE Order 5000.3B, May 14, 1993.

11. DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities, July 9, 1990.

12. WP 15-MD3100, Lessons Learned Program, March 25, 1994.

13. Westinghouse Electric Corporation, Waste Isolation Division Voluntary Protection Program Application, 1994.

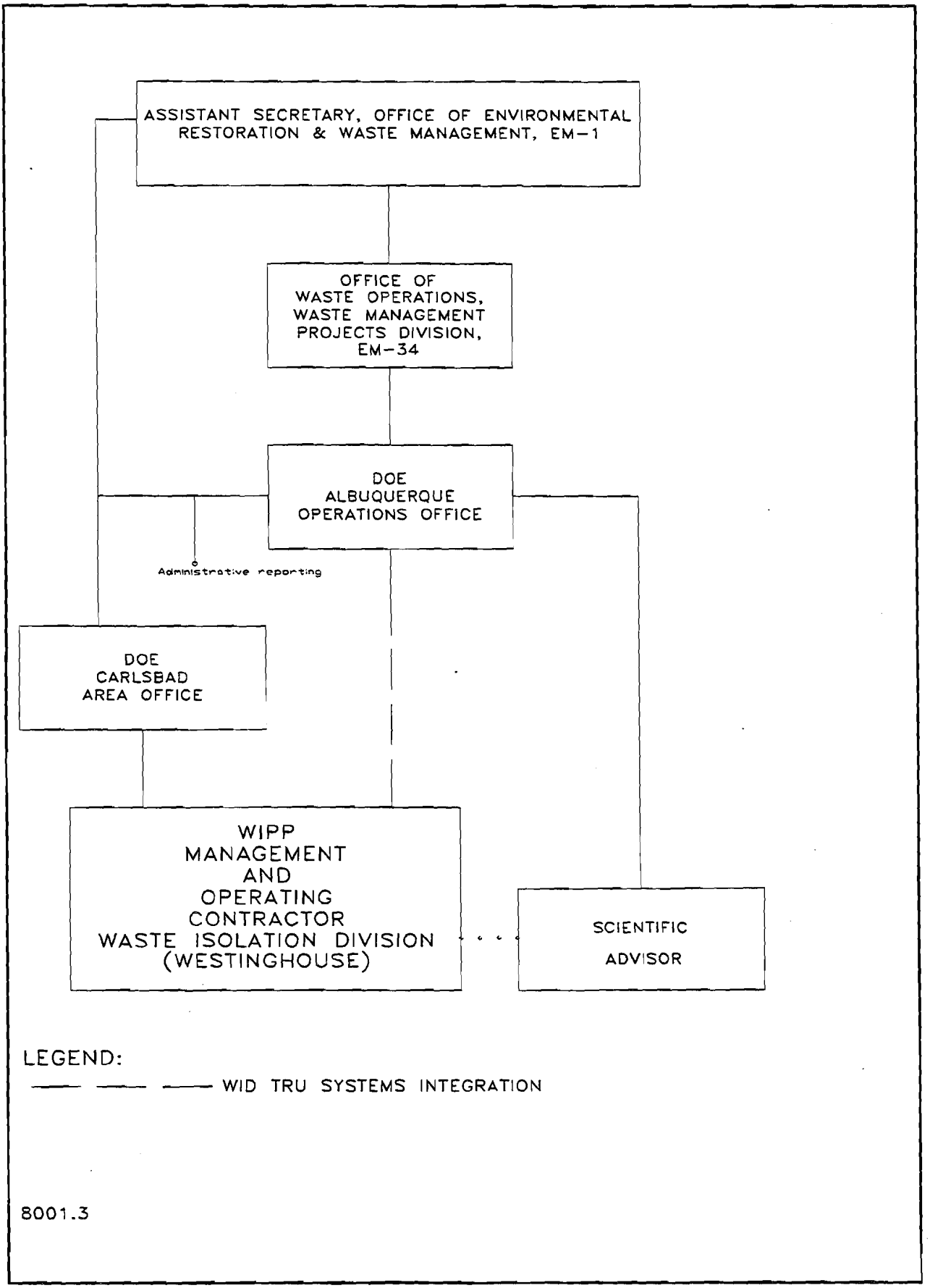

Figure 8.1-1, WIPP Facility Operations Responsibility

8.2 Procedures and Training

8.2.1 Introduction

The MOC is responsible for establishing training programs for operations and maintenance personnel. These training programs establish the minimum requirements for selecting personnel, for training and qualification, and for maintaining certification. Included is a program that provides for general employee training to all persons employed at the WIPP facility. Operations procedures are provided to ensure the facility is operated within its safety basis.

8.2.2 Requirements

Minimum requirements for the selection, qualification, and training of personnel at the WIPP are specified in DOE Order 5480.20A, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities.[1] The minimum requirements for procedures are specified in DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities.[2]

8.2.3 Procedures Program

Formal written operating procedures are prepared for all critical activities that would affect the safety and/or the design purpose of the facility. Procedures govern configuration control of the facility and those systems critical to the operation of the facility. In addition, surveillance procedures are used to insure compliance with the safety envelope of the site. Work on equipment essential to operation of the facility is controlled procedurally.

Procedures are established to ensure the satisfactory preparation and thorough review of the original operating procedures and any modifications to the procedures that may be necessary.

A master file of operating procedures is kept current, and controlled copies are available. The QA requirements for procedures are discussed in Chapter 9.

8.2.3.1 Development of Procedures

Procedure selection or need is determined by the cognizant organization manager (COM), who then assigns a cognizant individual (CI) to develop the technical content of the document. The COM determines which organizations will review the procedure, verifying its technical content and requirements; and the validation process, to determine if the procedure can be performed as written. An independent safety review may also be required. Following successful completion of the technical review and validation process, the procedure is approved for use by an authorizing manager.

8.2.3.2 Maintenance of Procedures

Procedures undergo a periodic review during which a CI must review the procedure for any new or existing requirements, cancellations, deletions, or additions. The change process allows for procedure changes that require immediate correction. Changes to the procedures mandate a technical review that must be signed off by the authorizing manager and a technically competent person before issuance as an approved change.

8.2.4 Training Program

The training program for employees, visitors, and subcontractors at the WIPP facility is a formally organized and continuing program. Training programs address the training of WIPP personnel and any site subcontractors in job-related training subjects spanning all levels of the organization from fundamental technical skills and speciality training to supervisory and management skills training. A formal Training Program for the WIPP facility operation staff and technical support personnel has been established. Training program policies and procedures define job function, responsibility, authority and accountability of WID personnel involved in managing, implementing and conducting training. Management is responsible for the training of their personnel.

8.2.4.1 Development of Training

The training program is organized and managed to facilitate planning, directing, evaluating, and controlling a systematic training process that fulfills job-related needs and considers regulatory requirements. Implementation of training at the WIPP is a shared effort between the functional groups and the training section. WIPP formal classroom instruction is provided in the following areas:

- Facility Operations
- Underground Operations
- Industrial Safety
- Waste Handling
- Emergency Preparedness
- Instructor Training
- Accreditation Support
- Radiation Safety
- Non-Radiological Hazardous Materials
- Maintenance Training

Formal instruction (Classroom or On-shift) is designed and developed around a Systematic Approach to Training (SAT) methodology described in detail in the WIPP Technical Training Procedures Manual,
WP 14-TR.[3] Training for employees working in critical positions is subject to the requirements established for accreditation by the Training Accreditation Program (TAP).

The MOC is responsible for administering training programs, for complying with training standards affecting both regular and contract personnel, and for maintaining current and accurate records reflecting the training of each employee. Records activities follow an approved "Records Inventory and Disposition Schedule," reviewed and updated at least annually to comply with federal codes, policies, or directives concerning training records administration.

8.2.4.2 Maintenance of Training

Training programs are periodically reviewed, focusing on changes in job scope, task, performance, procedure, and regulation. Training programs are approved and authorized by appropriate line management and WIPP Training management before being implemented or revised.

8.2.4.3 Modification of Training Materials

When it is decided that existing programs require revision, a formal process is implemented to ensure program quality is maintained and enhanced.

Using the combined efforts of WIPP training and cognizant personnel, programs are revised and updated. These updates may be due to changes in task performance, modifications to equipment or noted human factors deficiencies. At the completion of program modification, cognizant line management and WIPP training must approve any revision before implementation.

References for Section 8.2

1. DOE Order 5480.20A, Personnel Selection, Qualification, Training Requirements for DOE Nuclear Facilities, November 15, 1994.

2. DOE Order 5480.19, Conduct Of Operations Requirements For DOE Facilities, July 9, 1990.

3. WP 14-TR, WIPP Technical Training Procedures Manual.

8.3 Initial Testing, In Service Surveillance, and Maintenance

8.3.1 Introduction

The MOC is responsible for testing and maintaining the equipment and systems at the WIPP.

8.3.2 Requirements

The plans and provisions for initial and in-service surveillance, are provided in DOE Order 5480.23, Nuclear Safety Analysis Reports.[1] The requirements for maintaining DOE property is provided in DOE Order 4330.4B, Maintenance Management Program.[2]

8.3.3 Initial Test Program

8.3.3.1 Start-up Testing & Preoperational Checkout

Equipment and systems important for continued and safe operation of the WIPP facility shall undergo start-up testing before operation. The testing shall verify established design criteria, prove functional requirements and safe handling of the equipment or systems. The WIPP Procedure Manuals includes a Start-up Testing Program covering initiating, executing, revising & canceling start-up test procedures; start-up documents/records control; and qualification requirements for start-up testing personnel.

8.3.3.2 Start-up Testing Program Objective

The basic objective of the Start-up Program is to verify that the plant's equipment and systems operate safely according to established plant design and approved test procedures.

8.3.3.3 Administrative Procedures for Conducting the Start-up Testing Program

Administrative procedures are established to ensure that the test procedures, before their execution, are prepared, reviewed and approved by qualified personnel. Testing shall be performed by certified individuals, and test results shall be documented and evaluated for adequacy using start-up program procedures. Test procedure changes are controlled and evaluated to ensure that changes do not adversely impact the intent of the test. Plant modifications identified by start-up testing shall be controlled in the same manner as the original design. Implementation of such modifications/changes, including retesting, shall be accomplished by the latest approved applicable project and start-up program procedures.

8.3.3.4 Vendor Testing

Some equipment or system tests may be conducted at the vendor's facility according to contractual specifications, however, it is recognized that often equipment and systems can only be adequately tested after they are installed and integrated with other systems at the WIPP facility. Equipment and systems that fail vendor tests are rejected until repairs, adjustments, or modifications are completed and failed equipment or systems are retested. Nonconformances may be authorized after evaluation by responsible engineering and management personnel.

8.3.3.5 Preoperational Checkout

Beyond vendor and start-up testing, preoperational waste handling demonstration checkouts shall be conducted using simulated waste. Simulated waste handling operations shall be performed in sequence from receipt through final emplacement. The checkouts listed in Table 8.3-1 shall be done according to the latest approved operating procedures and preoperational checkout demonstration procedures. Preoperational checkout objectives include:

- Demonstrating that WIPP personnel can safely handle CH TRU waste packages, including unloading an internally contaminated TRUPACT
- Demonstrating the satisfactory operation of WIPP Waste Handling equipment
- Demonstrating that the WIPP operating procedures are comprehensive and sufficiently detailed to perform normal waste handling operations, and to recover from off-normal occurrences encountered during waste handling operations
- Establishing the aggregate time estimate for WIPP waste handling operations
- Providing the basis for estimating the dose to be received by WIPP waste handling personnel

8.3.4 In-Service Surveillance Program

After systems have completed the start-up processes, they are available for day-to-day operations. It is important to ensure that systems remain within their nominal performance parameters. If systems fail to operate, repairs are implemented and operability is re-established.

Responsibility for ongoing evaluation falls with many organizations depending on the nature of the evaluation. For example some equipment is subjected to periodic operability checks to ensure that operating parameters are within the range allowed for reliable operations. Examples are environmental continuous air samplers (covered by the WIPP Environmental Procedures Manual, WP 02-3[3]) and systems important to safe operation covered by the TSR's in Attachment 1 and covered by WP 04-7, Safety Requirements Administration Manual.[4]

Other systems require periodic preventive maintenance. This is performed according to WP 10-1, WIPP Site Maintenance Plan manual.[5]

Analytical and measurement equipment are entered into a calibration recall system to ensure timely calibration and recalibration of this equipment.

8.3.5 Maintenance Program

Under normal operations, equipment requiring regular maintenance is expected to remain free of hazardous materials. However, it is assumed that any equipment in waste handling areas may become contaminated. Equipment decontamination provisions include smooth surfaces, minimizing void spaces, and designing for easy removal. Floors, walls, ceilings, and structural steel surfaces in the waste handling areas have special protective coatings to simplify decontamination. Where decontamination is impractical, space is provided for installing temporary shielding or the equipment may be removed for repair or disposal.

The WIPP is fully committed to achieving compliance with the requirements of DOE Order 4330.4B.[2] The WIPP Site Maintenance Action Plan[5] (SMAP) provides an annual performance-based action plan to implement DOE Order 4330.4B.[2] The SMAP provides the basis for the Department of Energy review and approval of the adequacy of provisions for maintenance at the WIPP. The SMAP is updated and approved on an annual basis. The maintenance program set forth under DOE Order 4330.4B,[2] Chapter I has been established, developed, and implemented at the WIPP Site.

The MOC is responsible for operating the WIPP facility, including the responsibility for maintenance. The organization, responsibilities, work scope, management and control, and interfaces are prescribed in the WIPP Site Maintenance Plan, WP 10-1.[5]

8.3.5.1 Waste Handling Building

The Waste Handling Building (WHB) has certain provisions incorporated above those which are required for routine maintenance activities.

Equipment in the CH TRU and RH waste handling areas is designed for contact maintenance. The hot cell equipment includes manual overrides to ensure that waste handling equipment can place waste canisters in a shielded area before maintenance is performed.

There is a crane maintenance gallery next to the hot cell where the hot cell crane can be moved and isolated from the hot cell atmosphere without being removed from its rails. This provides shielding from RH TRU waste containers during crane maintenance or repairs. A manipulator repair room is located next to the hot cell operating gallery. The master-slave manipulators can be removed via the operating gallery and taken to the manipulator repair room for required repair operations without personnel entering the hot cell. Hot cell equipment is modularized to the maximum extent practical to simplify its removal when replacement or major repair is required. The facility cask and its transfer car can be taken into the RH cask receiving area for maintenance.

The Waste Shaft hoist area includes sufficient space for maintenance. An overhead handling system is included for the hoist equipment, and means are provided for transferring the hoist equipment to the ground level for maintenance or disposal.

The piping and components of the liquid radwaste processing system have provisions for flushing with fresh water to reduce radiation levels before inspection or maintenance or disposal.

8.3.5.2 Shafts

The mine shafts are designed for periodic inspection and maintenance. The top of the Waste Shaft cage, the Air Intake Shaft (AIS) cage, and the Salt Handling (SH) skip/cage are designed to be used as inspection platforms, with associated overhead protection bonnets installed during inspections of those shafts. Inspections in the Exhaust Shaft are conducted with remote controlled TV cameras since there is no hoist installed in this shaft.

8.3.5.3 Subsurface Areas

Maintenance and repairs are conducted in the underground for excavating equipment and waste handling and emplacement equipment. Waste storage equipment that requires maintenance is surveyed and decontaminated, if required, before being taken to subsurface maintenance facilities.

In the event that the facility cask malfunctions during emplacement or retrieval operations, local maintenance equipment can be set up with local shielding as required. Manual overrides are provided on the waste handling equipment to allow for canister transfer operations to be completed, or recovery of the canister to a safely shielded condition, if the equipment malfunctions. Normal waste-handling equipment maintenance is performed underground at the storage horizon.

Manufacturers' recommended maintenance procedures are expected to be adequate for the underground mechanical equipment. As in any type of operation, however, regular and periodic inspections are required of all equipment and structures.

To minimize any maintenance excavation or re-excavation, all openings are designed large enough initially to allow for creep.

8.3.5.4 Air Filtering Equipment

The filter systems are periodically inspected and filters are changed when the pressure drop across them reaches a predetermined level. If leaks are found, repairs are implemented and the system is retested.

High Efficiency Particulate Air (HEPA) filters, associated with the underground ventilation system, are located in the Exhaust Filter Building in large filter housings. To prevent contamination from spreading, the used HEPA filters are removed and bagged within the housing for disposal. Access to the filter chamber room, where the housings are located is through an air lock that provides a boundary preventing the spread of contamination. Positive airflow into the filter chamber room is maintained during the filter change-out activity. Personnel working within the plenum are provided with protective clothing and respiratory protective equipment.

For the WHB HEPA filters and other smaller filter systems, personnel replacing filters wear suitable protective clothing and carry respiratory equipment. However, they do not enter the housings. Contaminated filters are bagged before they are removed to prevent contamination from spreading during filter change-out. Filter housing maintenance, except for cleaning, is unnecessary.

8.3.5.5 Equipment Decontamination Provisions

Contaminated items are bagged and are then disposed of as radioactive wastes or decontaminated in a designated area. Decontamination of waste transporters, by wiping with damp rags as frequently as necessary, can be accommodated in either the CH TRU or RH TRU unloading area.

The general decontamination philosophy for the WIPP is to minimize the amounts of waste generated due to decontamination operations and is accomplished by wiping with damp rags soaked in detergent or a decontamination solution.

8.3.5.6 Other Surface Structures

Surface structures other than the WHB and the Exhaust Filter Building (EFB) are associated with either direct support activities (switchyards, substation, sewage treatment, emergency power, shaft headframe, and hoist houses), or indirect support activities (Support Building and Warehouse Building). These facilities contain systems that require routine maintenance according to common industrial practice and manufacturers' recommendations. No special or unusual maintenance features are incorporated in the design of these facilities.

References for Section 8.3

1. DOE Order 5480.23, Nuclear Safety Analysis Reports, April 10, 1992.

2. DOE Order 4330.4B, Maintenance Management Program, February 10, 1994.

3. WP 02-3, WIPP Environmental Procedures Manual, Rev. 1, September 18, 1991.

4. WP 04-7, Safety Requirements Administration Manual.

5. WP 10-1, WIPP Site Maintenance Plan Manual, Rev. 4, May 13, 1994.

Table 8.3-1, WIPP Preoperational Checkout Program

Test Title	Plant Condition	Test Objectives
CH Waste Handling	Before receiving CH Waste	Verify all systems associated with the CH waste storage function as described in Section 4.3.1.
RH TRU Waste Handling System	Before receiving RH TRU Waste	Verify all systems associated with the RH TRU waste storage function as described in Section 4.3.2.

8.4 Operational Safety

8.4.1 Introduction

The MOC ensures that all operations are conducted according to DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities.[1] The SAR considers the term "operations" reflecting those daily activities, resources, management, and communication required to support the WIPP in meeting goals and objectives for the intended facility purpose.

Operation of the facility will be according to approved operation procedures, TSRs, and good operating practices. Supervisors are responsible for reporting to the Facility Shift Manager (FSM) any conditions that may affect the quality of operation or operability of the facility. Supervisors must obtain approval for the operation and/or maintenance of the plant equipment and system through the Plan-of-the-Day (POD).

Pre-job briefings will be conducted regularly by supervisors before the evolution for new or complex activities to ensure that they are completed safely, correctly, and efficiently.

8.4.2 Requirements

The MOC's Conduct of Operations is directed by DOE Order 5480.19,[1] and is implemented by all employees through use of WID procedures.

8.4.3 Conduct of Operations

8.4.3.1 Controlled Access Area Activities

Entry to controlled access areas will be limited to persons who need to be in the area on required business. This access will be granted by the control area operator. Additionally, Facility Operations management and designated Operations Assistance Team (OAT) personnel, are granted unrestricted access to the Central Monitoring Room (CMR).

Only persons specifically authorized by administrative procedures may operate controlled area equipment.

8.4.3.2 Communications within the Facility

Timely communication within the facility is enabled by the: public address system which includes Site Notification System (plectrons), radios, beepers, mine pagers and phones, and touch tone telephones. When making site-wide announcements, the Central Monitoring Room Operator (CMRO) will use the PA system (including the Site Notification System [SNS]), and the mine phone.

Personnel notification is by flashing lights, vibrating personnel pagers, or by persons dedicated to notifying personnel working in areas where the public address system cannot be heard. Emergency communication public address systems will be periodically tested to ensure functionality.

8.4.3.3 Control of On-Shift Training

On-Shift training will be conducted by Level 1 Instructors. A qualified subject matter expert (SME) or SME Evaluator will observe trainee performance skills to ensure that no adverse actions occur. Procedure steps, cautions, and notes must be discussed with the instructor before operating any equipment until the student has demonstrated proficiency in performing a skill. Trainees will continue being monitored until demonstrating the proper proficiency.

Training procedures provide documentation guidance for operator qualification and certification programs. Qualification cards will be signed by the SME, documenting that the trainee has successfully and adequately demonstrated proficiency of that skill.

8.4.3.4 Control of Equipment and System Status

The FSM is responsible for maintaining proper configuration and authorizing changes of general surface and underground equipment, and all TSR equipment and systems. The respective manager or supervisor is responsible for maintaining proper configuration for other activities including: hoisting equipment, waste handling equipment and systems.

Equipment and systems will be checked for proper alignment before placing the equipment or system into operation. Checklists will be used to ensure that equipment is controlled, checked, and monitored. Following maintenance, equipment will be checked for proper alignment before being returned to operation.

A system is in place to monitor the status of on-site alarms. Procedures initiating appropriate action are in place to monitor equipment parameters for abnormal conditions that could be masked by deficient alarms.

Programs are in place to ensure that operating personnel receive and use the latest revisions or changes to engineering drawings and/or specifications.

8.4.3.5 Lockouts and Tagouts

WIPP procedure WP 04-AD3011, Equipment Tagout/Lockout[2] sets forth the policy requiring each employee to properly implement the requirements of DOE Order 5480.19,[1] Chapter IX, to protect personnel, DOE property and plant systems, and prior to entry into a high energy system. This procedure provides for placing, removing, and auditing Operations tags and locks for configuration control, and in addition, provides for caution tags. Equipment tagout/lockout uses WP 10-AD3005, Control and Use of Maintenance Locks,[3] when conducting maintenance activities which complies with DOE Order 5480.19[1] and 29 CFR 1910.147.[4]

8.4.3.6 Independent Verification

Independent Verification is performed on components critical to safe and reliable operation when circumstances warrant.

Individuals performing independent verification will be instructed and trained in the appropriate techniques for verifying the correct position of facility components and will perform the necessary checks in accordance with documented procedures and guidelines.

8.4.3.7 Log Keeping

Logbooks will be kept at all key shift positions as determined by the importance of the sequential information related to shift events, and the importance of the shift position regarding establishing or maintaining regulatory or DOE requirements.

As a minimum a logbook will be maintained by the FSM or the CMRO. Information will be recorded accurately and efficiently. The prescribed type, scope, and format of log entries will be strictly adhered to by operating procedures and guidance.

8.4.3.8 Operations Turnover

A process will be in place to ensure that during the supervisory turnover process any conditions related to abnormal lineups, status of major components, surveillance planned or in progress, or evolutions planned or in progress are reported to the oncoming supervisor.

Oncoming personnel and supervisors will conduct a comprehensive review of appropriate written and visual information before responsibility for the shift position is transferred. The off-going supervisor will explain all items noted at a time when facility conditions are stable to the oncoming personnel.

8.4.3.9 Operational Occurrences

WP 12-918, Reporting Occurrences in Accordance with DOE Order 5000.3B[5] establishes a system for reporting events to the Facility Manager (FM)/Facility Manager Designee (FMD) for categorization. Events reported to the FM/FMD are categorized within two hours of discovery per the criteria listed in Attachment 1 of WP 12-918.[5] Events are categorized as off-normal, unusual, or emergency occurrences based upon the severity of the incident. All occurrences are investigated and documented per the requirements of WP 12-135, Root Cause Analysis Investigation Procedure,[6] to determine the root cause, direct cause, and contributing cause. In addition, corrective actions are developed, scheduled, and lessons learned identified. A Notification Report shall be prepared by the FM/FMD and uploaded into the Occurrence Reporting Processing System (ORPS) database before the close of the next business day from the time of categorization, not to exceed 80 hours. A 10-Day Occurrence Report shall be prepared by the FM/FMD and uploaded into the ORPS database within 10 working days of categorization using the information available at the time. A Final Occurrence Report shall be prepared by the FM/FMD uploaded into the ORPS database within 45 days of categorization of the occurrence.

8.4.4 Fire Protection

The fire protection program at the WIPP facility ensures the safety of plant personnel, the reliability and continuity of plant operations, and the minimization of property loss. These objectives are met by incorporating automatic fire suppression systems, by using fire resistant materials in facility construction, by providing fire barriers and fire doors in areas susceptible to fires, and by enclosing vertical openings in buildings preventing the spread of fires.

8.4.4.1 Fire Hazards

The fire hazards at the WIPP due to electrical equipment failure, spontaneous ignition, highly flammable materials, maintenance activities, fuel storage, and office materials are considered to be normal industrial-type fires and could occur in any site area.

8.4.4.2 Fire Protection Program and Organization

Responsibility for the fire protection program is assigned to the General Manager (GM), while administration, formulation, and implementation of the program is assigned to the manager of Environment, Safety and Health, (ESH).

8.4.4.3 Combustible Loading Control

The objectives for fire protection at the WIPP facility are to ensure the safety of plant personnel, the reliability and continuity of plant operations, and to minimize property loss. To meet these objectives, the WIPP facility design incorporates the following features:

- With the exceptions of some temporary and other noncritical structures (such as the off-site air monitoring system), all buildings and their support structures are protected by fixed, automatic fire suppression systems designed to the specific, individual hazards of each area. Each building is evaluated annually to determine the fire risk associated with the occupancy.

- Noncombustible construction, fireproof masonry construction, and fire resistant materials are used whenever possible.

- Areas susceptible to fire are separated by fire walls and automatic fire doors to contain and isolate hazardous materials or operations. Fire separations are installed where required because of different occupancies per the Uniform Building Code (UBC).

- All vertical openings in buildings are protected by enclosing stairways, elevators, pipeways, electrical penetrations, etc., to prevent fire from spreading to upper floors.

- The exhaust ventilation systems, which remove hot fire gases, toxic contaminants, and explosive gases and smoke, are designed with a high fire integrity.

- The components of the electric service and distribution systems are listed by Underwriters' Laboratory or approved by Factory Mutual Engineering Corporation. These systems are installed to minimize possible ignition of flammable material and maximize safety.

As part of the improved risk fire protection program, certain passive and active design features including area separation, noncombustible construction, fixed fire suppression systems (water and dry chemical), and manual fire suppression capabilities are used.

To ensure reliability of the active fire protection systems, inspection, testing, and maintenance programs are provided. There are also administrative controls for the fire system impairments, hot work and internal audits of the inspection, testing and maintenance, and other program elements essential to the maintenance of an improved risk fire protection program, as required by DOE orders.

8.4.4.4 Fire Fighting Capabilities

Facilities, equipment, and trained personnel are available to provide the following emergency services for the WIPP facility:

- Fire fighting
- Emergency medical response
- Industrial rescue
- Mine rescue
- Hazardous material response and control

Fire fighting capability includes a fully-equipped pumper engine, an underground fire truck, associated firefighting equipment, and trained fire fighters. Firefighting activities are led by an emergency services technician (EST), on duty 24 hours a day. Backup fire fighting personnel are provided using cross-trained personnel.

The ESTs are state licensed emergency medical technicians and provide 24-hour emergency medical response capability at the WIPP facility. During the day shift, a full-time registered nurse is on the site. A fully-equipped first-aid room, ambulance, underground ambulance, and rescue vehicle are available to provide basic and advance life support activities.

The ESTs also provide industrial rescue for vehicle accidents, confined space extrication, and other industrial incidents. The technicians provide high angle rope rescue through the use of state-of-the-art hydraulic and manual equipment.

Mine rescue services are provided using two trained mine rescue teams at the WIPP facility. These teams are fully trained in the use of mine rescue procedures and techniques, as well as the use of self-contained breathing apparatus and firefighting equipment. A mine rescue station has been developed and equipped with MSHA-approved, properly maintained self-contained breathing apparatus, mine rescue supplies, and required spare parts.

The WIPP facility utilizes numerous materials that meet the NFPA, EPA, or DOT classifications as a hazardous material. The emergency preparedness staff has the equipment and trained personnel necessary to respond to control spills and leaks of these materials and, in some cases, clean up the spills for the protection of life, health, property, and the environment.

An Emergency Plan has been prepared for the WIPP facility. The WIPP Emergency Plan and Administrative Procedures[7] provides an organized plan of action for dealing with identified credible emergencies at the WIPP. The plan identifies lines of authority, the responsibilities of emergency response personnel and organizations, and the WIPP manpower and equipment resources available to cope with emergencies.

8.4.4.5 Fire Fighting Readiness Assurance

Exercises and drills are used to demonstrate the effectiveness of the established Emergency Management Program. Evaluations of these exercises ensure an effective and efficient program is in place, and that it is truly capable of mitigating the credible emergency scenarios. Exercises and drills are conducted on a regularly scheduled basis for all WIPP facility response personnel and equipment. WIPP facility Emergency Management promotes involvement in emergency response activities outside the scope of the WIPP facility. In an effort to maintain a high level of interest and motivation among response personnel, various response teams participate in local, regional, and national competitions.

The safety program is objectively evaluated by trend analysis and by determining current status of training, inspections, sampling, monitoring, drills and exercises, and accident frequency. In addition, assessments of the safety program include those conducted by the DOE-CAO.

References for 8.4

1. DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities, July 9, 1990.
2. WP 04-AD3011, Equipment Tagout/Lockout, Rev. 1, January 20, 1995.
3. WP 10-AD3005, Control and Use of Maintenance Locks, Rev. 0, September 29, 1992.
4. 29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout), September 20, 1990
5. WP 12-918, Reporting Occurrences in Accordance with DOE Order 5000.3B, May 14, 1993.
6. WP 12-135, Root Cause Analysis Investigation Procedure, May 14, 1995.
7. WP 12-9, WIPP Emergency Plan and Administrative Procedures, Rev. 9, September 30, 1994.

8.5 Emergency Preparedness Program

8.5.1 Introduction

This section briefly describes the significant aspects of the Emergency Preparedness program. The Emergency Preparedness Program is implemented through WP 12-9, WIPP Emergency Plan and Administrative Procedures.[1]

The WIPP facility Emergency Plan applies to all personnel employed at or assigned to the WIPP facility and defines emergency response roles and responsibilities. The facility emergency plan does not include any required DOE radiological response to transportation accidents that occur away from the facility. Such DOE response, if requested by the state, is directed by the cognizant DOE Operations Office. WIPP facility personnel will be available to support local and state organizations in such cases, as directed by the DOE Albuquerque Operations Office.

8.5.2 Requirements

The Emergency Preparedness Program establishes the requirements and procedures in compliance with the following:

- DOE Order 5500.3A, Planning and Preparedness for Operational Emergencies[2]
- DOE Order 5500.1B, Emergency Management System[3]
- DOE Order 5500.2B, Emergency Categories, Classes, and Notification and Reporting Requirements[4]
- DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information[5]
- DOE Order 5500.10, Emergency Readiness Assurance Program[6]
- DOE Order 5500.7B, Emergency Operating Records Protection Program[7]
- 40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities[8]
- 40 CFR 265, Subpart D, Contingency Plan and Emergency Procedures[9]
- 40 CFR 265.37, Arrangements with Local Authorities[10]
- 40 CFR 265.52 (c), Content of Contingency Plan[11]

8.5.3 Scope of Emergency Preparedness

The Emergency Preparedness Program applies to safety response actions relative to the following:

- Radiological emergencies
- Underground emergencies
- Industrial emergencies

- Security emergencies
- National emergencies
- Continuity of government emergencies

8.5.4 Emergency Preparedness Planning

Emergency Preparedness is addressed by the WID Emergency Plan. The plan identifies necessary actions for dealing with site-wide and area emergencies and defines the lines of authority. Responsibilities of emergency response personnel and organizations are detailed in the Plan, including a discussion of the WIPP labor and resources required.

Operational Emergencies at the WIPP are classified by Emergency Action Levels (EALs) that provide specific predetermined criteria allowing WIPP emergency personnel to categorize Operational Emergencies. The classification of Operational Emergencies is detailed in procedure WP 12-ER3904, Categorization and Classification of Operational Emergencies.[12]

Emergencies that involve or affect DOE, are grouped into three broad categories defined as Operational, Emergency, and Continuity of Government. These three classes are further broken down into classes dependent upon the actual or potential consequence of the emergency.

8.5.4.1 Emergency Response Organization

Activation of any emergency response actions is directed by the Crisis Manager and includes the DOE facilities within the Carlsbad city limits. Management of an emergency depends on the time and location of the event as determined by the FSM or Crisis Manager (CM). The FSM directs the event until the Emergency Operations Center (EOC) is activated. Upon activation of the EOC, the WIPP program provides for immediate on-site management response and for proper notifications made during an emergency.

The WIPP also has in place a Crisis Management Team (CMT) executive decision-making group tasked specifically to respond to emergencies. The WID GM or designated alternate will function as the CM. The CMT consists of several personnel experienced in dealing with emergencies. The WIPP tactics team is activated with the CMT to provide technical, logistical, and administrative support. Individuals on these teams are governed by specific directions found within the WIPP Emergency Plan.[1]

All on-site emergencies shall be reported immediately to the CMRO, where specific information will be gathered relating to that incident.

8.5.4.2 Assessment Actions

A WIPP dose assessment code (WIPPDAC), used for radiological release dose calculations, contains radionuclide decay data used in the GENII dose assessment code, and dose factors are derived from International Commission on Radiation Protection document 30, ICRP-30.[13] The software package calculates consequences of an accidental release of radionuclides with atmospheric dispersion and downwind doses. Doses calculated include lungs, bone surface, red marrow, thyroid, and effective dose equivalent.

8.5.4.3 Notification

The WID Public Affairs Emergency Response Plan describes the off-site notification procedure and maintains project credibility by providing timely and accurate information dissemination to the maximum extent permitted by the emergency situation. These emergencies include: Sabotage, bombing, kidnaping, hostage incident, WIPP site accident, malfunction of significant equipment, environmental hazard, natural disaster, or highway accident involving a WIPP shipment. Notification is achieved through the Stakeholder Relations Department as described in WP 15-8, Stakeholders Relations Policies and Procedures Manual.[14]

8.5.4.4 Emergency Facilities and Equipment

Facilities and equipment related to emergency response are closely monitored at the WIPP. The EOC is controlled by WIPP security officers. Monthly surveillance of items such as radios, telephones, computers, and un-interruptible power supplies are conducted using a checklist and surveillance log.

8.5.4.5 Memorandums of Understanding and/or Agreements

Memorandums of Understanding (MOU) between the WIPP and several key community organizations are important aspects of the available protective actions governed by legal cooperation agreements. A tabular summary of these Agreements including their purpose is as follows:

1. JOINT POWERS AGREEMENT BETWEEN THE UNITED STATES DEPARTMENT OF ENERGY AND THE CITY OF CARLSBAD AND THE COUNTY OF EDDY AND NEW MEXICO ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT FOR A JOINT-USE ALTERNATE EMERGENCY OPERATIONS CENTER. This MOU directs that the parties involved shall share in establishing and maintaining an alternate EOC.

2. MEMORANDUM OF AGREEMENT BETWEEN THE CITY OF CARLSBAD, NEW MEXICO, AND WESTINGHOUSE ELECTRIC CORPORATION. This MOU allows the WIPP to receive technical assistance from the Carlsbad/South Eddy County Ambulance Service.

3. MEMORANDUM OF UNDERSTANDING EMERGENCY RADIOLOGICAL TREATMENT CENTER FOR THE WASTE ISOLATION PILOT PLANT PROJECT. This MOU establishes the availability of the Lea Regional Emergency Radiological Treatment Center (ERTC) for WIPP personnel.

4. MUTUAL AID FIRE FIGHTING AGREEMENT BETWEEN THE EDDY COUNTY COMMISSION AND THE U.S. DEPARTMENT OF ENERGY. This Agreement provides for the actual assistance of the parties in the furnishing of fire protection for the Eddy County Fire District and the WIPP Site.

5. FEDERAL BUREAU OF INVESTIGATION/DEPARTMENT OF ENERGY MEMORANDUM OF UNDERSTANDING. This MOU provides a basis for contingency response planning, coordination, and cooperation between the Federal Bureau of Investigation (FBI) and the DOE.

6. MEMORANDUM OF UNDERSTANDING BETWEEN THE UNITED STATES DEPARTMENT OF ENERGY AND THE NEW MEXICO DEPARTMENT OF PUBLIC SAFETY CONCERNING MUTUAL ASSISTANCE AND EMERGENCY MANAGEMENT. The MOU applies to any actual or potential emergency or incident that: Involves a significant threat to employees, or the public; involves DOE property; involves threat to environment reportable to an off-site organization; requires combined resources of the DOE and the State; requires DOE resources unavailable from the State or vice versa; involves any other incident for which a joint determination has been made by the DOE and the State that the provisions of this MOU will apply.

7. AGREEMENT BETWEEN CAO MANAGER, U.S. DEPARTMENT OF ENERGY, GENERAL MANAGER WESTERN AGRICULTURE MINERALS, POTASH FACILITY, MISSISSIPPI POTASH INC., EDDY POTASH, IMC FERTILIZER, NEW MEXICO POTASH. This Agreement provides for mine operators having two mine rescue teams available whenever miners are underground, and backup rescue capability is deemed desirable.

8. MEMORANDUM OF UNDERSTANDING: EMERGENCY RADIOLOGICAL TREATMENT CENTER FOR THE WASTE ISOLATION PILOT PLANT PROJECT BETWEEN THE U.S. DEPARTMENT OF ENERGY AND GUADALUPE MEDICAL CENTER. This MOU provides for an Emergency Radiological Treatment Center (ERTC) at the GUADALUPE Medical Center.

9. MUTUAL AID AGREEMENT BETWEEN THE CITY OF CARLSBAD AND THE U.S. DEPARTMENT OF ENERGY. This Agreement authorizes assistance in times of declared emergency where the enormity of the emergency exceeds the response capability of the responsible jurisdiction.

10. MUTUAL AID AGREEMENT BETWEEN THE CITY OF HOBBS AND THE U.S. DEPARTMENT OF ENERGY. This Agreement authorizes assistance in times of declared emergency where the magnitude of the emergency exceeds the response capability of the responsible organization.

8.5.4.6 Training and Exercises

Emergency management training consists of formal classroom instruction, on-the-job training, drills and exercises, and a qualification system. This training allows all emergency management related participants to function safely and skillfully. Qualification cards detailing required reading, and practicals, have been developed for the EOC, the Emergency Operations Information Center (IC), and the Emergency Response Team (ERT). Individuals participating in these areas must be trained, and be qualified before they are allowed to assist in emergencies.

The Emergency Management Section has developed a procedure for the effective management of drills and exercises. A coordinated program of drills and exercises enhances the ability of specialized teams, and individual personnel in responding to potentially adverse situations. The Emergency Management Section conducts a variety of drills and exercises.

A full participation exercise is conducted periodically to demonstrate an integrated emergency response capability. The integrated exercise includes Federal, state, local, regulatory, and/or emergency response organizations which may include DOE/HQ, DOE/AL, and CAO participants.

8.5.4.7 Reentry and Recovery

Guidance for the reentry and recovery following an emergency is based on regard for human life and conditions existing at the time. The recovery process detailed in WP 12-ER3903, Event Recovery,[15] evaluated the proposed actions by comparing the risks of the hazards to the actual or potential benefits to be gained.

References for Section 8.5

1. WP 12-9, WIPP Emergency Plan and Administrative Procedures, Rev. 9, September 30, 1994.

2. DOE Order 5500.3A, Planning and Preparedness for Operational Emergencies, April 30, 1991.

3. DOE Order 5500.1B, Emergency Management System, April 30, 1991.

4. DOE Order 5500.2B, Emergency Categories, Classes, and Notification and Reporting Requirements, April 30, 1991.

5. DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information, January 19, 1993.

6. DOE Order 5500.10, Emergency Readiness Assurance Program, April 30, 1991.

7. DOE Order 5500.7B, Emergency Operating Records Protection Program, October 23, 1991.

8. 40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, June 1993.

9. 40 CFR 265, Subpart D, Contingency Plan and Emergency Procedures, May 1980.

10. 40 CFR 265.37, Arrangements with Local Authorities, May 1980.

11. 40 CFR 265.52 (c), Content of Contingency Plan, May 1980.

12. WP 12-ER3904, Categorization and Classification of Operational Emergencies, July 15, 1994.

13. International Commission on Radiation Protection-30, 1979 to 1982.

14. WP 15-8, Stakeholders Relations Policies and Procedures, Rev. 1, November 19, 1993.

15. WP 12-ER3903, Event Recovery, July 15, 1994.

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QUALITY ASSURANCE

This chapter discusses the quality assurance (QA) requirements applicable to WIPP nuclear safety as specified in Title 10 CFR 830.120,[1] *Quality Assurance Requirements*. The WID will maintain complete and accurate records as necessary to substantiate its compliance with the requirements.

9.1 General Requirements

To provide a comprehensive QA program, 10 CFR 830.120[1] provides the general quality assurance requirements: Management, Performance and Assessment. The following requirements apply to those activities required to comply with the SAR.

9.1.1 Management

9.1.1.1 Program

The WID Quality Assurance Program Description[2] (QAPD) includes the QA requirements of 10 CFR 830.120.[1] The QAPD also incorporates QA requirements of ASME NQA-1,[3] ASME NQA-2,[4] 10 CFR 71 Subpart H,[5] DOE Order 5700.6C,[6] and others as reflected in the CAO QAPD, CAO-94-1012.[7]

During the design and construction phase of the WIPP, the QA program was based on ANSI/ASME NQA-1-1979,[8] basic and supplementary requirements. Therefore, the WIPP Design Class system, showing a graded approach to application of the QA requirements for design and construction of WIPP systems also reflects ANSI/ASME NQA-1-1979.[8]

9.1.1.2 Personnel Training and Qualification

Formal training and qualification programs are administered by the WID Technical Training section. Each WID line organization unit is responsible for indoctrination and training of personnel, as necessary, and for ensuring that suitable proficiency is achieved and maintained. The line organization is also responsible for ensuring that personnel working under their supervision are qualified and are provided the necessary training, resources, and administrative controls to accomplish assigned tasks.

9.1.1.3 Quality Improvement

The focus of quality improvement is to reduce the variability of every process influencing the quality of the product. Management at all levels is to be involved in the quality improvement process to ensure that proper focus is given, adequate resources are allocated and difficult issues are resolved. Quality improvement programs in place include the nonconformance program, the work authorization program, the process improvement program, and the corrective action program. In the event significant conditions adverse to quality are identified, these conditions are to be reported in accordance with the requirements of DOE Order 5000.3B,[9] *Occurrence Reporting and Processing of Operations Information*, as appropriate. Significant conditions adverse to quality include events which could affect the health and safety of the public, seriously impact the operation of WIPP, have a noticeable adverse impact on the environment, or endanger the health or safety of WIPP workers. All personnel are granted the freedom and authority to stop work until effective evaluation and/or corrective action is taken. Appropriate corrective actions are required to address the following:

- Determine root cause of the problem
- Resolve the initial problem
- Preclude recurrence of the problem
- Impact of the problem on related items or activities
- Forecast completion dates for the required actions, and individuals responsible for follow-up

The extent of root cause analyses for nonconforming items and processes is commensurate with the importance or significance of the problem.

9.1.1.4 Documents and Quality Assurance Records

The document control system scope includes drawings, specifications, system design descriptions, the SAR, plans, procedures, and instructions. The distribution and use of controlled documents and forms that document or prescribe work, are controlled as follows:

- Documents used to perform work are distributed and available to personnel and used at the work location
- Effective dates are established for and placed on approved documents
- Obsolete or superseded documents and forms are controlled to avoid their inadvertent use
- Controls are established and maintained to identify the current status/revision of controlled documents and forms. Quality assurance records are documents that furnish evidence of the quality of items and/or activities affecting quality.

Quality assurance records are identified, prepared, collected, stored, maintained, and dispositioned by all WID departments involved in the performance or control of quality-related activities. Quality assurance records provide documentary evidence that such activities are adequately controlled, and that associated parts, components, systems, facilities, and services comply with applicable requirements. Requirements and responsibilities for quality assurance record transmittal, distribution, retention, maintenance, and disposition are established and documented according to the WID QAPD.[2]

9.1.2 Performance

9.1.2.1 Work Processes

Work process parameters are controlled in accordance with approved instructions or procedures. In addition, conditions necessary for accomplishment of work processed are also listed in procedures or instructions. These conditions include proper equipment, controlled parameters of the process (such as temperature, pressure, flow rate, etc.), and calibration requirements. Specified environmental conditions (e.g., atmospheric conditions, moisture content levels, temperature, etc.) are required to be maintained. Handling, storage, cleaning, packaging, shipping, and preservation of Quality Code 1, 2 and 3 items are controlled to prevent damage, loss, or deterioration. Marking and labeling of items is maintained throughout packaging, shipping, handling, and storage, to provide information to identify the items or special controls to preserve their integrity. Monitoring and Data Collection (M&DC) Equipment (a subcategory of M&TE) used in the collection of monitoring data for the establishment of test conditions and the collection of general data is calibrated, adjusted, and maintained at prescribed intervals, or prior to use, against certified equipment having known valid relationships to nationally recognized standards.

9.1.2.2 Design

Design control provisions include control of design requirements, inputs, processes, outputs (verification), changes, documentation and records, and organizational interfaces. The graded approach to quality assurance is linked directly to the design class of the item or system. The Design Classification System is provided in Section 3.1.3.1.

9.1.2.3 Procurement

Procurement planning, development of documentation, selection of suppliers and evaluation of supplier performance are the elements of procurement control implemented for WIPP items and services. Purchased items and services are accepted using specified methods such as: review of manufacturing process control data, source verification, receipt inspection, preinstallation and postinstallation tests, certificates of conformance, or a combination of these methods. Nonconformances consist of one or more of the following: A technical or material requirement is violated; a requirement in a WID-approved supplier document is violated; the deficiency cannot be corrected by continuation of the original manufacturing process or by rework; the item or service does not conform to the original requirement. Methods for disposition of supplier nonconformances must contain provisions for (a) through (e) below:

(a) Submittal of notice of nonconformance to the WID

(b) Evaluation of nonconformances

(c) WID approval of supplier-recommended disposition

(d) Verifying implementation of the approved disposition

(e) Maintenance of records of supplier-submitted nonconformances

9.1.2.4 Inspection and Acceptance Testing

Inspections or surveillance required to verify conformance of an item or activity to specified requirements are planned and executed. Characteristics to be inspected and inspection methods to be employed are required to be specified and inspection results are documented. Inspection or surveillance for acceptance is performed by personnel other than those who performed or directly supervised the work. Results are documented and conformance to acceptance criteria is evaluated. Test procedures are required to include or reference test objectives, and provisions for ensuring that prerequisites for the given test have been met, that adequate instrumentation is available and used, that necessary monitoring is performed and that suitable environmental conditions are maintained. Test results are evaluated by a responsible authority to ensure those test requirements have been satisfied. Tools, gauges, instruments, and other M&TE used for activities affecting quality are controlled and are calibrated and adjusted to maintain accuracy within necessary limits at specified periods. The status of inspection, test, and operation activities are required to be identified either on the items or in documents traceable to the items to ensure that required inspections and tests are performed, and to ensure that items that have not passed the required inspections and tests are not inadvertently installed, used, or operated. In addition, a nonconformance program is in place to ensure correction of adverse quality conditions and promote improvement.

9.1.3 Assessment

9.1.3.1 Management Assessment

The overall goal for performance of planned and periodic management assessment is quality improvement. The WID management assessment process involves all levels of management: supervisors, first-line (group) managers, intermediate (section) managers, senior management, and the General Manager's Office. Senior management directly participates in management assessment, in the evaluation of identified areas for quality improvement from two separate sources, including self-assessments performed by line management, and in independent assessments of the activities performed by the QA department. Once areas for improvement are positively identified and documented, senior management directs the implementation of preventive or corrective actions.

9.1.3.2 Independent Assessment

The WID independent assessment program includes surveillance and audits. Independent assessment is conducted to evaluate compliance with applicable QAPD requirements and implementing procedures, as well as the effectiveness of the overall quality program. Such assessments are performed as an administrative control for activities carried out to comply with the Technical Safety Requirements (TSRs), as described in Chapter 6. Independent assessment is also used to provide independent oversight of self-assessment performed by WID line management. Results from independent assessment are transmitted to senior management as input for determination of the effectiveness of the integrated quality assurance program. In this regard, personnel performing independent assessments act in a management advisory function.

References for Chapter 9

1. 10 CFR 830.120, Quality Assurance Requirements, 1994.

2. WP 13-1, WID Quality Assurance Program Description, January 1995.

3. ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facilities, 1991.

4. ASME NQA-2, Quality Assurance Program Requirements for Nuclear Facilities, 1990.

5. 10 CFR 71, Subpart H, Quality Assurance, 1988.

6. DOE Order 5700.6C, Quality Assurance, 1991.

7. CAO-94-1012, U.S. Department of Energy Carlsbad Area Office Quality Assurance Program Description, June 1994.

8. ANSI/ASME NQA-1-1979, Quality Assurance Program Requirements for Nuclear Facilities, 1979.

9. DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information, 1993.

10. CAO-94-1001, Carlsbad Area Office Information Management Plan, April 1994.

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DECONTAMINATION AND DECOMMISSIONING

10.1 Introduction

The WIPP facility is designed for an operating life of 25 years and will be decommissioned after waste emplacement is completed. Lacking further requirements to operate the WIPP facility, decontamination of the facility to acceptable contamination and radiation levels in conjunction with facility decommissioning will be performed. The ongoing performance assessment documented in (Chapter 3) of SAND 92-0700/1-UC-791[1] is designed to determine the acceptability of the WIPP facility and surrounding site by showing compliance with the requirements of 40 CFR 191, Subpart B.[2] Sections 10.1 through 10.5 are written with the assumption that the WIPP facility is shown to be acceptable as a repository and, therefore, decommissioning activities begin near the end of its operational life.

Some post-operational requirements exist for the WIPP facility in 40 CFR 191, Subpart B.[2] These "Assurance Requirements," developed by the Environmental Protection Agency (EPA), ensure that cautious steps are taken by the implementing agency (in this case, the DOE) to reduce the uncertainties in projecting the behavior of the natural and engineered components for many thousands of years. The application of these assurance requirements to the WIPP facility is described in detail in DOE/WIPP 91-029.[3]

Decommissioning requirements applicable to the WIPP facility are included in the Resource Conservation and Recovery Act (RCRA) as implemented in 40 CFR Part 264[4] and New Mexico Hazardous Waste Management Regulations, Part V.[5] The Closure/Post Closure Plan[6] implements RCRA regulations.

10.2 WIPP Facility Description

At the completion of WIPP facility operations, the facility will consist of surface structures, shafts, and subsurface structures. Major surface structures will include the Waste Handling Building, the Support Building, the Exhaust Filter Building, the Guard and Security Building, the Salt Storage Area, and other support and warehouse structures. Four shafts, the Waste Shaft, the Salt Handling Shaft, the Exhaust Shaft, and the Air Intake Shaft, extend from the surface to the storage horizon 2150 feet (650 meters) below the surface. The shafts are lined from the surface to the top of the salt formation which is approximately 850 feet (260 m) below the surface. Subsurface structures include the waste storage areas, the shaft pillar areas, and the experimental areas. These structures are discussed in greater detail in Chapters 3 and 4 of the SAR.

10.3 Decontamination and Decommissioning

The WIPP facility has been designed and will be operated in a manner that will allow ease of decontamination and decommissioning (D&D). Actual D&D activities will be initiated prior to the cessation of WIPP facility operation as required by the WIPP Land Withdrawal Act.[7] The overall goal is to restore the surface area now housing the WIPP facility to essentially preconstruction and preoperational conditions. Surface radiological levels shall be returned to levels commensurate with regulatory guidelines. Records of the project shall be listed in the public domain and monuments or markers shall exist at the site to inform future generations of the presence of the WIPP repository (Section 10.4).

10.3.1 Decontamination and Decommissioning Design Features

During the design phase of the facility, general guidance from DOE Order 6430.1[8] was followed to design and construct the facility. This guidance incorporated structural and internal features that would facilitate the safe and economical decontamination and decommissioning of the facility. To the extent practical, the following features and measures have been incorporated into the WIPP facility design:

- coatings provide easily cleanable surfaces
- cracks, crevices, and joints are sealed to prevent contamination spread to inaccessible areas
- exhaust filters at points of potential contamination minimize contamination of long sections of duct work and downstream exhaust equipment
- architectural or structural features allow the dismantlement and removal of equipment from areas of contamination or potentially high radiation levels to other areas for decontamination, maintenance, or repair.

10.3.2 Decontamination and Decommissioning Activities

Decontamination and decommissioning activities will involve three primary areas; surface structures, subsurface structures, and the shafts. Detailed planning for these activities will begin several years prior to their actual initiation and will incorporate currently available technologies and prescribed decontamination limits.

Surface structures will be decontaminated in accordance with current guidelines and dismantlement of the buildings will be established in the decommissioning plan.

Decontamination operations and surveillance checks will be conducted during the decommissioning demonstrating personnel and public exposure limits are maintained as low as reasonably achievable and within the limits of 10 CFR 835, Occupational Radiation Protection.[9]

Since safety is of paramount importance, potentially hazardous operations will not begin until precautions are taken against the release of contamination. These precautions include development of decontamination plans, decontamination procedures, and safety analysis.

10.4 Closure, Monuments, and Records

Closure of the WIPP facility will result in the following:

- Shafts will be closed and sealed, minimizing the intrusion of fluids into the repository.
- Human intrusion after closure will be unlikely.
- Physical and environmental surveillance can be minimized.

Substantial permanent monuments will identify the WIPP facility. The location of these markers will be established in detail by the decommissioning plan. The markers will contain site description, date of closure, land survey data, and other information required by applicable regulations.

Detailed records shall be filed with local, state, and federal government agencies to ensure that location of the WIPP facility is easily determined. This information together with land survey data will be on record with the United States Geological Survey and other agencies as provided by the decommissioning plan. The DOE will maintain permanent administrative authority over those aspects of land management assigned by law (i.e., by the permanent withdrawal legislation).

10.5 Post Closure Surveillance

Due to filling of the repository and extensive decommissioning, maintenance of the physical security of the WIPP facility after closure can be minimized. The physical surveillance requirements will be provided in the final decommissioning plan.

Environmental surveillance after closure will include appropriate radiation monitoring, soil, vegetation, water, and wildlife sample analysis. Frequency and duration of the environmental surveillance program will be defined in the final decommissioning plan as prescribed by standards applicable at the time.

References for Chapter 10

1. SAND 92-0700/1-UC-791, Preliminary Performance Assessment for the Waste Isolation Pilot Plant, Volume 1: Third comparison with 40 CFR 191, Subpart B, December 1991.

2. 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes, U.S. Environmental Protection Agency, September, 1985.

3. DOE/WIPP 91-029, Implementation of the Resource Disincentive 40 CFR Part 191.14(e) at the Waste Isolation Pilot Plant, Rev. 1, June, 1993.

4. 40 CFR Part 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, U.S. Environmental Protection Agency, May 19, 1980 and subsequent amendments.

5. New Mexico Hazardous Waste Management Regulations, New Mexico Environmental Improvement Division, October 30, 1988.

6. Closure and Post Closure Plans, Waste Isolation Pilot Plant, Carlsbad, New Mexico, Westinghouse Electric Corp., August 1988.

7. Public Law 102-579, Waste Isolation Pilot Plant Land Withdrawal Act.

8. DOE Order 6430, General Design Criteria Manual for Department of Energy Facilities, June 10, 1981 draft.

9. 10 CFR 835, Occupational Radiation Protection, December 14, 1993.

APPENDIX - A
Waste Container Inventory Calculations

Table A-1, CH Curies Stored by Site

Baseline Inventory Report - App. E (IDB Rev. 10)

Radio-nuclide	ANLE	ETEC	HANF	INEL	LBL	LLNL	LANL	MOUND	NVTS	ORNL	PADU	PANTEX	RFP	SNLA	SRS	MURR	Total Curies
Ac-225	8.2E-06	0.0E+00	1.1E-01	1.3E+00	4.5E-06	1.9E-13	7.2E-02		2.1E-03	1.2E-01			9.4E-12	1.3E-19	1.1E-05		1.6E+00
Ac-227	3.8E-13		4.5E-05	4.1E-02	1.0E-16	1.8E-12	2.5E-01	4.3E-11	1.9E-04	3.1E-07			4.8E-11	5.8E-21	2.9E-07		2.9E-01
Ac-228	2.5E-17		5.1E-02	3.0E-01	1.0E-19	5.1E-17	1.5E-03		8.8E-17	3.0E-02			3.4E-15		8.7E-03		3.9E-01
Ag-109m							2.0E+01										2.0E+01
Ag-110			1.8E-06	1.4E-08			3.1E-11		2.2E-10	6.0E-12							1.8E-06
Ag-110m			1.4E-04	1.1E-06			2.3E-09		1.7E-08	4.5E-10							1.4E-04
Am-241	5.7E+00	4.4E-01	3.0E+03	9.0E+04	9.2E-02	1.3E+02	8.7E+03		2.8E+02	2.3E+03			1.1E+04	1.0E-02	1.6E+04	4.8E-02	1.3E+05
Am-242						3.9E-03											3.9E-03
Am-242m						4.0E-03											4.0E-03
Am-243	9.5E-02		9.1E-02	3.8E-01	3.9E-02	5.2E-03	4.8E+00		1.2E+00	9.4E+00					7.6E-01		1.7E+01
Am-245				5.4E-09	1.8E-13		9.5E-15		2.6E-13	2.7E-09							8.1E-09
At-217	8.2E-06		1.1E-01	1.3E+00	4.5E-06	1.9E-13	7.2E-02		2.1E-03	1.2E-01			9.4E-12	1.3E-19	1.1E-05		1.6E+00
Ba-137m		2.3E-01	6.7E+02	6.0E+01		1.9E-06	5.0E+01		3.8E-01	2.1E+03					6.4E-01		2.8E+03
Bi-210	3.6E-06		5.4E-02	2.6E-02	7.4E-03	4.3E-14	2.4E-01	3.5E-10	5.5E-02	1.0E-01			1.1E-12		7.9E-07		4.8E-01
Bi-211	3.5E-13		4.4E-05	4.1E-02	9.5E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Bi-212	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.1E-16		8.1E-03		2.7E+01
Bi-213	8.2E-06		1.1E-01	1.3E+00	4.5E-06	1.9E-13	7.2E-02		2.1E-03	1.2E-01			9.4E-12	1.3E-19	1.1E-05		1.6E+00
Bi-214	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.2E+00
Bk-249				3.7E-04	1.2E-08		6.5E-10		1.8E-08	1.8E-04							5.6E-04
Bk-250					5.4E-07				2.6E-10								5.4E-07
C-14			5.9E+00	1.7E-01			5.0E-04		2.5E-04								6.0E+00
Cd-109							2.0E+01										2.0E+01
Cd-113m			1.4E-05	3.7E-08			8.6E-07		7.6E-09	2.9E-08							1.5E-05
Ce-144			2.7E+01	2.0E-01			9.1E-04		5.0E-03	1.7E-04					5.4E-12		2.7E+01
Cf-249				1.0E-02	3.1E-03		9.7E-04		1.1E-02	1.1E+00							1.1E+00
Cf-250					2.2E-04				3.5E-01								3.5E-01
Cf-251							1.6E-03										1.6E-03
Cf-252			6.0E+01	3.7E-03					2.9E-02	4.1E-01					6.1E-01		6.1E+01
Cm-242				6.1E-07		8.4E-04	7.6E-16			3.2E-03							4.0E-03
Cm-243			6.9E-02				4.5E-01										5.2E-01
Cm-244			1.1E+02	5.3E+02	2.2E-02	3.2E+01	1.7E+02		2.5E+02	1.3E+03					6.6E+02		3.0E+03
Cm-245			1.7E+01	7.4E-06	1.8E-06		1.4E-06		7.6E-06	1.6E-03							1.7E+01
Cm-246				1.5E-03	3.7E-07	6.2E-04	4.0E-02		5.2E-04								4.3E-02
Cm-247							1.2E-09										1.2E-09
Cm-248			7.6E-03	4.6E-07					3.5E-06	2.0E-02					1.6E-04		2.7E-02
Co-58			1.8E-05	1.6E-11			1.1E-08										1.8E-05
Co-60			2.3E+01	8.1E+01			2.3E-02			1.2E-02					5.9E-02		1.0E+02
Cr-51																	0.0E+00

Table A-1, CH Curies Stored by Site

Baseline Inventory Report - App. E (IDB Rev. 10)

Radio-nuclide	ANLE	ETEC	HANF	INEL	LBL	LLNL	LANL	MOUND	NVTS	ORNL	PADU	PANTEX	RFP	SNLA	SRS	MURR	Total Curies
Cs-134			1.9E+00	2.5E-03			8.8E-03		8.3E-04	1.4E-04							1.9E+00
Cs-135			2.4E-03	8.5E-06			2.2E-04		1.3E-06	9.2E-06							2.6E-03
Cs-137		2.4E-01	7.0E+02	6.3E+01		2.0E-06	5.3E+01		4.0E-01	2.2E+03					6.8E-01		3.0E+03
Es-254					5.4E-07				2.6E-10								5.4E-07
Eu-150				3.6E-05													3.6E-05
Eu-152			2.0E+00	1.8E-01		1.2E-06	9.2E-04		1.2E+00	1.7E-05							3.3E+00
Eu-154			9.5E+00	7.6E-01		3.8E-07	3.4E-02		5.0E-01	8.9E-04					3.3E-04		1.1E+01
Eu-155			1.3E+01	5.1E-01			3.2E-01		5.3E-03	6.4E-03					4.1E-06		1.4E+01
Fe-55				3.3E-05													3.3E-05
Fe-59			9.2E-06	2.6E-16			1.0E-10			1.4E-02							1.4E-02
Fr-221	8.2E-06		1.1E-01	1.3E+00	4.5E-06	1.9E-13	7.2E-02		2.1E-03	1.2E-01			9.4E-12	1.3E-19	1.1E-05		1.6E+00
Fr-223	5.2E-15		6.2E-07	5.7E-04	1.4E-18	2.5E-14	3.4E-03	5.9E-13	2.6E-06	4.3E-09			6.6E-13	8.0E-23	4.0E-09		4.0E-03
H-3			3.1E-08	8.9E-01					7.2E-02								9.6E-01
I-129			4.2E-10														4.2E-10
Kr-85									2.2E-01								2.2E-01
Mn-54			2.0E-03	4.3E-03			3.1E-04								5.0E-10		6.6E-03
Nb-95			1.6E-01	6.9E-06			1.0E-08		4.4E-14	2.3E-16							1.6E-01
Nb-95m			5.4E-04	2.3E-08			3.3E-11		1.5E-16	7.8E-19							5.4E-04
Ni-59															1.3E-03		1.3E-03
Ni-63				9.2E-05						1.1E-04					1.6E-01		1.6E-01
Np-237	1.5E-03		2.6E-01	7.9E-01	7.2E-03	4.0E-04	2.7E-02		5.6E-03	6.0E+00	5.5E+01		1.0E-02	3.3E-09	8.6E+00	1.8E-04	7.1E+01
Np-238						2.0E-05											2.0E-05
Np-239	9.5E-02		9.1E-02	3.8E-01	3.9E-02	5.2E-03	4.8E+00		1.2E+00	9.4E+00					7.6E-01		1.7E+01
Np-240			5.1E-13	3.1E-17					1.1E-09	8.7E-13					1.5E-14		1.1E-09
Np-240m			4.6E-10	2.8E-14					1.0E-06	7.9E-10					1.3E-11		1.0E-06
Pa-231			1.9E-04	1.1E-05	2.0E-15	5.7E-11	1.2E-03	3.0E-10	5.0E-04	1.6E-06			1.1E-09	1.9E-19	1.4E-06		1.9E-03
Pa-233	6.2E-07		2.6E-01	7.9E-01	7.2E-03	4.0E-04	2.6E-02		5.6E-03	6.0E+00			9.6E-03	2.9E-09	8.6E+00		1.6E+01
Pa-234	9.9E-15		7.9E-03	1.5E-04	2.0E-14	4.4E-07	5.3E-06		7.3E-08	3.4E-05					6.8E-06		8.1E-03
Pa-234m	7.6E-12		6.0E+00	1.2E-01	1.5E-11	3.4E-04	4.0E-03		5.6E-05	2.6E-02					5.2E-03		6.2E+00
Pb-209	8.2E-06		1.1E-01	1.3E+00	4.5E-06	1.9E-13	7.2E-02		2.1E-03	1.2E-01			9.4E-12	1.3E-19	1.1E-05		1.6E+00
Pb-210	3.6E-06		5.4E-02	2.6E-02	7.4E-03	4.3E-14	2.4E-01	3.5E-10	5.5E-02	1.0E-01			1.1E-12		7.9E-07		4.8E-01
Pb-211	3.5E-13		4.4E-05	4.1E-02	9.3E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Pb-212	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.1E-16		8.1E-03		2.7E+01
Pb-214	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.2E+00
Pd-107			3.5E-04	1.3E-06			3.2E-05		1.9E-07	1.4E-06							3.9E-04
Pm-147			4.0E+02	4.5E+00			3.6E+00		1.9E-01	7.2E-02					2.1E-05		4.1E+02
Po-210	1.9E-06		4.7E-02	2.4E-02	6.7E-03	2.7E-14	2.2E-01	3.0E-10	5.0E-02	7.1E-02			6.8E-13		6.9E-07		4.2E-01
Po-211	9.6E-16		1.2E-07	1.1E-04	2.6E-19	4.3E-15	6.8E-04	1.1E-13	5.2E-07	8.4E-10			1.2E-13	1.4E-23	7.8E-10		7.9E-04

Table A-1, CH Curies Stored by Site

Baseline Inventory Report - App. E (IDB Rev. 10)

Radio-nuclide	ANLE	ETEC	HANF	INEL	LBL	LLNL	LANL	MOUND	NVTS	ORNL	PADU	PANTEX	RFP	SNLA	SRS	MURR	Total Curies
Po-212	5.2E-18		1.3E-01	1.7E+01	3.3E-20	2.7E-09	7.2E-04		1.0E-02	1.9E-01			5.8E-16		5.2E-03		1.7E+01
Po-213	8.0E-06		1.1E-01	1.3E+00	4.4E-06	1.9E-13	7.0E-02		2.0E-03	1.2E-01			9.2E-12	1.2E-19	1.1E-05		1.6E+00
Po-214	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.1E+00
Po-215	3.5E-13		4.4E-05	4.1E-02	9.5E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Po-216	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.1E-16		8.1E-03		2.7E+01
Po-218	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.2E+00
Pr-144			2.7E+01	2.0E-01			9.1E-04		5.0E-03	1.7E-04					5.4E-12		2.7E+01
Pu-236				1.7E-02													1.7E-02
Pu-238	2.1E+00	1.1E-01	8.2E+04	6.1E+04	2.4E-04	2.0E+01	1.2E+05	7.2E+02	2.0E+02	6.8E+03			3.5E+02		4.7E+05		7.4E+05
Pu-239	3.3E+01	1.8E+00	2.7E+04	4.0E+04	7.7E-03	1.5E+02	7.3E+04	2.0E+02	2.8E+03	8.0E+02	5.6E+01	5.6E-02	9.9E+03	2.0E-06	8.6E+03	2.1E-02	1.6E+05
Pu-240	9.4E+00	6.0E-01	6.1E+03	9.8E+03	5.1E-03	6.1E+01	1.5E-01		1.9E+01	7.3E+02			7.2E+03		2.1E+03		2.6E+04
Pu-241	6.0E+01	8.1E+00	9.4E+04	1.7E+05	2.9E-07	1.7E+03	1.8E+00		2.6E+02	5.5E+04			5.7E+04		6.3E+04		4.4E+05
Pu-242	1.0E-02	4.0E-05	3.7E-01	9.4E-01	1.0E-02	1.9E-02	5.1E+02		8.7E-02	5.5E+00					3.8E-01		5.2E+02
Pu-243							1.2E-09										1.2E-09
Pu-244			4.6E-10	2.8E-14					1.0E-06	7.9E-10					1.3E-11		1.0E-06
Ra-223	3.5E-13		4.4E-05	4.1E-02	9.5E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Ra-224	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.1E-16		8.1E-03		2.7E+01
Ra-225	8.3E-06		1.1E-01	1.3E+00	4.5E-06	2.0E-13	7.2E-02		2.1E-03	1.2E-01			9.6E-12	1.4E-19	1.1E-05		1.6E+00
Ra-226	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.2E+00
Ra-228	2.5E-17		5.1E-02	3.0E-01	1.0E-19	5.1E-17	1.5E-03		8.8E-17	3.0E-02			3.4E-15		8.7E-03		3.9E-01
Rh-106			1.3E+01	4.8E-02			4.2E-03		3.9E-03	1.9E-04					8.4E-10		1.3E+01
Rn-219	3.5E-13		4.4E-05	4.1E-02	9.5E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Rn-220	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.1E-16		8.1E-03		2.7E+01
Rn-222	1.2E-04		3.2E-01	4.8E-02	3.4E-02	1.2E-12	9.0E-01	3.1E-09	2.5E-01	1.6E+00			2.9E-11		5.5E-06		3.2E+00
Ru-106			1.3E+01	4.8E-02			4.2E-03		3.9E-03	1.9E-04					8.4E-10		1.3E+01
Sb-125			5.1E+00	6.2E-03		4.1E-08	5.1E-02		2.4E-03	8.4E-04					4.3E-05		5.1E+00
Sb-126			6.4E-04	2.3E-06			5.8E-05		3.4E-07	2.5E-06							7.1E-04
Sb-126m			4.6E-03	1.6E-05			4.2E-04		2.4E-06	1.8E-05							5.0E-03
Se-79			2.1E-03	7.4E-06			1.9E-04		1.1E-06	8.0E-06					1.3E-07		2.3E-03
Sm-151			7.6E+00	2.6E-02			6.4E-01		4.0E-03	2.6E-02					3.2E-04		8.3E+00
Sn-119m			2.2E-03	1.8E-05			3.5E-08		2.5E-07	6.4E-09							2.2E-03
Sn-121m			1.5E-01	4.8E-04			1.2E-02		7.8E-05	4.7E-04							1.6E-01
Sn-126			4.6E-03	1.6E-05			4.2E-04		2.4E-06	1.8E-05							5.0E-03
Sr-90		2.3E-01	7.1E+02	2.2E+00			4.9E+01		3.4E-01	1.3E+03					1.2E-02		2.1E+03
Ta-182																	0.0E+00
Tc-99			1.2E-01	2.2E-03			1.1E-02		6.3E-05	1.8E+01					4.5E-06		1.8E+01
Te-125m			2.1E-04	4.0E-09			5.3E-08		3.3E-18	1.7E-20					1.0E-28		2.1E-04
Te-127			1.0E-02	1.1E-05			1.5E-08		2.5E-10	1.7E-12							1.0E-02

Table A-1, CH Curies Stored by Site

Baseline Inventory Report - App. E (IDB Rev. 10)

Radio-nuclide	ANLE	ETEC	HANF	INEL	LBL	LLNL	LANL	MOUND	NVTS	ORNL	PADU	PANTEX	RFP	SNLA	SRS	MURR	Total Curies
Te-127m			1.0E-02	1.2E-05			1.6E-08		2.6E-10	1.8E-12							1.0E-02
Th-227	3.6E-13		4.4E-05	4.1E-02	9.8E-17	1.7E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.6E-11	5.4E-21	2.9E-07		2.9E-01
Th-228	8.1E-18		2.0E-01	2.7E+01	5.2E-20	4.2E-09	1.1E-03		1.6E-02	2.9E-01			9.2E-16		8.1E-03		2.7E+01
Th-229	8.5E-06		1.1E-01	1.4E+00	4.5E-06	2.1E-13	7.2E-02		2.1E-03	1.2E-01			1.0E-11	1.7E-19	1.1E-05		1.7E+00
Th-230	7.0E-10		6.9E-03	2.1E-02	7.7E-14	1.9E-09	3.9E-04	1.4E-06	8.0E-07	6.5E-04			4.7E-08		1.9E-03		3.1E-02
Th-231	6.0E-04		5.7E-01	6.2E-02	3.8E-11	1.3E-04	4.2E-01	2.1E-06	5.6E-05	6.6E-03			2.8E-05	5.9E-15	5.5E-03		1.1E+00
Th-232	1.6E-16		6.4E-02	3.3E-01	3.7E-19	3.7E-16	2.4E-03		4.6E-16	3.4E-02			3.3E-14		1.0E-02		4.4E-01
Th-234	7.6E-12		6.1E+00	1.2E-01	1.5E-11	3.4E-04	4.1E-03		5.6E-05	2.6E-02					5.2E-03		6.2E+00
Tl-207	3.5E-13		4.4E-05	4.1E-02	9.5E-17	1.6E-12	2.5E-01	4.2E-11	1.9E-04	3.1E-07			4.4E-11	5.2E-21	2.9E-07		2.9E-01
Tl-208	2.9E-18		7.2E-02	9.6E+00	1.9E-20	1.5E-09	4.1E-04		5.8E-03	1.1E-01			3.3E-16		2.9E-03		9.7E+00
Tl-209	1.8E-07		2.5E-03	2.9E-02	9.7E-08	4.1E-15	1.6E-03		4.4E-05	2.6E-03			2.0E-13	2.7E-21	2.5E-07		3.6E-02
Tl-210	2.5E-08		6.6E-05	1.0E-05	7.1E-06	2.5E-16	1.9E-04	6.4E-13	5.2E-05	3.4E-04			6.2E-15		1.2E-09		6.6E-04
U-232				2.6E+01					1.7E-02	2.9E-01							2.6E+01
U-233	3.0E-02		7.9E+01	9.0E+02	4.8E-03	2.2E-09	4.5E+01		1.8E+00	8.9E+01			7.5E-08	5.8E-15	8.9E-03		1.1E+03
U-234	3.1E-05		5.1E+01	5.8E+00	3.4E-09	1.1E-04	5.2E+00	2.2E-02	1.2E-02	8.9E+00			2.9E-03		2.3E+01		9.4E+01
U-235	6.0E-04		5.7E-01	6.2E-02	3.8E-11	1.3E-04	4.2E-01	2.1E-06	5.6E-05	6.6E-03			2.8E-05	5.9E-15	5.5E-03		1.1E+00
U-236	1.4E-06		2.1E-03	4.7E-03	1.5E-09	3.9E-06	2.0E-08		3.1E-06	2.4E-04			4.9E-04		4.5E-02		5.2E-02
U-237	1.5E-03	2.0E-04	2.3E+00	4.0E+00	7.1E-12	4.1E-02	4.3E-05		6.5E-03	1.4E+00			1.4E+00		1.5E+00		1.1E+01
U-238	5.3E-05		6.1E+00	1.2E-01	1.5E-11	3.5E-04	4.1E-03		5.6E-05	3.5E-02					5.2E-03	1.0E-10	6.2E+00
U-240			4.6E-10	2.8E-14					1.0E-06	7.9E-10					1.3E-11		1.0E-06
Y-90		2.3E-01	7.1E+02	2.2E+00			4.9E+01		3.4E-01	1.3E+03					1.2E-02		2.1E+03
Zn-65				1.2E-08													1.2E-08
Zr-93			2.7E-02	9.6E-05			2.4E-03		1.4E-05	1.0E-04							2.9E-02
Zr-95			7.3E-02	3.1E-06			4.5E-09		2.0E-14	1.1E-16							7.3E-02
Total	1.1E+02	1.2E+01	2.2E+05	3.7E+05	4.6E-01	2.1E+03	2.0E+05	9.2E+02	3.8E+03	7.4E+04	1.1E+02	5.6E-02	8.5E+04	1.0E-02	5.6E+05	6.9E-02	1.5E+06
Stored CH (CM)	2.9E+01	1.9E+00	9.3E+03	3.5E+04	8.4E-01	2.1E+02	1.1E+04	2.6E+02	6.2E+02	7.8E+02	3.5E+00	6.2E-01	1.1E+03	8.0E+00	1.5E+04	6.0E-02	7.3E+04
Avg Ci/CM	3.8E+00	6.3E+00	2.3E+01	1.0E+01	5.5E-01	9.8E+00	1.8E+01	3.5E+00	6.1E+00	9.5E+01	3.2E+01	9.0E-02	7.8E+01	1.3E-03	3.7E+01	1.1E+00	2.0E+01
Avg Ci/CF	1.1E-01	1.8E-01	6.6E-01	3.0E-01	1.6E-02	2.8E-01	5.1E-01	1.0E-01	1.7E-01	2.7E+00	8.9E-01	2.5E-03	2.2E+00	3.5E-05	0.0E+00	3.2E-02	5.1E-01
% TRU	1.0E+02	9.2E+01	9.8E+01	1.0E+02	2.6E+01	9.8E+01	1.0E+02	1.0E+02	9.3E+01	8.9E+01	5.0E+01	1.0E+02	1.0E+02	1.0E+02	1.0E+02	1.0E+02	9.0E+01
	ANLE	ETEC	HANF	INEL	LBL	LLNL	LANL	MOUND	NVTS	ORNL	PADU	PANTEX	RFP	SNLA	SRS	MURR	

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058)

91-058 Pu Mixes Scaled to 200 FGE 55 Gallon Drums

Pu-83 Mix[a]						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	80	597.944	1.71E+01	1.02E+04	1.13E+00	9.05E+03
Pu-239	16.3	121.831	6.22E-02	7.58E+00	1.00E+00	7.58E+00
Pu-240	3	22.423	2.28E-01	5.11E+00	1.00E+00	5.11E+00
Pu-241	0.6	4.485	1.03E+02	4.62E+02	5.20E+01	8.88E+00
Pu-242	0.1	0.747	3.93E-03	2.94E-03	1.06E+00	2.77E-03
Totals	100	747.430		10699.45		9070.11

Pu-57 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci. Wt. Factor	PE-Ci[c]
Pu-238	0.23	0.553	1.71E+01	9.45E+00	1.13E+00	8.36E+00
Pu-239	75.1	180.420	6.22E-02	1.12E+01	1.00E+00	1.12E+01
Pu-240	20.9	50.210	2.28E-01	1.14E+01	1.00E+00	1.14E+01
Pu-241	3.4	8.168	1.03E+02	8.41E+02	5.20E+01	1.62E+01
Pu-242	0.45	1.081	3.93E-03	4.25E-03	1.06E+00	4.01E-03
Totals	100.08	240.432		873.44		47.22

Pu-51 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.014	0.030	1.71E+01	5.05E-01	1.13E+00	4.47E-01
Pu-239	93.55	197.175	6.22E-02	1.23E+01	1.00E+00	1.23E+01
Pu-240	5.888	12.410	2.28E-01	2.83E+00	1.00E+00	2.83E+00
Pu-241	0.536	1.130	1.03E+02	1.16E+02	5.20E+01	2.24E+00
Pu-242	0.023	0.048	3.93E-03	1.91E-04	1.06E+00	1.80E-04
Totals	100.011	210.793		131.96		17.79

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058)

Pu-52 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci. Wt. Factor	PE-Ci[c]
Pu-238	0.01	0.021	1.71E+01	3.61E-01	1.13E+00	3.19E-01
Pu-239	93.89	198.108	6.22E-02	1.23E+01	1.00E+00	1.23E+01
Pu-240	5.75	12.133	2.28E-01	2.77E+00	1.00E+00	2.77E+00
Pu-241	0.34	0.717	1.03E+02	7.39E+01	5.20E+01	1.42E+00
Pu-242	0.02	0.042	3.93E-03	1.66E-04	1.06E+00	1.56E-04
Totals	100.01	211.021		89.33		16.83
Pu-53 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.03	0.065	1.71E+01	1.11E+00	1.13E+00	9.79E-01
Pu-239	90.82	195.853	6.22E-02	1.22E+01	1.00E+00	1.22E+01
Pu-240	8.3	17.899	2.28E-01	4.08E+00	1.00E+00	4.08E+00
Pu-241	0.77	1.661	1.03E+02	1.71E+02	5.20E+01	3.29E+00
Pu-242	0.09	0.194	3.93E-03	7.63E-04	1.06E+00	7.20E-04
Totals	100.01	215.672		188.39		20.53
Pu-54 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.05	0.111	1.71E+01	1.89E+00	1.13E+00	1.68E+00
Pu-239	86.36	191.279	6.22E-02	1.19E+01	1.00E+00	1.19E+01
Pu-240	11.75	26.025	2.28E-01	5.93E+00	1.00E+00	5.93E+00
Pu-241	1.63	3.610	1.03E+02	3.72E+02	5.20E+01	7.15E+00
Pu-242	0.21	0.465	3.93E-03	1.83E-03	1.06E+00	1.72E-03
Totals	100	221.490		391.72		26.66

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058) Page 3 of 6

Pu-55 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.02	0.046	1.71E+01	7.91E-01	1.13E+00	7.00E-01
Pu-239	83.7	193.498	6.22E-02	1.20E+01	1.00E+00	1.20E+01
Pu-240	14.9	34.446	2.28E-01	7.85E+00	1.00E+00	7.85E+00
Pu-241	1.1	2.543	1.03E+02	2.62E+02	5.20E+01	5.04E+00
Pu-242	0.24	0.555	3.93E-03	2.18E-03	1.06E+00	2.06E-03
Totals	99.96	231.088		282.64		25.63
Pu-56 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.014	0.032	1.71E+01	5.54E-01	1.13E+00	4.90E-01
Pu-239	80.5	186.148	6.22E-02	1.16E+01	1.00E+00	1.16E+01
Pu-240	16	36.998	2.28E-01	8.44E+00	1.00E+00	8.44E+00
Pu-241	2.5	5.781	1.03E+02	5.95E+02	5.20E+01	1.15E+01
Pu-242	0.74	1.711	3.93E-03	6.72E-03	1.06E+00	6.34E-03
Totals	99.754	230.671		615.60		32.01
91-058 Pu Mixes Scaled to 325g for SWB						
Pu-83 Mix[a]						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	80	971.656	1.71E+01	1.66E+04	1.13E+00	1.47E+04
Pu-239	16.3	197.975	6.22E-02	1.23E+01	1.00E+00	1.23E+01
Pu-240	3	36.437	2.28E-01	8.31E+00	1.00E+00	8.31E+00
Pu-241	0.6	7.287	1.03E+02	7.51E+02	5.20E+01	1.44E+01
Pu-242	0.1	1.215	3.93E-03	4.77E-03	1.06E+00	4.50E-03
Totals	100	1214.570		17371.61		14739.00

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058)

Pu-57 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.23	0.898	1.71E+01	1.54E+01	1.13E+00	1.36E+01
Pu-239	75.1	293.183	6.22E-02	1.82E+01	1.00E+00	1.82E+01
Pu-240	20.9	81.592	2.28E-01	1.86E+01	1.00E+00	1.86E+01
Pu-241	3.4	13.273	1.03E+02	1.37E+03	5.20E+01	2.63E+01
Pu-242	0.45	1.757	3.93E-03	6.90E-03	1.06E+00	6.51E-03
Totals	100.08	390.702		1422.21		76.72
Pu-51 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.014	0.048	1.71E+01	8.20E-01	1.13E+00	7.26E-01
Pu-239	93.55	320.381	6.22E-02	1.99E+01	1.00E+00	1.99E+01
Pu-240	5.888	20.165	2.28E-01	4.60E+00	1.00E+00	4.60E+00
Pu-241	0.536	1.836	1.03E+02	1.89E+02	5.20E+01	3.64E+00
Pu-242	0.023	0.079	3.93E-03	3.10E-04	1.06E+00	2.92E-04
Totals	100.011	342.508		214.32		28.90
Pu-52 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.01	0.034	1.71E+01	5.86E-01	1.13E+00	5.19E-01
Pu-239	93.89	321.930	6.22E-02	2.00E+01	1.00E+00	2.00E+01
Pu-240	5.75	19.716	2.28E-01	4.50E+00	1.00E+00	4.50E+00
Pu-241	0.34	1.166	1.03E+02	1.20E+02	5.20E+01	2.31E+00
Pu-242	0.02	0.069	3.93E-03	2.70E-04	1.06E+00	2.54E-04
Totals	100.01	342.914		145.09		27.35

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058)

Pu-53 Mix						
Isotope	Weight %	Mass	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.03	0.105	1.71E+01	1.80E+00	1.13E+00	1.59E+00
Pu-239	90.82	318.261	6.22E-02	1.98E+01	1.00E+00	1.98E+01
Pu-240	8.3	29.086	2.28E-01	6.63E+00	1.00E+00	6.63E+00
Pu-241	0.77	2.698	1.03E+02	2.78E+02	5.20E+01	5.34E+00
Pu-242	0.09	0.315	3.93E-03	1.24E-03	1.06E+00	1.17E-03
Totals	100.01	350.465		306.23		33.36
Pu-54 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.05	0.180	1.71E+01	3.08E+00	1.13E+00	2.72E+00
Pu-239	86.36	310.827	6.22E-02	1.93E+01	1.00E+00	1.93E+01
Pu-240	11.75	42.291	2.28E-01	9.64E+00	1.00E+00	9.64E+00
Pu-241	1.63	5.867	1.03E+02	6.04E+02	5.20E+01	1.16E+01
Pu-242	0.21	0.756	3.93E-03	2.97E-03	1.06E+00	2.80E-03
Totals	100	359.920		636.02		43.32
Pu-55 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.02	0.075	1.71E+01	1.28E+00	1.13E+00	1.14E+00
Pu-239	83.7	314.436	6.22E-02	1.96E+01	1.00E+00	1.96E+01
Pu-240	14.9	55.975	2.28E-01	1.28E+01	1.00E+00	1.28E+01
Pu-241	1.1	4.132	1.03E+02	4.26E+02	5.20E+01	8.19E+00
Pu-242	0.24	0.902	3.93E-03	3.54E-03	1.06E+00	3.34E-03
Totals	99.96	375.520		459.68		41.65

Table A-2, Scaled Pu Mixes For 55 Gallon Drums and SWBs (Ref. DOE/WIPP 91-058) Page 6 of 6

Pu-56 Mix						
Isotope	Weight %	Mass (g)[b]	Specific Activity (Ci/g)	Activity (Ci)	PE-Ci Wt. Factor	PE-Ci[c]
Pu-238	0.014	0.053	1.71E+01	9.00E-01	1.13E+00	7.96E-01
Pu-239	80.5	302.495	6.22E-02	1.88E+01	1.00E+00	1.88E+01
Pu-240	16	60.123	2.28E-01	1.37E+01	1.00E+00	1.37E+01
Pu-241	2.5	9.394	1.74E+01	9.68E+02	5.20E+01	1.86E+01
Pu-242	0.74	2.781	3.93E-03	1.09E-02	1.06E+00	1.03E-02
Totals	99.754	374.846		1001.41		51.94

Notes:

a. It is noted that thermal power limitations will limit the transuranic content for this mix to a value that is less than the content allowable based on the WAC Nuclear Criticality Limits. However, the calculations are performed here for comparision purposes.

b. Isotopic mass scaled to 200 Pu-239 Fissile Gram Equivalents (FGEs) for 55-gal drums and 325 FGEs for Standard Waste Boxes. The following equation is used to calculate the scaled isotopic masses:

$$Pu\text{-}239\ FGE = \sum_{i=1}^{n} * M_i\ (FGE\ Factor)_i$$

where: Pu-239 FGE = 200g for drums or 325g for SWBs
M_i = mass of isotope I = $(wt\%)_i$ (Total FGE scaled mass, M_{Pu}, of Pu in grams)
FGE $Factor_i$ = FGE Factor from Table 10.1 of Nu Pac TRUPACT-II SAR

for example, for 55-gal drums:

$$200g = (wt\%\ Pu\text{-}238)(M_{Pu})(1.13E\text{-}01)+(wt\%\ Pu\text{-}239)(M_{Pu})(1)+(wt\%\ Pu\text{-}240)(M_{Pu})(2.25E\text{-}02)+(wt\%\ Pu\text{-}241)(M_{Pu})(2.25)+(wt\%\ Pu\text{-}242)(M_{Pu})(7.5E\text{-}03)$$

c. Pu-239 Equivalent Curies (PE-Ci) are calculated using the following equation:

$$PE\text{-}Ci_{mix} = \sum_{i=1}^{n} * \frac{M_i\ *(Specific\ Activity\ Ci/g)}{PE\text{-}Ci\ Weighting\ Factor}$$

See Appendix B for PE-Ci Weighting Factors

APPENDIX - B
Plutonium-239 Equivalent Activity

The concept of Plutonium-239 Equivalent Activity (PE-Ci) is intended to eliminate the dependency of radiological analyses on specific knowledge of the radionuclide composition of a transuranic waste stream. A unique radionuclide composition and/or distribution is associated with virtually every transuranic waste generator and storage site. By normalizing all radionuclides to a common radiotoxic hazard index, radiological analyses can be conducted for the WIPP facility, which are essentially independent of these variations. Plutonium-239, as a common component of virtually all defense transuranic wastes, was selected as the radionuclide to which the radiotoxic hazard of other transuranic radionuclides could be indexed.

Operational releases from the WIPP facility, including both routine and accident related, are airborne. There are no significant liquid release pathways during the operational phase of the facility. This, and the fact that transuranic radionuclides primarily represent inhalation hazards, allows a valid relationship to be established, which normalizes the inhalation hazard of a transuranic radionuclide to that of Pu-239 for the purpose of the WIPP radiological analyses. In effect, the radiological dose consequences of an airborne release of a quantity of transuranic radioactivity with a known radionuclide distribution will be essentially identical to that of a release of that material expressed in terms of a quantity of Pu-239.

To obtain this correlation, the 50-year effective whole-body dose commitment or dose conversion factor (DCF) for a unit intake of each radionuclide will be used.

For a known radioactivity quantity and radionuclide distribution, the Pu-239 equivalent activity is determined using radionuclide specific weighting factors. The Pu-239 equivalent activity (AM) can be characterized by:

$$AM = \sum_{i=1}^{K} A_i/WF_i$$

where K is the number of TRU* radionuclides, Ai is the activity of radionuclide i, and WF_i is the PE-Ci weighting factor for radionuclide i.

WF_i is further defined as the ratio:

$$WF_i = E_o/E_i$$

where, E_o (rem/μCi) is the 50-year effective whole-body dose commitment due to the inhalation of Pu-239 particulates with a 1.0 μm AMAD (Activity Median Aerodynamic Diameter) and a W pulmonary clearance class, and E_i (rem/μCi) is the 50-year effective whole-body dose commitment due to the inhalation of radionuclide particulates with a 1.0 μm AMAD and the pulmonary clearance class resulting in the highest 50-year effective whole-body dose commitment.

The values of E_o and E_i may be obtained from DOE/EH-0071.[1] Weighting factors calculated in this manner are presented in Table B-1 for selected radionuclides of interest.

*TRU as designated in this equation refers to any radionuclide with an atomic number greater than 92 and including U-233.

Table B-1, PE-Ci Weighting Factors for Selected Radionuclides

Radionuclide	Pulmonary Clearance Class*	Weighting Factor
Pu-238	W	1.13
Pu-239	W	1.0
Pu-240	W	1.0
Pu-241	W	52.0
Pu-242	W	1.06

*(D) Daily; (W) Weekly, (Y) Yearly

References for Appendix B

1. DOE/EH-0071, Internal Dose Conversion Factors for Calculation of DOSE to the Public, July 1988.

APPENDIX - C
Hazop Session Summary Table

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
1) Transporter at Front Gate	Exceeds Acceptance Criteria (WAC)	Technician or instrumentation error Shift of internal shielding Shipment sent by Generator above WAC limits for dose rate	Potential inability to perform radiation survey and security checks Potential inability to bring transporter on site Potential to block primary vehicle access into site Potential to delay unloading transporter Potential for personnel radiation exposure Potential to expose dosimeters located in the security building Potential for sabotage of facility Potential to remove TRUPACT-II or transporter from service Potential for notification to DOE, DOT and the State of violation of the shipping requirements Potential for DOE\DOT investigation into the violation	Generator processes provide for shipping in accordance with the WAC requirements Radiation survey upon arrival provides early detection Instruments are periodically calibrated Training and certification of health physics personnel conducting surveys Instrument calibration programs are periodically audited Health physics certification programs are periodically audited WIPP conducts periodic audits on the Generator processes TRUPACT-II certified as a DOT Type B shipping container	0,3	2, 3
1) Transporter at Front Gate	No Notice of Arrival	Generator fails to notify facility of shipment	Potential inability to perform radiation survey and security checks Potential inability to bring transporter on site Potential to block primary vehicle access into site Potential to delay unloading transporter Potential for personnel radiation exposure Potential to expose dosimeters located in the security building Potential for sabotage of facility	Notification from TRANSCOM Physical fence partitions transporter from personnel Physical manifest for transporter received prior to transporter arrival at site Physical data on waste form and dose rate on TRUPACT-II contents Procedure of receipt of transporter at the gate Radiation survey of transporter and TRUPACT-II Procedures in place for reading dosimeters on a periodic basis Administrative control for inspection of transporter enroute and before leaving Generator DOT physical inspection of transporter to manifest at state lines WAC shipping requirements		2, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
1) Transporter at Front Gate	Shipping Papers Do Not Correlate	Generator's personnel error in matching manifest papers to shipment Transporter driver connects to incorrect trailer at Generator site	Potential to delay unloading transporter Potential to notify Generator that paperwork is incorrect for shipment received	Periodic paperwork checks by DOT as transporter crosses state lines during transit WIPP performs audits of Generator's shipping procedures on a periodic basis		1, 3
1) Transporter at Front Gate	TRUPACT-II Damage	Vehicle accident Road debris Sabotage Rifle fire	Potential to delay unloading transporter Potential for personnel radiation exposure Potential to expose dosimeters located in the security building Potential inability to perform normal operations Potential to lose continuing usage of a TRUPACT-II container Potential to contaminate surface Potential need to decontaminate area or contain contamination Potential economic loss	TRUPACT-II certification as a DOT Class B shipping container Radiation surveys are performed on incoming shipments Hourly inspections enroute are performed by the drivers Driver training and certification Procedures in place for placing TRUPACT-II in a safe condition WAC shipping requirements		3, 1
1) Transporter at Front Gate	Transporter Breakdown	Mechanical or electrical failure Operator error No fuel	Potential for delay in positioning and unloading the trailer	Alternate means available to position the trailer		1, 3
1) Transporter at Front Gate	Transporter Fire	Diesel fuel line breaks spraying diesel fuel on hot manifold Electrical fire Brake defect Collision with another vehicle	Potential to delay unloading transporter Potential to lose use of the access gate Potential to lose guard house in a fire Potential to rupture fuel tank Potential for explosion Potential for personnel injury or fatality Potential to lose security vehicles in a fire Potential to release combustion products to the environment Potential to contaminate water used to control fire Potential environmental concern Potential for smoke entering the mine Potential economic loss	Transporter driver required certification and qualification Fire extinguisher available on transporter Frequent inspection of transporter Site fire fighting personnel available to minimize loss Provisions in place for alternate site access Procedures in place to shutdown ventilation preventing smoke from entering the mine Procedures in place to monitor fire water run-off Emplacement dikes surround perimeter of site to capture fire water TRUPACT-II design	0,2	4, 2
1) Transporter at Front Gate	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
2)Transfer Trailer from Gate to Unloading Position	Damage To Trailer Jockey During Hook Up	Mechanical/electrical failure of trailer jockey Operator error in adjusting the 5th wheel plate elevation on the trailer jockey	Potential to delay unloading trailer Potential to damage trailer Potential to drop the trailer Potential for TRUPACT-II to slip from trailer Potential to disrupt facility operations	Operator certification and qualification provides for proper use of the trailer jockey Preventative maintenance of the trailer jockey Outside trucking services available to position the trailer Tie-downs prevent TRUPACT-II from slipping from trailer		1, 3
2)Transfer Trailer from Gate to Unloading Position	Jockey and Trailer Low Speed Accident	Mechanical or electrical failure Operator error	Potential to damage the waste handling building, trailer and/or jockey Potential to lose the negative pressure in the waste handling building Potential to lose the negative pressure boundary of the air lock Potential to slow down or stop unloading operations Potential for collision with another trailer Potential for fire Potential for personnel injury Potential to release combustion products to the environment Potential to slip TRUPACT-II from trailer Potential for collision with another vehicle	Operator training and qualifications provide for proper operation of equipment Vehicle preventative maintenance provides for proper equipment operation Tie-downs prevent TRUPACT-II from slipping from trailer Trailer jockey has fire suppression equipment installed TRUPACT-II design Low speed during equipment operation TRUPACT-II handling area is restricted to people and equipment Emergency Response Team available	0,4	2, 4
2)Transfer Trailer from Gate to Unloading Position	Trailer Jack Failure During Unhooking	Mechanical failure of the trailer jack stand Operator error during unhooking operation Inclement weather	Potential to delay unloading trailer Potential to drop trailer Potential to damage tractor Potential to damage trailer Potential for TRUPACT-II to disengage from the trailer Potential to disrupt facility operations	Transporter driver required certification and qualification Trailer maintenance and inspection programs provide assurance for proper operation of the jacks TRUPACT-II tie-downs are designed to restrain the TRUPACT-II to the trailer TRUPACT-II design	0,3	2, 3
2)Transfer Trailer from Gate to Unloading Position	Transporter Breakdown	Mechanical or electrical failure Empty fuel tank	Potential slight delay in positioning trailer	Alternate means available to move trailer		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
2)Transfer Trailer from Gate to Unloading Position	Transporter Crashes Through Gate	Transporter brake system fails Driver error	Potential to damage the access gates Potential to damage sections of the facility Potential for personnel injury or fatality Potential economic loss	Drivers are trained, qualified and certified for proper transporter operation Transporter is equipped with emergency brakes Transporter maintenance provides for proper equipment operation Access road has a 90 degree turn immediately prior to approaching the main access gate, minimum speeds achieved Access roads are level	0,1	4, 1
2)Transfer Trailer from Gate to Unloading Position	Transporter/ Trailer Low Speed Accident	Operator error Mechanical or electrical failure Pedestrian inadvertently in roadway Restricted access path	Potential to delay unloading trailer Potential for personnel injury Potential to upset trailer Potential to damage trailer Potential to damage fire protection post indicator valves Potential to reduce fire protection capacity to some buildings Potential to slip load from trailer Potential to damage TRUPACT-II Potential for collision with another vehicle Potential economic loss	TRUPACT-II certification as a DOT Type B shipping container Driver training and certification Trailer designed to withstand low speed impacts Site limits vehicle speed through facility Barricades around post indicator valves Dual fire protection loop	0,4	2, 4
2)Transfer Trailer from Gate to Unloading Position	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRAILER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
3) Unloading of the Trailer	Failure to Properly Disconnect Trailer	Operator error in disconnecting trailer jockey from trailer	Potential to damage trailer Potential to lose continuing usage of trailer Potential for maintenance on trailer Potential to delay unloading trailer	Operators are trained and certified to operate the equipment safely Preventative maintenance is performed on the trailer and the trailer jockey to provide reliable equipment operation Operator follows check list during the unhooking operation		1, 3
3) Unloading of the Trailer	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
4) Transfer TRUPACT-II from Trailer to TRUDOCK	Failure to Remove TRUPACT From Trailer	Operator error Mechanical or electrical failure of fork lift Failure to remove tie-downs	Potential to delay unloading trailer Potential to damage TRUPACT-II Potential to damage trailer	Operator training and certification Procedures are in place to perform operation Preoperational check list used during operation		1, 2
4) Transfer TRUPACT-II from Trailer to TRUDOCK	Failure to Remove Tie-downs	Operator error Mechanical Failure	Potential to stretch and break tie-downs	Operator training and certification Operating procedures are in place to perform this operation		1, 3
4) Transfer TRUPACT-II from Trailer to TRUDOCK	Improper Stabilization of Trailer	Operator error	Potential for trailer to roll Potential for personnel injury Potential to damage trailer jockey Potential to damage fence, building or other trailers Potential to damage fire water post indicator valve Potential to lose fire protection water in the trailer staging area Potential economic loss	Traffic barricades stationed around post indicator valves Operator training and certification Procedures in place to perform operation Trailer brake has fail safe mode of operation Trailer staging area is level prohibiting trailer from rolling	0,3	2, 3
4) Transfer TRUPACT-II from Trailer to TRUDOCK	Improper Transit to TRUDOCK	Operator error Mechanical/electrical failure of fork lift Collision with another vehicle, a pedestrian, building, or air lock door Air lock door interlock failure Air lock door(s) fail to fully open TRUDOCK doors fail to fully open	Potential to slightly damage TRUPACT-II Potential to damage fork lift Potential to damage Waste Handling Building Potential to damage air lock Potential for personnel injury Potential to damage TRUDOCK Potential to lose ventilation in the air lock Potential to damage air lock duct work Potential to activate the fire protection system in the air lock	Operator training and certification TRUPACT-II design and certification as a DOT Class B container Spotter used during transit Low battery indicator on the fork lift Equipment preventative maintenance program provides for reliable equipment operation Backup fork lift available Alternate air locks are available Procedures are in place to perform operation Air lock duct work may be isolated Air lock fire protection may be isolated Fire watches may be used to supplement fire protection loss	0,3	2, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
4) Transfer TRUPACT-II from Trailer to TRUDOCK	Misalignment of Fork Lift to TRUPACT-II	Operator error Failure to remove TRUPACT-II fork lift access covers Fork lift mechanical or electrical failure	Potential to knock TRUPACT-II off trailer Potential for personnel injury or fatality Potential to damage TRUPACT-II Potential to damage trailer Potential to damage fork lift	Operator training and certification Second person used during the operation to spot the fork lift properly Procedures are in place to perform operation TRUPACT-II design mitigates damage Preoperational checks of equipment prior to use Work practices minimize unnecessary personnel from the work area Area is a radiological controlled area during the handling of waste Trailer jockey is equipped with two television cameras and monitors to aid in positioning	0,2	4, 2
4) Transfer TRUPACT-II from Trailer to TRUDOCK	All Other Deviations		NAHI			
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Lift OCV Lid	Locking ring fails to rotate OCV lid binds	Potential to delay unloading operations Potential to damage TRUPACT-II	Operator training and certification Preoperational checks are used prior to starting the process		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Move OCV Lid to Lid Stand	Radioactive contamination found inside the TRUPACT-II Crane mechanical or electrical failure Crane lift cable fails	Potential to lose use of TRUDOCK Potential to reclose TRUPACT-II and transfer to the Overpack and Repair Room (OP & RR) Potential for spot decontamination Potential to drop OCV lid Potential to damage OCV lid Potential for personnel injury or fatality Potential to damage TRUDOCK	Operator and health physics technician training and certification Procedures are in place to perform operation Overhead crane fails as is on loss of power ACGLF provided with indicating light when engaged in pallet Crane designed with a double lifting cable Duplicate lifting fixtures are available Preventative maintenance checks on crane, cables, ACGLF, and hook are performed monthly Generator ships in accordance with the WAC shipping limitations Radiological surveys identify radiation levels and contamination levels as found WIPP lifting practices comply with DOE hoisting and rigging regulations	0,2	4, 2
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Move OCV Lid to Stand (Cont.)			Generator checks shipment prior to departure WIPP Waste Information Syatem (WWIS) data received from the Generator Second TRUDOCK available		
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Prep OCV Lid For Removal	Operator error Jammed access plug	Potential to delay unloading operation Potential to perform maintenance on access port	Operator training and certification Maintenance procedures for rework of the access plug or other TRUPACT-II available		1, 3
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Pull Vacuum on OCV Lid	Mechanical/electrical failure of the vacuum system Operator error Failure to remove access plug Leak in TRUPACT-II Loss of HVAC system	Potential inability to remove the OCV lid Potential to delay unloading operations	TRUPACT-II certification as a DOT Class B container TRUPACT-II container integrity is checked during annual maintenance by WIPP personnel Operator training and certification Redundant HVAC system available to support operations Backup vacuum pumps are available		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
5) Removal of Outer Containment Vessel (OCV) Lid	Failure to Verify System Conditions	Operator error	Potential to violate administrative controls/operating procedures Potential to lose negative pressure in the Waste Handling Building Potential to delay waste handling operations	Operator training and certification Procedures are in place to check and verify system conditions Conduct of Operations provides guidelines for activities Local audible and visual alarm when inadequate negative pressure exists in the Waste Handling Building	0,3	2, 3
5) Removal of Outer Containment Vessel (OCV) Lid	Missing Security Seals	Generator fails to install seals Seal(s) lost in transit	Potential to delay unloading operations	DOT checks presence of seals during inspections at the state lines Design of the security seal minimizes inadvertent loss Procedures require checking for the seals		1, 3
5) Removal of Outer Containment Vessel (OCV) Lid	_All Other Deviations		NAHI			
6) Removal of Inner Containment Vessel (ICV) Lid	Failure to Establish Vent Hood Operation	Loss of HVAC in the CH bay Loss of ventilation at the TRUDOCK Damper out of position Valve fails	Potential to delay unloading operations	Verification of vent flow is required Valve positions are verified Operator training and certification Periodic preventative maintenance performed on equipment Periodic equipment checks during the process Procedures are in place to perform process Redundant trains available in the CH HVAC system	0,4	1, 4
6) Removal of Inner Containment Vessel (ICV) Lid	Failure to Lift the ICV Lid	Locking ring fails to rotate Lid binds	Potential to delay unloading operations Potential to damage TRUPACT-II	Operator training and certification		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
6) Removal of Inner Containment Vessel (ICV) Lid	Failure to Move ICV Lid to ICV Lid Stand	Radioactive contamination found inside the TRUPACT-II Crane mechanical or electrical failure Crane lift cable fails Airborne contamination found	Potential to lose use of TRUDOCK Potential to reclose the TRUPACT-II and transfer to OP&RR Potential for spot decontamination Potential to drop ICV lid Potential to damage ICV lid Potential for personnel injury or fatality Potential to damage TRUDOCK Potential to contaminate the area Potential need to decontaminate area Potential to sound alarms on the continuous air monitors (CAM) Potential need to issue Report of Occurrence on activation of CAM alarms Potential personnel radiation exposure Potential environmental concern Potential economic loss	Operator and Health Physics technician training and certification Procedures are in place to perform operation Overhead crane fails as is on loss of power ACGLF provided with indicating lights when engaged in pallet Crane designed with a double lifting cable Duplicate lifting fixtures are available Monthly preventative maintenance checks on crane, cables, ACGLF, and hook Generator ships in accordance with the WAC shipping requirements WIPP lifting practices comply with DOE hoisting and rigging regulations WIPP WWIS data received from generator Radiological surveys identify radiation levels and contamination levels as found Generator checks shipment prior to departure Contaminated TRUPACT-II bagged prior to placing in the OP&RR Abnormal operation procedures available for guidance Vent hood design and use Radiological instrumentation alarms	0,2	4, 2
6) Removal of Inner Containment Vessel (ICV) Lid	Failure to Prep ICV Lid For Removal	Operator error	Potential to delay unloading operations	Operator training and certification		1, 3
6) Removal of Inner Containment Vessel (ICV) Lid	Failure to Pull Vacuum on ICV Lid	Mechanical or electrical failure of the vacuum system Operator error Leak in TRUPACT-II Loss of HVAC system	Potential inability to remove the ICV lid Potential to delay unloading operations	TRUPACT-II certification as a DOT Class B container TRUPACT-II container integrity is checked during annual maintenance by WIPP personnel Operator training and certification Redundant HVAC system available to support operations Backup vacuum pumps are available		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
6) Removal of Inner Containment Vessel (ICV) Lid	Radiological Assessment > Background	Possible airborne contamination	Potential to delay unloading of the TRUPACT-II Potential to move the TRUPACT-II to the Overpack and Repair Room Potential to replace tool and filter due to internal contamination	Health Physics survey confirms contamination levels Health Physics personnel training and certification Simplistic design of filter and sample rig Procedures are in place to perform process Generator conforms to shipping per WAC regulations Ventilation system prefilter and HEPA filter available for removing radioactive material from exhaust stream WAC shipping limits	0,4	2, 4
6) Removal of Inner Containment Vessel (ICV) Lid	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
7) TRUPACT-II Internal Condition	Fire in TRUPACT-II	Spontaneous ignition in a waste drum due to corrosion, chemical breakdown or anaerobic decomposition or pyrophoric interaction	Potential to shut down operations Potential to damage TRUPACT-II Potential to damage overhead crane Potential to rupture waste container Potential to spread contamination Potential need to decontaminate area Potential to damage TRUDOCK Potential for explosion Potential for personnel injury or fatality Potential to damage WHB Potential to lose containment Potential to release radioactive material Potential for personnel radiation exposure Potential to release combustion products to the environment Potential environmental concern Potential to notify DOE, EPA, and State of environmental violation Potential for adverse media attention Potential to shutdown site operations Potential for site evacuation Potential economic loss	Generator ships waste in accordance to WAC shipping criteria Drums are characterized Fissile loading is known Minimum liquids contained in drums Drums are vented thru carbon filters Drums, due to storage prior to shipment, are more stable and lessens the likelihood of fire Drum integrity is tested TRUPACT-II integrity On-site emergency responders available Building has fire suppression capability Drums are designed and certified as DOT Class A containers Building ventilation is filtered through prefilters and HEPA filters ICV lid can be reinstalled to aid in controlling fire in TRUPACT-II Smoke may be visible through hoses on vacuum systems Portable fire fighting equipment available Fire hose station available Limited combustibles in the area Building design is noncombustible Building design has two hour fire rating Emergency response team available Fire suppression system	3,3	4, 3
7) TRUPACT-II Internal Condition	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
8) Transfer of Payload from TRUDOCK to Facility Pallet	Failure To Place Load On Facility Pallet	Operator error Equipment failure Loss of power	Potential to misposition waste drums or SWB on facility pallet Potential to delay operations	Operator training and certification Maintenance procedures available Spotters used during transit of payload Preventative maintenance program in place Procedures used to perform operation Preoperational checks of equipment prior to use Adequate lighting in area Backup power available		1, 3
8) Transfer of Payload from TRUDOCK to Facility Pallet	Failure of Lifting Equipment	Mechanical or electrical failure Operator error	Potential to drop the load Potential to damage CAMS Potential to damage TRUDOCK Potential to rupture waste container Potential for personnel injury or fatality Potential to release radioactive material Potential to contaminate surface Potential need to decontaminate area Potential for personnel radiation exposure Potential to delay operations Potential for fire Potential for explosion Potential to shutdown operations Potential to release combustion products to the environment Potential to damage Waste Handling Building Potential to lose containment Potential environmental concern Potential to notify DOE, EPA, and State of environmental violation Potential for adverse media attention Potential for site evacuation Potential economic loss	Generator ships waste in accordance to WAC Operator training and certification Preventative maintenance Equipment is designed as fail safe Drums are designed and certified as DOT Class A containers Seven packs are wrapped restricting free motion Ventilation is designed to contain rad releases through use of HEPA filters WHB has fire suppression systems and portable fire extinguishers and hose station available Emergency response team on site WIPP lifting practices comply with DOE Hoisting and Rigging regulations Limited combustibles in area Building design is noncombustible	2,3	4, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
8) Transfer of Payload from TRUDOCK to Facility Pallet	Failure to Secure Load	Operator error Damaged securing devices	Potential to lose load during transit Potential to drop the load Potential to damage CAMS Potential to damage TRUDOCK Potential to rupture waste container Potential for personnel injury or fatality Potential to release radioactive material Potential to contaminate surface Potential need to decontaminate area Potential for personnel radiation exposure Potential to delay operations Potential for fire Potential for explosion Potential to shutdown operations Potential to release combustion products to the environment Potential to damage Waste Handling Building Potential to lose containment Potential environmental concern Potential to notify DOE, EPA, and State of environmental violation Potential for adverse media attention Potential for site evacuation Potential economic loss	Generator ships waste in accordance to WAC Operator training and certification Preventative maintenance Preoperational checks of equipment prior to use Equipment is designed as fail safe Drums are certified as DOT Class A containers Seven packs are wrapped restricting free motion Ventilation is designed to contain rad releases through use of HEPA filters WHB has fire suppression systems, fire extinguishers and hose station Emergency response team on site WIPP lifting practices comply with DOE Hoisting and Rigging regulations Limited combustibles in area Building design is noncombustible	2,3	4, 3
8) Transfer of Payload from TRUDOCK to Facility Pallet	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
9) Transfer Facility Pallet to Conveyance Car	Fork Lift Improper Engagement of Load	Operator error Fork lift mechanical or electrical failure	Potential to puncture drum Potential to lose load Potential to damage TRUDOCK Potential to rupture waste container Potential to release radioactive material Potential need to decontaminate area Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to shutdown operations Potential to damage fork lift Potential to damage Waste Handling Building Potential to release combustion products to the environment Potential to lose containment Potential environmental concern Potential to notify DOE, EPA, and State of environmental violation Potential adverse media attention Potential site evacuation Potential economic loss Potential loss of remote alarms	Generator ships waste in accordance to WAC Operator training and certification Maintenance procedures available Spotters used during engagement and transit of payload Preventative maintenance program in place Procedures used to perform operation Preoperational checks of equipment prior to use Adequate lighting in area Backup power available Fire suppression systems Emergency response team available Building construction	2,3	4, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
9) Transfer Facility Pallet to Conveyance Car	Mislocation On the Conveyance Car	Operator error Fork lift mechanical or electrical failure Air lock door failure	Potential to puncture drum Potential to lose load Potential to rupture waste container Potential to release radioactive material Potential need to decontaminate area Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to damage fork lift Potential to damage building Potential to release combustion products to environment Potential to notify proper authorities of release Potential vehicle collision Potential building collision Potential to damage the CMS monitor Potential to lose remote alarms Potential to lose air lock door interlock Potential to damage conveyance car Potential to damage conveyance room door seal Potential to lose secondary egress from underground Potential for adverse media attention Potential environmental concern Potential economic loss	Generator ships waste in accordance to WAC Drums are certified as DOT Class A containers Seven packs are wrapped restricting free motion Ventilation designed to contain rad releases through HEPA filters Operator training and certification Fire suppression, fire extinguishers, hose station available Spotters are used during load movements Restricted access to qualified personnel Local alarms on CAM's and ventilation system Air intake and salt shafts are available for egress from underground Reinforced shield door and thick concrete containment walls Air lock doors are interlocked Tie-down straps and lateral straps	2,3	4, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
9) Transfer Facility Pallet to Conveyance Car	Moving Accident	Operator error Fork lift mechanical or electrical failure	Potential to puncture drum Potential to lose load Potential to rupture waste container Potential to release radioactive material Potential need to decontaminate area Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to damage fork lift Potential to damage building Potential to damage TRUDOCK Potential to release combustion products to the environment Potential to notify DOE, EPA, and State of environmental violation Potential vehicle collision Potential building collision Potential for adverse media attention Potential for site evacuation Potential economic loss Potential to damage the CMS monitor Potential loss of remote alarms	Generator ships waste in accordance to WAC Operator training and certification Spotters are used during load movements Preventative maintenance on equipment Drums are designed and certified as DOT Class A containers Seven packs are wrapped restricting free motion Ventilation is designed to contain rad releases through use of HEPA filters WHB has fire suppression systems, fire extinguishers and hose station Emergency response team on site Limited combustibles in area Building design is noncombustible Tie-down straps and lateral straps	2,3	4, 3
9) Transfer Facility Pallet to Conveyance Car	_All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
10) Transfer Conveyance Car Load onto the Waste Cage	Driving Conveyance Car Into Empty Shaft	Operator error Equipment malfunction	Potential loss of operations Potential to damage equipment Potential to rupture drum Potential to have a fire in waste shaft Potential to drop load down shaft Potential to contaminate the underground Potential need to decontaminate area Potential to fill underground with smoke Potential for explosion Potential for personnel injury or fatality Potential to release combustion products to the environment Potential environmental concern Potential to notify DOE, EPA, and State of environmental violation Potential to evacuate the underground Potential economic loss Potential for adverse media attention	Generator ships waste in accordance to WAC Operator training and certification Position sensors on conveyance car automatically stop car prompting operator to use bypass Shaft tender in attendance Rail extensions engage cage rails to the floor to enable transferring the car Procedures are in place to perform operation Front wheels dropping off the track will high center the car stopping car movement	3,1	4, 1
10) Transfer Conveyance Car Load onto the Waste Cage	Failure of Conveyance Car	Mechanical or electrical failure	Potential to delay operations Potential to lose conveyance car Potential loss of operations	Maintenance programs Preventative maintenance program Preoperational checks Car can be manually removed from waste cage Operator training and certification Durability of conveyance car		1, 3

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NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II PAYLOAD

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
10) Transfer Conveyance Car Load onto the Waste Cage	Moving Accident	Failure to raise car lift table Failure to lower pins on the waste car chairs Alignment of waste cage with the tracks Operator error Mechanical or electrical failure	Potential to lose load Potential to rupture waste container Potential to release radioactive material Potential need to decontaminate area Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to release combustion products to environment Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media attention Potential for waste hoist cage collision Potential to damage the chairs Potential to damage the facility pallet Potential to delay operations Potential economic loss	Operator training and certification Procedures available to perform operation Preoperational checks prior to use Maintenance programs Preventative maintenance programs in place Car speed very slow Load is strapped down Positive engagement of pallet to chairs Engineering design Restricted access Shaft tender, spotter and operator in attendance Table height interlock design Alignment system	2,3	4, 3
10) Transfer Conveyance Car Load onto the Waste Cage	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: WASTE HOIST

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
11) Waste Hoist	Waste Hoist Drop	Brake failure Cable failure	Potential loss of facilities Potential to lose waste emplacement capabilities Potential for personnel injury or fatality Potential to release radioactive material Potential to contaminate underground Potential unfiltered release Potential to release combustion products to the environment Potential to drop car into shaft Potential for fire Potential for explosion Potential to loss all electrical power in mine Potential to lose plant air line and air services Potential to lose underground air locks and lighting Potential to evacuate underground personnel Potential need to decontaminate the underground Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media attention Potential economic loss	Waste hoist is held by six ropes, each capable of holding load Catch gear in head frame to hold load Redundant brake systems available Four independent valve failures required to fail brakes Waste hoist design fails towards the "cage up" condition Controls are redundant Control system has elevation check mechanisms Maintenance procedures Maintenance program Weekly inspections Qualified personnel to operate NDT on ropes and bolts Acoustics emissions to check for fatigued parts Independent verification on shaft inspections by MSHA Vendor inspects annually Visual inspection of structural steel assemblies Preoperational checks before handling any loads including upper and lower limits and dump valves and backups are functioning Full power used to check the brakes 130 foot sump at bottom of shaft below mine level Other shafts available for egress Personnel underground trained in use of safety equipment Alternate source of power to the mine Exhaust filtration available Ventilation can be secured Gate and barriers established during hoist movement Plate out and depletion in mine Portable fire fighting equipment underground Transporter has built in fire suppression Rescue tools and equipment available Self rescuers available Underground has limited combustibles Brake system tested at maximum load and speed	3,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: WASTE HOIST

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
11) Waste Hoist	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
12) Overpack and Repair Room (OP&RR)	Failure to Prep the OP&RR	Operator error Equipment failure	Potential to stop OP&RR operations	Operator training and certification Procedures available to perform operation Spotters available during operation Maintenance programs Preventative maintenance programs		1, 3
12) Overpack and Repair Room (OP&RR)	Inability to Decontaminate OP&RR	Contaminated SWB or drums	Potential to increase personnel radiation exposure Potential to contaminate equipment and room Potential to lose contaminated equipment Potential to slow down operations Potential to grind top layer of contaminated concrete floor Potential economic loss	Operator training and certification Equipment design Procedure for lining the room prior to bringing in TRUPACT-II Enclosure designed with stainless steel walls and epoxy floors and taped seams Radiological practices to minimize the amount of equipment brought into room Briefings prior to use	1,2	2, 2
12) Overpack and Repair Room (OP&RR)	Transfer Failure From TRUDOCK to OP&RR	Operator error Equipment failure Air lock door failure TRUDOCK gates not operable Collision with another vehicle	Potential to drop load Potential to rupture drum Potential for personnel injury or fatality Potential to release radioactive material Potential to spread contamination Potential need to decontaminate area Potential for personnel radiation exposure Potential to delay operations Potential for fire Potential for explosion Potential off site release Potential to release combustion products to the environment Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential economic loss	Operator training and certification Maintenance procedures Spotters used during transit of TRUPACT-II Preventative maintenance program Procedures available to perform this operation Preoperational checks of equipment prior to use Adequate lighting available in area TRUPACT-II design WHB has fire suppression systems, fire extinguishers and hose stations Emergency response team Limited combustibles in area	2,3	4, 3
12) Overpack and Repair Room (OP&RR)	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
13) Removal of ICV Lid, Slip Sheets, and Drums	Failure to Remove ICV Lid	Equipment failure Operator error	Potential to delay operations	Operator training and certification Health physics training and certification		1, 3
13) Removal of ICV Lid, Slip Sheets, and Drums	Failure to Remove Pay Load	Operator error Mechanical or electrical failure Cable failure	Potential to damage ICV lid Potential to damage TRUPACT-II Potential to damage waste drums Potential to release radioactive material Potential for fire Potential for explosion Potential to spread contamination outside the decontamination enclosure Potential need to decontaminate area Potential for personnel injury or fatality Potential inability to overpack	Generator ships waste in accordance to WAC Operator training and certification Fire suppression system available Two operators perform operations Air purification respirators available Special training for personnel to perform operations Dedicated ventilation and filtration available Decontamination room pressure below remainder of building to maintain containment of radiation TRUPACT-II design WHB has fire suppression systems, fire extinguishers and hose stations Emergency response team Limited combustibles in area	2,2	4, 2
13) Removal of ICV Lid, Slip Sheets, and Drums	Moving Accident With ICV Lid	Operator error Mechanical or electrical failure Cable failure	Potential to damage ICV lid Potential to damage TRUPACT-II Potential to damage waste drums Potential to release radioactive material Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to spread contamination outside the decontamination enclosure Potential for personnel radiation exposure Potential need to decontaminate area Potential inability to overpack Potential to release combustion products to the environment Potential environmental concern Potential economic loss	Generator ships waste in accordance to WAC Operator training and certification Fire suppression system available Two operators perform operations Air purification respirators available Special training for personnel to perform operations Dedicated ventilation and filtration available Decontamination room pressure below remainder of building to contain contamination WIPP lifting practices comply with the DOE Hoisting and Rigging regulations TRUPACT-II design WHB has fire suppression systems, fire extinguishers and hose stations Emergency response teams Limited combustibles	2,2	4, 2

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRANSPORTER

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
13) Removal of ICV Lid, Slip Sheets, and Drums	Moving Accident With Payload	Operator error Mechanical or electrical failure Rigging equipment failure	Potential to damage TRUPACT-II Potential to damage waste drums Potential to breech drum Potential to release radioactive material Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to spread contamination outside the decontamination enclosure Potential for personnel radiation exposure Potential need to decontaminate area Potential inability to overpack Potential to release combustion products to the environment Potential environmental concern Potential economic loss	Generator ships waste in accordance to WAC Operator training and certification Fire suppression system available Two operators perform operations Air purification respirators available Special training for personnel to perform operations Dedicated ventilation and filtration available Decontamination room pressure below remainder of building to contain contamination DOE rigging and load test program	2,2	4, 2
13) Removal of ICV Lid, Slip Sheets, and Drums	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: TRUPACT-II

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
14) Shielded Storage Room	Failure to Transfer Drums	Mechanical or electrical failure Operator error	Potential to drop the load Potential to rupture drum Potential for personnel injury or fatality Potential to release radioactive material Potential to spread contamination Potential need to decontaminate area Potential for personnel radiation exposure Potential to delay operations Potential for fire Potential for explosion Potential for off site release Potential to notify DOE, EPA, and State of environmental violation Potential for adverse media attention Potential to release combustion products to the environment Potential environmental concern Potential economic loss	Generator ships waste in accordance to WAC Procedures available to perform operations Operator training and certification Preventative maintenance on equipment Equipment is designed as fail safe Design of waste drums as DOT Class A container Seven packs are wrapped restricting free motion (containerized) preventing loss of drums Ventilation is designed to contain rad releases WHB has fire suppression systems, portable fire extinguishers and hose station available Emergency response team is on site WIPP lifting practices comply with DOE Hoisting and Rigging regulations	1,3	4, 3
14) Shielded Storage Room	Fire in Waste Container	Spontaneous combustion	Potential to spread fire and smoke through ventilation Potential to damage ventilation duct work Potential to lose negative pressure in Shielded Storage Room Potential to release radioactive material Potential for personnel radiation exposure Potential need to decontaminate area Potential for smoke to be released to the environment Potential for smoke to enter mine Potential for underground evacuation	Generator ships waste in accordance to WAC Room not occupied Fire detection system available Ventilation system continually vents air through HEPA filtration devices Fire suppression system available Construction of room has a 3 hr fire rating Alarm in CMS HEPA filtration designed not to ignite Double HEPA filtration (room and main exhaust filters) Procedures for compensatory fire protection measures Weekly inspection performed in room Periodic check of sprinklers and detectors Site emergency response team		2, 1
14) Shielded Storage Room	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: NATURAL EVENTS

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
15) Natural Events	Range Fire	Range fire	Potential to stop site operations Potential for smoke to enter the mine shaft Potential for underground evacuation Potential for smoke to enter facility buildings	CMS shuts down mine ventilation systems Interior buildings available for relocation of personnel Fire break installed Mutual aid agreements with the local communities for fire fighting assistance Emergency response team	0,4	2, 4
15) Natural Events	Seismic Event (Design Basis Event)	Earthquake	Potential to stop operations Potential to lose site utilities Potential to drop waste container Potential to rupture drum Potential to release radioactive material Potential to release combustion products to the environment Potential for personnel radiation exposure Potential for fire Potential for explosion Potential for personnel injury or fatality Potential to breach electrical switchgear or circuits Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential economic loss Potential for adverse media attention	Low probability of earthquake Building is designed for DBE Procedures in place to shutdown equipment Drum, SWB, and TRUPACT-II integrity Generator ships waste in accordance to WAC CH bay overhead crane is seismically qualified	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: NATURAL EVENTS

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
15) Natural Events	Tornado (Design Basis Event)	Tornado	Potential to stop operation Potential to lose site utilities Potential for personnel injury or fatality Potential for tornado driven missile through the WHB, impacting TRUPACT-II or waste container causing a breach Potential for fire Potential for explosion Potential to release radioactive material Potential to release combustion products to the environment Potential for radiation exposure Potential need to decontaminate area Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media exposure Potential economic loss	Waste Handling Building designed to withstand tornados Procedures in place to warn personnel to stay inside permanent buildings TRUPACT-II and waste containers confine material Procedures require shutdown of operations CMR operator monitors weather channel Generator ships waste in accordance to WAC	2,2	4, 2
15) Natural Events	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: EXTERNAL EVENTS

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
16) External Events	Aircraft Crashes Into WHB	Personnel error Equipment failure	Potential to lose Waste Handling Building Potential to breech TRUPACT-II Potential for fire Potential for personnel injury or fatality Potential to release radioactive material Potential for personnel radiation exposure Potential need to decontaminate area Potential to release combustion products to the environment Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media attention Potential economic loss	Physical location of site is remote Air space above facility is not part of normal flight patterns Restricted flight pattern within a 500 foot radius of site Generator ships waste in accordance to WAC	3,1	4, 1
16) External Events	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: ABNORMAL OPERATION

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
17) Abnormal Operation (Accident Status)	Cold Weather Nat'l Ventilation Pressure	Cold weather caused Natural Ventilation Pressure (NVP)	Potential to stop waste handling operations Potential to, in the event of an accident, spread airborne contamination to the environs Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt Potential for waste shaft hoist to fail	Operator qualification and certification Engineering designs Procedures Test and balance Shaft pressures are monitored at the CMR Alarms for pressure problems WIPP ventilation simulator used for guidance Underground ventilation remote monitoring control system (monitors air flows and d/p's and enable CMR operator to adjust dampers to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure) Isolation of mine splits Backup power available to operate fans for flow through the panel area		3, 1
17) Abnormal Operation (Accident Status)	Hot Weather Natural Ventilation Pressure	Hot weather caused Natural Ventilation Pressure (NVP)	Potential to leak radiation outside radiological controlled area Potential for personnel radiation exposure Potential to release radioactive material Potential need to decontaminate area Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media attention Potential to stop waste handling operations Potential to, in the event of an accident, spread airborne contamination to the environs Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt Potential for waste shaft hoist to fail	Operator training and certification Engineering design waste shaft hoist systems Preventative maintenance procedures Test and balance Monitoring at bulkhead 309 Bulkhead 309 redesign (recent) to pressurize the chamber between the walls of the 309 bulkhead using fans Procedures to maintain differential pressures in the mine WIPP ventilation simulator used for guidance Underground ventilation remote monitoring control system (monitors air flows and d/p's and enable CMR operator to adjust dampers to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure) Isolation of mine splits Backup power available to operate fans for flow through the panel area Alarms for pressure problems		3, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: ABNORMAL OPERATION

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
17) Abnormal Operation (Accident Status)	Loss of Fire Protection	Loss of power Loss of 180,000 gallon fire water storage tanks DBE tornado	Potential inability to fight fires Potential excessive loss of facility Potential for personnel injury or fatality Potential to release radioactive material Potential need to decontaminate area Potential to release combustion products to environment Potential to notify DOE, EPA, and State of environmental violation Potential environmental concern Potential for adverse media attention Potential economic loss	Design and construction of fire suppression Two on site fire water storage tanks containing 180,000 gallons (One storage tank capacity sufficient for DBF) Two fire pumps, one electrical and one diesel, available Limited amount of combustibles on site WHB fire design and compartmentized fire areas WHB segregated from other structures Emergency response fire fighting capability Fire truck and fire fighting equipment Assistance from surrounding communities All fire related systems, training, inspection, and testing are in accordance to NFPA and NEC regulations Two new fire trucks, to replace existing units,on order Procedures available for control of hot work Inspections and functional tests of system performed on a periodic basis Independent assessments by customer Fire detection systems available 24 hour battery backup for fire detection system available in Waste Handling Building	0,2	4, 2
17) Abnormal Operation (Accident Status)	Loss of HVAC systems	Loss of compressed air Loss of electrical power Operator error	Potential to stop operations Potential to release radioactive material Potential for personnel radiation exposure Potential for underground evacuation Potential need to decontaminate the facility	Redundant compressors available Backup diesel generator (2) power available for selected loads Operator training and certification Maintenance programs in place Preventative maintenance programs Adequate separation exists between alternate compressors	0,2	3, 2

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: ABNORMAL OPERATION

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
17) Abnormal Operation (Accident Status)	Loss of On Site-Communication	Excavation work Loss of site power loss of UPS Equipment malfunction RF interference Loss of telephone system causes loss of paging system	Potential to lose TRANSCOM Potential to lose control of an accident Potential to delay evacuation Potential inability to communicate for off site assistance Potential to lose meteorological data Potential to lose off site notification capability Potential inability to notify headquarters of an event	Preventative maintenance system checks Redundant and multiple means to communicate UPS systems available with backup battery power Microwave/ground line for off site communication Procedures in place for notification of casualties Emergency and security vehicles equipped for broadcast	0,1	4, 1
17) Abnormal Operation (Accident Status)	Loss of Power (localized) On Site	Operator error Equipment failure Excavation work External causes	Potential to release radioactive materials to environment Potential to contaminate mine Potential to shutdown operations Potential inability to control underground ventilation Potential for underground evacuation Potential need to decontaminate Potential to lose fire water Potential to lose lighting Potential to lose CMS indication	Multiple paths of routing power Operator training and certification Maintenance programs in place Preventative maintenance programs Thermography availability	0,2	3, 2
17) Abnormal Operation (Accident Status)	Loss of Utility Power	Interruption of electrical service	Potential to shutdown operations Potential inability to control underground ventilation Potential to release radioactive material Potential for underground evacuation Potential need to decontaminate surface and underground areas Potential to lose fire water Potential to lose lighting Potential to lose CMS indication	Backup diesel generator (2) power system available UPS available with backup battery for important loads Diesel fire pump available Operators trained to reconfigure power distribution to plant Alternate means to remove personnel (secondary egress) from mine	0,2	3, 2
17) Abnormal Operation (Accident Status)	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
18) Waste Transfer Cage to Transporter	Transporter Failure	Transporter mechanical or electrical defect	Potential inability to start transporter Potential inability to unload cage Potential to tie up the shaft Potential to slow down operations	A backup transporter is available Preoperational checks Monthly preventative maintenance schedules	0,4	1, 4
18) Waste Transfer Cage to Transporter	Transporter Fire	Injector line breaks spraying diesel fuel onto exhaust Hydraulic system failure Brakes overheating	Potential for diesel engine fire on transporter Potential to slow down operations Potential to shutdown operations Potential for underground evacuation Potential for personnel injury or fatality Potential for heat damage to slip sheets Potential to melt bands holding waste containers onto pallet Potential for recovery operation Potential environmental concern Potential to damage waste container Potential to release Transuranic (TRU) waste material from waste container to environment Potential for airborne contamination Potential for personnel radiation exposure Potential for surface contamination Potential need to decontaminate surface and underground areas Potential for heat radiation into waste container and increased VOC emissions Potential for adverse media attention Potential to weaken the drifts ceiling Potential to release combustion products to to the environment Potential economic loss	Fire suppression system with linear thermal detection capability available on transporter Dry chemical system to auto dump when activated from heat sensor Auto-manual operation of fire suppression system Inspection monthly by Emergency Service Tech (EST) Vendors check fire suppression equipment on periodic basis Operator training for fire scenarios Certification and qualification of operators Limited quantity of diesel fuel contained in transporter Portable fire extinguishers available Braided hydraulic lines (steel jacketed) Preoperational checks Quarterly inspections Fire resistant hydraulic fluid Minimal amount of combustibles in area Low sulphur fuel used Isolated ventilation path Periodic exhaust temperature checks Few sources of ignition Emergency response teams available Assembly areas with safety equipment WAC criteria Manual shift to HEPA filtered exhaust Operator training on fire scenarios	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
18) Waste Transfer Cage to Transporter	Transporter Mishaps	Operator inattentive in operating transporter Transporter mechanical defect	Potential to damage cage Potential to damage transporter Potential to push pallets through back of cage Potential to knock waste containers from facility pallet Potential to rupture waste containers Potential to release Transuranic (TRU) waste material from waste container to environment Potential for airborne contamination Potential for personnel radiation exposure Potential for underground evacuation Potential for surface contamination Potential for recovery operation Potential inability to transport waste Potential for personnel injury or fatality Potential for shutdown of operations Potential environmental concern Potential for spontaneous ignition Potential for explosion Potential for adverse media attention Potential to weaken the drifts ceiling Potential to release combustion products to the environment Potential economic loss	Qualified & Certified operators Preoperational procedures Whole operation proceduralized Spotter for operator Lock pins on opposite sides of facility pallets Transporter has a speed governer Distance to travel to cage is too short for transporter to pick up much speed Waste containers are secured to facility pallet Waste is above transporter to prevent ramming with transporter Cannot drive off cage with transporter WAC criteria Isolated ventilation path Fire suppression system with linear thermal detection system available on tranporter Dry chemical system to auto dump when activated from sensing system Auto-manual operation of fire suppression system Vendor checks fire suppression equipment on a periodic basis Operator training for fire scenarios Portable fire extinguishers available Manual shift to HBPA filtered exhaust Assembly areas with safety equipment	2,1	4, 1
18) Waste Transfer Cage to Transporter	Transporter Screw System Failure	Leak in transporter hydraulic screw system Metal fatigue	Potential to lose hydraulic fluid from the screw drive system Potential inability to operate screw drive system Potential inability to pull waste pallet onto transporter Potential to tie-up waste transfer cage Potential to slow down operations Potential to shutdown operations Potential need to readjust pallet on platform or transporter Potential to recover pallet	Preventative maintenance Preoperational checks Operator training Backup transporter available		1, 3
18) Waste Transfer Cage to Transporter	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
19) Transport of Waste from Transfer Cage to Storage Room	Air Lock Failure (415 and 416)	Loss of air lock control	Potential for damper to fail open or closed Potential for ventilation deficiencies Potential for lower differential pressure in mine Potential to shutdown operations	Preventative maintenance performed on a periodic basis Preoperational checks before handling waste Ventilation fan line up Surveillance Bulkhead design is fail-as-is	0,4	1, 4
19) Transport of Waste from Transfer Cage to Storage Room	Hold-down Failure (7 drum & SWB)	Mechanical failure Operator error Uneven loading Tie-down failure for 7 pack Z clamp failure for SWB	Potential to damage waste containers Potential for fire Potential to release Transuranic (TRU) waste materials from waste containers to the environment Potential to release combustion products to the environment Potential for personnel radiation exposure Potential for surface contamination Potential for recovery operation Potential for underground evacuation Potential environmental concern Potential to shutdown operations Potential for adverse media attention Potential for personnel injury or fatality Potential economic loss	Per procedure, operators are trained to inspect tie downs prior to transporting waste pallets Slow travel speed Emergency response teams available Safety training Assembly areas with safety equipment WAC criteria CMR operator initiated shift to HEPA filtered exhaust	2,1	4, 1
19) Transport of Waste from Transfer Cage to Storage Room	Loss of Electrical Power	Loss of site commercial power	Potential to lose ventilation fans Potential to lose ventilation Potential to shutdown operations Potential to evacuate underground personnel	Diesel generators (2) available for standby power UPS backup on all CAMs that initiate mine filtration to ensure radiation monitoring capabilities Isolated ventilation path	0,4	1, 4
19) Transport of Waste from Transfer Cage to Storage Room	Loss of Plant Air	Plant air compressor mechanical or electrical defect	Potential inability to supply plant air to bulkhead pneumatic cylinders Potential inability to automatically operate bulkhead doors Potential to slow down operations	Doors can be manually operated Preventative maintenance Facility operations surveillance Preoperational checks Backup compressor available Ability to isolate and use portable compressors		1, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
19) Transport of Waste from Transfer Cage to Storage Room	Loss of Ventilation Fans	Mechanical or electrical failure	Potential to lose ventilation Potential to lose containment Potential disruption of operations Potential for underground work stoppage Potential for underground evacuation	Preventative maintenance performed on a periodic basis Backup ventilation fans available Dampers set to fail in a safe operational mode Selective configuration control to pull air where needed Periodic inspections of fans Vibration monitors available on the two larger sized ventilation fans and alarmed to CMR	0,4	1, 4
19) Transport of Waste from Transfer Cage to Storage Room	Vehicular Collision	Operator inattentive in operating transporter Transporter mechanical defect	Potential for collision with another vehicle, bulkhead, personnel, or high voltage equipment Potential to damage vehicle Potential to spill battery acid/oil Potential to shutdown operations Potential for fire Potential for personnel injury or fatality Potential damage to waste containers Potential to release Transuranic (TRU) waste material from waste containers to environment Potential for personnel radiation exposure Potential for surface contamination Potential for recovery operation Potential to damage bulkhead Potential to weaken drifts ceiling Potential to shutdown diesel activities Potential to release combustion products to the environment Potential for underground evacuation Potential to upset differential pressure Potential environmental concern Potential for adverse media attention Potential for credibility damage Potential economic loss	Certification & Qualification of operators in vehicles use Pallets securely fixed to transporter Conduct of operations Safety procedures in place Major intersections have stop signs Limited access to bulkheads in planned path of transporters Access to area is restricted during waste handling operations Lighted intersections Mine operations are closely supervised WAC criteria Portable fire extinguishers available Minimal amount of combustibles in area Isolated ventilation path CMR operator initiated shift to HEPA filtered exhaust	2,1	4, 1
19) Transport of Waste from Transfer Cage to Storage Room	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
20) Storage Room Waste Handling Operations	Diesel Fire in Unloading Area	Injector line breaks spraying diesel fuel onto exhaust	Potential for diesel engine fire on transporter Potential to slow down operations Potential to shutdown operations Potential for underground evacuation Potential for personnel injury or fatality Potential for heat damage to slip sheets Potential to melt bands holding waste containers on pallet Potential to rupture waste containers Potential to release Transuranic (TRU) waste material from waste drums to the environment Potential for airborne contamination Potential for personnel radiation exposure Potential for recovery operation Potential to release combustion products to the environment Potential environmental concern Potential for heat concentration due to ventilation Potential to weaken the drifts ceiling Potential for adverse media attention Potential economic loss	Fire suppression system with linear thermal detection capability available on transporter Dry chemical system to auto dump when activated from heat sensor Auto-manual operation of fire suppression system Inspection monthly by Emergency Service Tech (EST) Vendors check fire suppression equipment on periodic basis Operator training for fire scenarios Certification and qualification of operators Limited quantity of diesel fuel contained in transporter Portable fire extinguishers available Braided hydraulic lines (steel jacketed) Pre operational checks Quarterly inspections Fire resistant hydraulic fluid Minimal amount of combustibles in the area Low sulphur fuel used Isolated ventilation path Periodic exhaust temperature checks Few sources of ignition Emergency response teams available Safety training Assembly areas with safety equipment Manual shift to HEPA filtered exhaust WAC criteria	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
20) Storage Room Waste Handling Operations	Fork Lift Accident	Operator inattentive in fork lift operation Fork lift mechanical failure	Potential to ram fork lift into stacked waste containers Potential to puncture waste containers with BRUDI lift fixture Potential to dislodge waste containers from facility pallet Potential to exceed waste container safe drop height Potential to release Transuranic (TRU) waste material from waste containers to environment Potential for airborne contamination Potential for personnel radiation exposure Potential for underground evacuation Potential for surface contamination Potential for recovery operation Potential inability to transport waste Potential for shutdown of operations Potential environmental concern Potential for personnel injury or fatality Potential for fire Potential for explosion Potential for adverse media attention Potential to weaken the drifts ceiling Potential to release combustion products to the environment Potential economic loss	Certification & Qualification of operators in operation of fork lifts Operator training Procedures in place Preventative maintenance performed on periodic basis on fork lift Spotter available during operations Preoperational checks prior to handling waste drums Emergency assembly areas available with safety equipment CMR operator initiated shift of HEPA exhaust filtration available Design of the BRUDI Design of the SWB handling fixture Electric fork lift limits speed Area lighting available during placement Health Physics available during placement Established ventilation flows during placement Boundaries established for radioactive materials Fire suppression system with linear thermal detection available Dry chemical system available Auto-manual operation of fire suppression system available Vendors check fire suppression system periodically Operator training for fire scenarios Portable fire extinguishers available Emergency response teams available Safety training	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
20) Storage Room Waste Handling Operations	Fork Lift Failure	Fork lift electrical or mechanical defect Hydraulic leak in lifting mechanism	Potential inability to start fork lift Potential to lose hydraulic fluid Potential to lose lifting capability Potential inability to unload transporter and stack waste containers Potential to lose hydraulic power when placing waste containers on stack Potential for waste containers to be hung up partially between fork lift and stack Potential to recover partially stacked waste containers Potential to slow down operations	Fork lift capable of controlled manual lowering Backup fork lift available Preventative maintenance Preoperational checks per shift Hydraulic controls return-to-neutral when released		1, 3
20) Storage Room Waste Handling Operations	Transporter Mishap	Operator error Transporter mechanical failure	Potential to drive transporter into stacked waste drums Potential to knock waste containers off of stack Potential to damage waste containers Potential to release Transuranic (TRU) waste material from waste drums to the environment Potential for airborne contamination Potential for personnel radiation exposure Potential for underground evacuation Potential for surface contamination Potential for recovery operation Potential inability to transport waste Potential to shutdown operations Potential environmental concern Potential to reduce ventilation Potential to shift ventilation filtration modes	Operator training Qualification & Certification Procedures in place Transporter keeps its distance to previously stacked drums Spotter used when backing transporter Preventative maintenance WAC criteria Preoperational checks Manual shift to HEPA filtered exhaust	2,1	4, 1
20) Storage Room Waste Handling Operations	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
21) Refueling Activities	Refueling Vehicle Mishap	Tank leakage or spill Hose break during refueling Isolation valve inadvertently opened or leaking	Potential to release diesel fuel to environment Potential for fire Potential for personnel injury or fatality Potential for underground evacuation Potential to shutdown operations Potential environmental concern Potential for adverse media attention Potential to weaken the drifts ceiling Potential to release combustion products to the environment Potential economic loss	Fuel dispensing is controlled by procedures All fuel tanks have bladders Fire suppression systems on all waste handling equipment Portable fire extinguishers on all vehicles Service vehicles have spill mitigation apparatus Training of personnel to dispense fuel Emergency response teams available Safety training Assembly areas with safety equipment WAC criteria	0,1	4, 1
21) Refueling Activities	All Other Deviations		NAHI			
22) Storage Room	Failure and Fallout of Roof Bolt	Bolt strength exceeded	Potential for personnel injury or fatality Potential to shutdown operations Potential to damage equipment Potential for adverse media attention	Low frequency of occurrence Daily inspections Protective equipment worn by underground personnel includes hard hats Area covered by mesh	0,3	4, 3
22) Storage Room	Floor Distortion	Floor failure due to heaves and buckles Normal traffic	Potential to slow down operations Potential to reconstitute floor Potential to stick fork lift in floor drop area especially along edges Potential need to pull fork lift free Potential to drop load Potential to damage waste container Potential to rupture waste container Potential to release Transuranic (TRU) waste from waste containers to the environment Potential for airborne contamination Potential for personnel radiation exposure Potential for surface contamination Potential for recovery operation Potential inability to transfer waste Potential environmental concern	Floor surveyed and prepared before filling room Waste handling supervisor performs periodic inspections of storage room Procedure exists for performing room inspections MSHA inspections WAC criteria CMR operator initiated shift to HEPA filtered exhaust Established ventilation flows during waste emplacement	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
22) Storage Room	Roof Collapse During Emplacement	Deterioration of roof	Potential to damage waste containers Potential to release Transuranic (TRU) waste material from waste containers to environment Potential for airborne contamination Potential for personnel radiation exposure Potential for underground evacuation Potential for recovery operation Potential for shutdown of operations Potential environmental concern Potential to lose storage room or panel Potential for personnel injury or fatality Potential to damage equipment Potential for radiological release Potential to lose project credibility Potential to release combustion products to the environment Potential for adverse media attention Potential economic loss	Predictive monitoring program Per procedure, rooms are checked before any drums are received and immediately prior to drum storage Instrumented and monitored extensively per DOE and external organization assessments and regulations Support systems specifically designed to handle conditions expected and may be instrumented and tied into monitoring and analysis Mine Safety and Health (MSHA) require shiftly work place inspections Bimonthly visual and instrument inspections and assessments Annual ground control plan and long term 5 year ground control plan All inspection plans are rolled over Inspections performed on a shift by shift basis Room closure on a room-by-room basis CMR operator initiated shift to HEPA filtered exhaust	2,3	4, 3
22) Storage Room	All Other Deviations		NAHI			
23) Life of Facility Area	Failure and Fallout of Roof Bolt	Bolt strength exceeded	Potential for personnel injury or fatality Potential to shutdown operations Potential to damage equipment Potential for adverse media attention	Low frequency of occurrence Daily inspections Protective equipment worn by underground personnel include hard hats Area covered by mesh	0,3	2, 3

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
23) Life of Facility Area	Floor Distortion	Floor failure due to heaves and buckles Normal traffic	Potential to slow down operations Potential to reconstitute floor Potential to stick fork lift in floor drop area especially along edges Potential need to pull fork lift free Potential to damage waste container Potential to rupture waste container Potential to release Transuranic (TRU) waste from waste container to the environment Potential for airborne contamination Potential for personnel radiation exposure Potential for surface contamination Potential for recovery operation Potential inability to transfer waste Potential environmental concern	Floor surveyed periodically Drift inspections are performed periodically MSHA inspections WAC criteria Established ventilation flows during waste emplacement CMR operator initiated shift to HEPA filtered exhaust	2,3	2, 3
23) Life of Facility Area	Roof Collapse Life of Facility	Deterioration of roof outside the storage area	Potential to damage waste containers Potential to release Transuranic (TRU) waste material from waste containers to environment Potential for airborne contamination Potential for personnel radiation exposure Potential for underground evacuation Potential for recovery operation Potential for shutdown of operations Potential environmental concern Potential to lose facility areas Potential to lose egress Potential for personnel injury or fatality Potential to damage equipment Potential for radiological release Potential to lose project credibility Potential for adverse media attention Potential economic loss	Instrumented and monitored extensively per DOE and external organization assessments and regulations Support systems specifically designed to handle conditions expected and will be instrumented and tied into monitoring and analysis (MSHA) require weekly inspections Bimonthly visual and instrument inspections and assessments Annual ground control plan and long term 5 year ground control plan All inspection plans are rolled over Inspections performed on a shift by shift basis Accessibility for maintenance CMR operator initiated shift to HEPA filtered exhaust WAC criteria Emergency response teams available Assembly areas with safety equipment	2,2	4, 2
23) Life of Facility Area	All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
24) Waste Criteria	Excessive H2 Emissions	Generation of Hydrogen gas from drummed Transuranic (TRU) waste material exceeds expected values	Potential to exceed VOC emission thresholds per RCRA/NMD Potential environmental concern Potential to violate permit Potential to receive fines and criminal penalties for violating permit Potential to lose permit Potential for fire Potential for explosion Potential to release radioactive material Potential to release combustion products to the environment Potential for personnel injury or fatality Potential for recovery operation Potential for underground evacuation Potential for adverse media attention	Ventilation available MSHA regulations followed WAC limits Operator safety training Certification and qualification of operators Portable fire extinguishers available Separate ventilation exhaust path Emergency response teams available Assembly areas with safety equipment CMR operator initiated shift to HEPA filtered exhaust	2,1	4, 1
24) Waste Criteria	All Other Deviations		NAHI			
25) Natural Events Underground	Earthquake	Earthquake occurrence	Potential to lose electrical power Potential to lose ventilation fans Potential for sensitive instrumentation to fail Potential for underground evacuation Potential to shutdown operations Potential ground fall Potential for personnel injury or fatality Potential to flood mine Potential to rupture waste containers Potential for fire Potential for explosion Potential release of radioactive material Potential for personnel radiation exposure Potential for recovery operation Potential for surface contamination Potential for airborne contamination Potential for adverse media attention Potential to release combustion products to the environment Potential economic loss	Site was selected because of low seismic conditions Regional seismic activities monitored Diesel generators available for standby power UPS systems available for radiation monitoring Shaft collars are sealed Drift ceilings support system Miner training and evacuation training Facility designed for DBE	2,1	4, 1

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
25) Natural Events Underground	Natural Disaster - Tornado	Tornado occurrence	Potential to lose site power Potential to lose ventilation fans Potential to lose ventilation Potential for underground evacuation Potential to shutdown operations Potential for adverse media attention	Diesel generators (2) available for standby power UPS system available for radiation monitoring Multiple ventilation fans available CMR monitors weather conditions Diesel powered hoist and bullet for personnel egress from the mine Mutual agreement with other mines for assistance WHB designed for DBT Multiple egress paths available from the mine	0,2	3, 2
25) Natural Events Underground	_All Other Deviations		NAHI			
26) UPS System, Electric Carts	UPS & Electric Cart Charging Mishaps	Overcharge of electrical battery Electrical contact sparking	Potential to buildup hydrogen in battery Potential to release H2 from battery to the environment Potential for explosion Potential for personnel injury or fatality Potential for fire Potential for release of combustion products to the environment Potential for recovery operation Potential for underground evacuation Potential for adverse media attention Potential economic loss	Preventative Maintenance Procedures UPS batteries are factory sealed and contain pressure reliefs Ventilation system dilutes hydrogen concentration UPS are enclosed units Cart operator training Portable fire extinguishers on all carts	0,2	4, 2
26) UPS System, Electric Carts	_All Other Deviations		NAHI			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
27) Drum Fire	Drum Fire	Spontaneous ignition in a waste container due to corrosion, chemical breakdown, anaerobic decomposition or pyrophoric interaction	Potential for fire in waste shaft station Potential to lose waste shaft station Potential for fire in storage room Potential to damage waste containers Potential to release Transuranic (TRU) waste material from waste containers to the environment Potential to release combustion products to the environment Potential to shutdown operations Potential for personnel radiation exposure Potential for surface contamination Potential ingestion of radioactive material Potential for underground evacuation Potential for recovery operation Potential for explosion Potential for adverse media attention Potential environmental concern Potential economic loss	Waste Acceptance Criteria No propagation expected Environment is stable	3,3	4, 3
27) Drum Fire	All Other Deviations		NAHI			
28) Storage Room Completion	Changes to Lighting & Air Services	Operator inattentive while disconnecting temporary lighting Operator inattentive while working with ladder Temporary lighting or ladder equipment failure	Potential for personnel injury or fatality Potential to damage equipment Potential to slow down or stop operations Potential for adverse media attention	Maintenance operations proceduralized or controlled Equipment inspections Equipment design Operator and electrician training Electricians disconnect temporary lighting	0,2	4, 2
28) Storage Room Completion	All Other Deviations		NAHI			
29) Room Finalization Proceed to the Next Room	Industrial Accident	Maintaining one room while emplacing waste in an adjoining room	Potential to generate dust Potential to damage cams Potential to increase maintenance Potential to slow down operations Potential to setoff false alarms Potential for personnel injury or fatality Potential for adverse media attention	Established procedures for ground control Operator training and certification Ventilation system design Ventilation system operating procedures	0,2	4, 2

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

HAZOP SESSION SUMMARY TABLE

SYSTEM/VESSEL: CH TRU Waste Handling System

Node or Line #	Deviation/ Guide Word	Possible Cause (Scenario)	Potential Hazard or Operability Consequences	Existing Safeguards	* Hazard Rank	* Total Rank
29) Room Finalization Proceed to the Next Room	_All Other Deviations		NAHI			
30) External Events	External Events		No Hazards Identified			

* The first number indicates consequence, and the second indicates the relative probability.

NAHI - No Additional Hazards Identified

APPENDIX - D
Determination of Frequencies for Selected Accidents

CH1 SPONTANEOUS IGNITION (DRUM) IN THE WHB

The HAZOP for CH TRU Waste Handling System[1] qualitatively ranked the likelihood of a spontaneous ignition as Unlikely (Unlikely $10^{-2} \geq p > 10^{-4}$). DOE/WIPP 91-018,[2] Position Paper on Flammability Concerns Associated with TRU Waste Destined for WIPP summarized the scenario as an "extremely unlikely event".

To calculate the scenario probability the fault tree modeling used in DOE\WIPP 87-005, Waste Drum Fire Propagation at the WIPP[3] was applied with updated data and assumptions. The following updated data sets were used:

- According to CAO-94-1005, Revision 1,"WIPP Transuranic Waste Baseline Inventory Report,"[4] 7.3E 04 m^3 (2.58E 06 ft^3) of transuranic waste exists in storage today which has been accumulating since 1970. It is also assumed that the disposal phase will last 35 years.

- No credit is taken for a 50/50 mixture of drums and standard waste boxes.

- Eight incidents are assumed to have occurred since 1970 rather than one. This is based on a summary by the Environmental Evaluation Group (EEG) in the Office of Nuclear Safety - Safety Notice Issue No. 93-1.[5]

- To obtain the average waste volume population since 1970 the volume was multiplied by 12.5 years. (25 yrs* ½)

- To obtain the CH volume of waste to be shipped to WIPP, the RH volume of waste was subtracted from the total volume. (6.2E+06ft^3-2.5E+05ft^3)

- Based on DOE\WIPP 87-005, Waste Drum Fire Propagation at the WIPP[3], calculations indicate that panels will be filled approximately every 2.4 years, however it was conservatively assumed that the panel would be closed after five-years. A factor of ½ is applied to the 5 years to average the panel contents over the emplacement period since rooms start empty and are filled at the end of the time period. (5 * ½)

- DOE\WIPP 87-005, Waste Drum Fire Propagation at the WIPP[3], the probability of the spontaneous ignition was determined to be conservative by a factor of 10. Therefore, these calculations also apply the factor of ten to remove the conservatism.

Using this fault tree modeling the annual probability of a sustained fire in a CH TRU waste container is 6.2E-5 with an annual spontaneous ignition frequency of 1.47E-2. In summary, a waste container fire accident is analyzed to be credible and classified as "extremely unlikely" ($10^{-4} \geq p > 10^{-6}$) instead of "unlikely" as conservatively determined by the HAZOP.

Calculation:

P(A) = P(1) x P(B) x P(2) (1)

where:

P(A) = Probability of a sustained fire

P(1) = Probability of spontaneous ignition {DOE\WIPP 87-005, page 39}

P(2) = Probability of spontaneous ignition has adequate heat of combustion = 1.0 {DOE\WIPP 87-005, page 18}

P(B) = Probability of sufficient oxidant being available = 4.2E-3 {DOE\WIPP 87-005, page 39}

$$P(1) = \frac{NUMBER\ OF\ FIRES}{VOLUME\ YRS\ (ALL\ SITES)} * \frac{VOLUME\ YRS\ (AT\ WIPP)}{YR}$$

$$P(1) = \frac{8\ FIRES}{7.3E{+}04M^3 * 25YRS * \frac{1}{2}} * \frac{(6.2E{+}06FT^3 - 250{,}000FT^3) * \frac{M^3}{35.314FT^3} * \frac{1}{2} * 5YEARS}{35\ YEARS}$$

$$P(1) = \frac{8}{7.3E4M^3 * 12.5YEARS} * \frac{1.20E4M^3}{YR}\ YEARS = \frac{1.06E{-}1}{YR}$$

$$P(1)(.1) = \frac{1.06E{-}2}{YR}$$

$$P(A) = \frac{1.06E{-}2}{YR} * 4.2E{-}3 * 1$$

$$P(A) = \frac{4.4E{-}5}{YR}$$

CH2 CRANE FAILURE IN THE WHB

No historical information exists for crane drop accidents at the WIPP therefore, other sites with similar operations were reviewed to determine reasonable estimates of crane drop probability. This review was necessary to substantiate the estimated probability of occurrence (Unlikely $10^{-2} \geq p > 10^{-4}$) performed in the HAZOP for the CH TRU Waste Handling Process.[1] A logic model is used to describe combinations of failures that can produce a specific failure of interest (TOP event). Basic Events provide specific component failure or human error data which provide input to the logic model to determine the probability of the TOP event. Logical AND (*) or OR (+) funtions (gates) are used to show how events can combine to cause the TOP event. The probability of the crane drop is estimated considering two Basic Events; 1) human error, and 2) equipment failure. The annual probability of the crane drop is calculated using the following equation:

$$P(A)_{CRANE\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \qquad (2)$$

Savannah River Site has established a Human Error Data Base for Nonreactor Nuclear Facilities (Savannah River Site Human Error Data Base Development for Nonreactor Nuclear Facilities, WSRC-TR-93-581).[6] The human error probabilities were based solely on generic models developed from industry literature. Results of the generic models for crane drops of load were established based on an operation, where operation is defined as a lift, move, and setting down of a load. For the crane drops a high case, nominal case, and low case are given, however, for this case analysis the low case for the human error probability (1.5 E-5/operation) is used to represent the probability of dropping the load from the crane during waste handling at the WIPP. This selection is based on the following:

- Standardized load
- Proceduralized process
- Spotters present
- Highly trained personnel

Equipment failure which results in a waste container being dropped during overhead crane operation has been based on INEL-94/0226, *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*.[7] The probability of a load drop per lift reported in the reference above is 2.7E-05 which 23% of the drops were attributed to equipment failure, therefore, the probability of a load drop per lift from equipment failure is 6.2E-06.

The annual probability of waste container drops from crane operations due to human error and equipment failure is calculated based on the throughput provided in Chapter 4, Table 4.3-2 of the SAR. This information is used to determine the frequency of crane operations expected at the WIPP. Based on current design of the Waste Handling Building two overhead cranes are available for unloading the waste containers from the TRUPACT IIs, therefore, the throughput data will be divided by two to properly estimate the probability of a drop of waste containers from each of the cranes.

Human error probability assumptions:

810 Shipment/Yr
Throughput assumed to be handled by 2 cranes (throughput *50%)
3 TRUPACT II/Shipment
1 Operation/TRUPACT II (during a lift the drums are assumed to be in 2-seven drum arrays or two SWBs)
Human errors involving crane drops =1.5 E-5/operation

$$P(1)_{HUMAN} = \frac{810\ Shipment}{Yr} * \frac{1}{2} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ Operation}{TRUPACT\ II} * \frac{1.5E-05\ Drops}{Operation} = \frac{0.018\ Drops}{Yr}$$

Equipment failure probability assumptions:

810 Shipment/Yr.
Throughput assumed to be handled by 2 cranes (throughput *50%)
3 TRUPACT II/Shipment
1 Operation/TRUPACT II(during a lift the drums are assumed to be in 2-seven drum arrays or two SWBs)
Equipment (crane) failure 2.7E-05drops/operation
23% of the drops were attributed to equipment failure (2.7E-05*.23=6.2E-06 Drops/Operation)
For conservatism the annual probability estimate assumes 100% of the waste containers that are assumed to drop are breached.

$$P(2)_{EQUIPMENT} = \frac{810\ Shipment}{Yr} * \frac{1}{2} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ Operation}{TRUPACT\ II} * \frac{6.2E-06\ Drops}{Operation} = \frac{0.008\ Drop}{Yr}$$

Considering the probabilities of the two basic events (human error and equipment failure)and 1/3 of the time the load is assumed to be in position which the height of the load is greater than 4 ft, the annual probability of the crane drop is estimated from equation (2) as follows:

$$P(A)_{CRANE\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \qquad (2)$$

$$P(A)_{CRANE\ DROP} = \left(\frac{0.018\ Drops}{Yr} + \frac{0.008\ Drops}{Yr}\right) * \frac{1}{3}$$

$$P(A)_{CRANE\ DROP} = \frac{0.0086\ Drops}{Yr}$$

This calculation supports the annual probability of a crane dropping the load in the WHB to be in the Unlikely range (Unlikely $10^{-2} \geq p > 10^{-4}$) as estimated in the HAZOP.

CH3 PUNCTURE AND DROP OF WASTE CONTAINERS BY FORK LIFT IN THE WHB

No historical information exist for drum handling accidents at the WIPP therefore other sites with similar operations were reviewed to determine reasonable estimates of drum puncture probability. This review was necessary to tune the estimated probability of occurrence (Unlikely $10^{-2} \geq p > 10^{-4}$) performed in the HAZOP for the CH TRU Waste Handling process.[1] The probability of a puncture and a drop of waste containers is estimated considering four basic events; human error, and equipment failure involving punctures from a forklift; and, human error, and equipment failure involving dropping a load with a forklift. A logic model is used to describe combinations of failures that can produce a specific failure of interest (TOP event). Basic Events provide specific component failure or human error data which provide input to the logic model to determine the probability of the TOP event. Logical AND (*) or OR (+) funtions (gates) are used to show how events can combine to cause the TOP event. The annual probability of the puncture and the drop combining these basic events is calculated using the following equation:

$$P(A)_{Puncture\text{-}Drop} = P(B)_{Puncture} * P(C)_{Drop} \tag{3}$$

$$P(A)_{Puncture\text{-}Drop} = (P(1)_{HUMAN} + P(2)_{EQUIPMENT})_{PUNCTURE} * (P(3)_{HUMAN} + P(4)_{EQUIPMENT})_{DROP}$$

Savannah River Site has established a Human Error Data Base for Nonreactor Nuclear Facilities (Savannah River Site Human Error Data Base Development for Nonreactor Nuclear Facilities, WSRC-TR-93-581).[6] These human error probabilities were based solely on generic models developed from industry literature. Results of the generic models for punctures and drops of a load when using a forklift were established based on an operation, where an operation was defined as a lift, move, and setting down of a load. For each case (punctures and drops) a nominal case, high case and the low case are given, however, for this analysis the low case of 1.0E-05/operation is used to represent the frequency of puncturing the load and the low case of 1.0E-04/operation is used to represent the frequency of dropping the load during waste handling at the WIPP. This selection is based on the following:

- Standardized load
- Proceduralized process
- Spotters present
- Highly trained and certified personnel

Equipment failure which results in a waste container being punctured or dropped during forklift operations has been based on INEL-94/0226, *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*.[7] The annual probability of a puncture or drop from a forklift due to equipment failure reported in the reference above is 1.3E-02 and 4.3E-03, respectively.

To determine the annual probability of a puncture or drop from a forklift due to human error, the frequency of forklift operations expected at the WIPP is used to estimate number of occurrences. The number of forklift operations is estimated by using data on throughput provided in Chapter 4, Table 4.3-2 of the SAR. Based on current design of the Waste Handling Building two TRUDOCKs each with a forklift are available for unloading the waste containers from the TRUPACT IIs, therefore, the throughput data will be divided by two to properly estimate the frequency of a puncture and drop from human error of waste containers due to forklift operations.

Human error annual probability assumptions:

810 Shipment/Yr.
Throughput assumed to be handled by 2 forklifts (throughput *50%)
3 TRUPACT II/Shipment
1 Operation/2 TRUPACT IIs (The assumed drum load of the facility pallet is two stacks of 2-seven drum arrays each or two stacks of 2 SWBs each.
Human errors resulting in punctures involving forklifts =1.0E-5/operation
Human errors resulting in dropping a load involving a forklift = 1.0E-04/operation
For conservatism the annual probability estimate assumes 100% of the waste containers that are assumed to drop and impacted by forklift are breached.

$$P(1)_{HUMAN} = \frac{810\ Shipment}{Yr} * \frac{1}{2} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ Operation}{2\ TRUPACT\ II} * \frac{1.0E-05\ Punctures}{Operation} = \frac{0.006\ Punctures}{Yr}$$

$$P(3)_{HUMAN} = \frac{810\ Shipment}{Yr} * \frac{1}{2} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ Operation}{2TRUPACT\ II} * \frac{1.0E-04\ Drops}{Operation} = \frac{0.06\ Drops}{Yr}$$

Equipment failure annual probabilities (as reported in INEL-94/0226[7], *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*):

$$P(2)_{EQUIPMENT} = = \frac{0.013\ Punctures}{Yr}$$

$$P(4)_{EQUIPMENT} = \frac{0.0043\ Drops}{Yr}$$

Considering the probabilities of the two basic events (human error and equipment failure) the annual probability of the puncture and drop due to forklift operations is estimated from equation (4) as follows:

$$P(A)_{Puncture-Drop} = (P(1)_{HUMAN} + P(2)_{EQUIPMENT})_{PUNCTURE} * (P(3)_{HUMAN} + P(4)_{EQUIPMENT})_{DROP} \quad (4)$$

$$P(A)_{PUNCTURE-DROP} = (\frac{0.006\ Punctures}{Yr} + \frac{0.013\ Punctures}{Yr}) * (\frac{0.06\ Drops}{Yr} + \frac{0.0043\ Drops}{Yr})$$

$$P(A)_{PUNCTURE-DROP} = \frac{0.0012\ Puncture-Drops}{Yr}$$

This calculation supports the probability of a puncture and drop in the WHB to be in the Unlikely range (Unlikely $10^{-2} \geq p > 10^{-4}$).

CH4 DROP OF WASTE CONTAINER BY FORK LIFT IN THE WHB

No historical information exists for waste containers dropped from forklifts at the WIPP therefore, other sites with similar operations were reviewed to determine reasonable estimates of forklift drop probability. This review was necessary to substantiate the estimated probability of occurrence (Unlikely $10^{-2} \geq p > 10^{-4}$) performed in the HAZOP for the CH TRU Waste Handling Process.[1] The probability of waste containers dropped from a forklift is estimated considering two basic events 1) human error and 2) equipment failure. Basic Events provide specific component failure or human error data which provide input to the logic model to determine the probability of the event of interest (TOP event). Logical AND (*) or OR (+) funtions (gates) show how events can combine to cause the TOP event. The probability of a waste container drop by a forklift is calculated using the following equation:

$$P(A)_{FORKLIFT\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \tag{5}$$

Savannah River Site has established a Human Error Data Base for Nonreactor Nuclear Facilities (Savannah River Site Human Error Data Base Development for Nonreactor Nuclear Facilities, WSRC-TR-93-581).[6] These human error probabilities were based solely on generic models developed from industry literature. Results of the generic models for a drop load when using a forklift were established based on an operation, where an operation is defined as a lift, move, and setting down of a load. A nominal case, high case and the low case are given for dropped load when using a forklift, however, for this analysis the low case of 1.0E-04/operation is used to represent the frequency of dropping a load during waste handling at the WIPP. This assumption is based on the following:

- Standardized load
- Proceduralized process
- Spotters present
- Highly trained and certified personnel

Equipment failure which results in a waste container being dropped from forklift operations has been based on INEL-94/0226, *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*.[7] The annual probability of a load drop from forklift operations reported in the reference above is 4.3E-03/yr. This annual probability will be used in the determination of the annual probability of a waste container dropped due to equipment failure of a forklift during waste handling operations at the WIPP.

To determine the annual probability of a drop from a forklift due to human error, the frequency of forklift operations expected at the WIPP is used to estimate number of occurrences. The number of forklift operations is estimated by using data on throughput provided in Chapter 4, Table 4.3-2 of the SAR. Based on current design of the Waste Handling Building two TRUDOSKs each with a forklift are available for unloading the waste containers from the TRUPACT IIs, therefore, the throughput data will be divided by two to properly estimate the annual probability of a drop of waste containers from forklift operations due to human error.

Human error annual probability assumptions:

810 Shipment/Yr.
Throughput assumed to be handled by 2 forklifts (throughput *50%)
3 TRUPACT II/Shipment
1 Operation/2TRUPACT II (The assumed drum load of the facility pallet is two stacks of 2-seven drum arrays each or two stacks of 2 SWBs each.
Human errors involving forklift drops =1.0E-04/operation
For conservatism the annual probability estimate assumes 100% of the waste containers that are assumed to drop are breached.

$$P(1)_{HUMAN} = \frac{810\ Shipment}{Yr} * \frac{1}{2} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ Operation}{2\ TRUPACT\ II} * \frac{1.0E-04 Drops}{Operation} = \frac{0.06\ Drops}{Yr}$$

Equipment failure annual probability assumptions:

Equipment failure annual probabilities (as reported in INEL-94/0226, *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*):

$$P(2)_{EQUIPMENT} = \frac{0.0043\ Drops}{Yr}$$

Considering the probabilities of the two basic events (human error and equipment failure) the annual probability of the waste container drop from a forklift is estimated from equation (5) as follows:

$$P(A)_{FORKLIFT\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \tag{5}$$

$$P(A)_{DROP} = \frac{0.06\ Drops}{Yr} + \frac{0.0043 Drops}{Yr}$$

$$P(A)_{DROP} = \frac{0.064\ Drops}{Yr}$$

This calculation supports the determination of the annual probability of a drop of waste containers in the WHB from a forklift is in the Anticipated range (Anticipated $10^{-1} \geq p \geq 10^{-2}$).

CH5 WASTE HOIST FAILURE

Brake System Analysis-

WCAP-13800, "WIPP Waste Hoist Brake System Analysis"[9] provides a Fault Tree Analysis of the current design configuration of the brake system with updated component failure rates. The reported annual probability of failure of the revised design is 1.3E-07. This is also an incredible event per the criteria of DOE Standard 3009-94.[8]

Five dominant accidents were developed in WSTD-TME-063, Probability of a Catastrophic Waste Hoist Accident at the WIPP.[10] These scenarios involve a sequence in which a power loss occurs and both brake systems subsequently malfunction.

Since the annual failure probability of the brake system itself is of the order of 10^{-7}, the probability of occurrence of any waste hoist accident, which is the probability of the combined failures (Initiating event and brake failure), would contribute to the reduction of the combined probability to orders of magnitude below 10^{-7}. Accordingly, the probability of a waste hoist accident is at least several orders of magnitude below the 10^{-6} annual probability of occurrence, the threshold probability of occurrence below which an accident scenario is considered Not-Credible.

CH6 SEISMIC EVENT

This section develops the scenario initiating event probability assuming that the preventative and mitigative measures function as designed during the accident scenario.

As discussed in (1) Chapters 2 and 3 of the existing WIPP FSAR WP 02-9 and the FY-95 Annual Update DOE/WIPP-Draft-2065, (2) the Draft Project Technical Baseline for Regulatory Compliance WP 02-RC1,[11] and (3) Final Environmental Impact Statement DOE/EIS-0026,[12] UC-70,[13] the Design Basis Earthquake (DBE) is the most severe credible earthquake that could occur at the WIPP site. The DBE is based on a 1000-yr return interval established through a site specific study. The maximum ground acceleration for the DBE is 0.1 g in both the horizontal and vertical directions, with 10 maximum stress cycles.

CH7 SPONTANEOUS IGNITION (DRUM) IN THE UNDERGROUND

The HAZOP for CH TRU Waste Handling System[1] ranked the likelihood of a spontaneous ignition as "Unlikely" ($10^{-2} \geq p > 10^{-4}$). To date no events resulting in spontaneous ignition of CH TRU-waste have occurred. Based on historical DOE operation and DOE/WIPP 91-018,[2] Position Paper on Flammability Concerns Associated with TRU Waste Destined for WIPP, this is an incredible event. However, in support of the defense in depth philosophy, a spontaneous ignition accident is conservatively postulated to occur. See CH1 for the calculations for the annual probability of a spontaneous ignition.

CH8 AIRCRAFT CRASH

This section develops the scenario initiating event probability assuming that the preventative and mitigative measures discussed below function as designed during the accident scenario.

- Air space share facility not part of normal flight patterns
- Remote location

Using NUREG-800,[14] the total aircraft hazard probability (combined airway, airport, and military designated airspace operations probability of an aircraft crash) is calculated as follows:

(1) Airport Operations

The Standard Review Plan (SRP) criteria state that if the number of annual operations is less than $1000d^2$, where d is the distance from the facility to the airport (d>10 mi) then the frequency of air crashes is assumed to be 1×10^{-7}/yr (considered to be the general frequency of aircraft crashes from airports and federal airways). The closest commercial airport to the WIPP site is in Carlsbad, NM, at a distance of 28 miles. Therefore, applying the SRP criteria, the minimum frequency of operations yields:

$$1000d^2 = 1000\ (28\ \text{mi})^2 = 784{,}000$$

This is well above the number of operations at the Carlsbad airport. Therefore, a frequency of 1×10^{-7}/yr is assigned for aircraft crashes into the WIPP WHB as a result of airport operations.

(2) Airways

The SRP provides a method to estimate the frequency of aircraft crashes due to activity along airways as follows:

$P_{fa} = C \times N \times A/w$

C = in-flight crash rate
N = number of flights per year along airway
A = effective area of plant
w = width of airway (plus twice distance from airway edge to site)

Two airways, J15 and V102 pass within 5 miles of the WIPP:

J15 (4 mi NE of site)

C = in-flight crash rate = 4×10^{-10}/flight-mile
N = number of flights per year along airway = (365d/yr)(23 flights/d) = 8,395 fights/yr
A = effective area of plant = $(0.25\ \text{mi})^2 = 0.063\ \text{mi}^2$ (Property Protection area)
w = width of airway = 10 mi + 2 (4mi) = 18 mi

$$P_{fa} = C \times N \times A/w = (4 \times 10^{-10}/\text{flight-mile})(8{,}395\ \text{fights/yr})[(0.063\ \text{mi}^2)/18\text{mi})] = 1.18 \times 10^{-8}/\text{yr}$$

V102 (3 mi NW of site)

C = in-flight crash rate = 4×10^{-10}/flight-mile
N = number of flights per year along airway = (365d/yr)(5 flights/d) = 1,825 flights/yr
A = effective area of plant = $(0.25\ mi)^2 = 0.063\ mi^2$ (Property Protection area)
w = width of airway = 10 mi + 2 (3mi) = 16 mi

$P_{fa} = C \times N \times A/w = (4 \times 10^{-10}/\text{flight-mile})(1{,}825\ \text{flights/yr})[(0.063\ mi^2)/16mi)] = 2.87 \times 10^{-9}/yr$

Therefore, the total aircraft hazard probability (combined airway and airport probability of an aircraft crash) =

$P_{fa} = (1 \times 10^{-7}/yr) + (1.18 \times 10^{-8}/yr) + (2.87 \times 10^{-9}/yr) = 1.03 \times 10^{-7}/yr$

CH9 DROP OF WASTE CONTAINERS BY FORKLIFT IN THE UNDERGROUND

No historical information exist for drum handling accidents at the WIPP therefore other sites with similar operations were reviewed to determine reasonable estimates of waste container drops from forklifts during waste handling operations. This review was necessary to tune the estimated probability of occurrence (Unlikely $10^{-2} \geq p > 10^{-4}$) performed in the HAZOP for the CH TRU Waste Handling process.[1] The probability of waste containers dropped from a forklift is estimated considering two basic events 1) human error and 2) equipment failure. Basic Events provide specific component failure or human error data which provide input to the logic model to determine the probability of the event of interest (TOP event). Logical AND (*) or OR (+) funtions (gates) show how events can combine to cause the TOP event. The probability of a waste container drop by a forklift is calculated using the following equation:

$$P(A)_{FORKLIFT\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \tag{5}$$

Savannah River Site has established a Human Error Data Base for Nonreactor Nuclear Facilities (Savannah River Site Human Error Data Base Development for Nonreactor Nuclear Facilities, WSRC-TR-93-581).[6] These human error probabilities were based solely on generic models developed from industry literature. Results of the generic models for a drop of a load when using a forklift were established based on an operation, where an operation was defined as a lift, move, and setting down of a load. A nominal case, high case and the low case are given for dropped load when using a forklift, however, for this analysis the low case of 1.0E-04/operation is used to represent the frequency of dropping a load during waste handling at the WIPP. This assumption is based on the following:

- Standardized load
- Proceduralized process
- Spotters present
- Highly trained and certified personnel

Equipment failure which results in a waste container being dropped from forklift operations has been based on INEL-94/0226, *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*.[7] The annual probability of a load drop from forklift operations reported in the reference above is 4.3E-03/yr. This annual probability will be used in the determination of the annual probability of a waste container dropped due to equipment failure of a forklift during waste handling operations at the WIPP.

To determine the annual probability of a drop from a forklift due to human error, the frequency of forklift operations expected at the WIPP is used to estimate number of occurrences. The number of forklift operations is estimated by using data on throughput provided in Chapter 4, Table 4.3-2 of the SAR.

Human error annual probability assumptions:

810 Shipment/Yr.
Throughput assumed to be handled by 1 forklift with Brudi attachment.
3 TRUPACT II/Shipment
1 facility pallet/2 TRUPACT II
2 Operation/pallet (drums are assumed to be handled in 2 seven drum arrays or two SWB at a time)
Human errors involving forklift drops =1.0E-04/operation
For conservatism the annual probability estimate assumes 100% of the waste containers that are assumed to drop are breached.

$$P(1)_{HUMAN} = \frac{810\ Shipment}{Yr} * \frac{3\ TRUPACT\ II}{Shipment} * \frac{1\ FacilityPallet}{2\ TRUPACTII} * \frac{2\ Operation}{Facility\ Pallet} * \frac{1.0E-04 Drops}{Operation} = \frac{0.24\ Drops}{Yr}$$

Equipment failure annual probability assumptions:

Equipment failure annual probabilities (as reported in INEL-94/0226[7], *Safety Analysis Report for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*):

$$P(2)_{EQUIPMENT} = = \frac{0.0043\ Drops}{Yr}$$

Considering the probabilities of the two basic events (human error and equipment failure)and 1/3 of the time the load is assumed to be in position which the height of the load is greater than 4 ft, due to the height of the lower two tiers. The probability has adjusted by a factor of 10 to take credit for the BRUDI push/pull rack attachment which allows for a more stable and controllable load. Therefore, the annual probability of the waste container drop from a forklift is estimated from equation (5) as follows:

$$P(A)_{FORKLIFT\ DROP} = P(1)_{HUMAN} + P(2)_{EQUIPMENT} \tag{5}$$

$$P(A)_{DROP} = \left(\frac{0.24\ Drops}{Yr} + \frac{0.0043\ Drops}{Yr}\right) * \frac{1}{3} * 0.1$$

$$P(A)_{DROP} = = 0.0081\ \frac{Drops}{Yr}$$

This calculation supports the annual probability of a drop of waste containers in the disposal area from a forklift is in the Unlikely range (Unlikely $10^{-2} \geq p \geq 10^{-4}$).

CH10 TORNADO EVENT

This section develops the scenario initiating event probability assuming that the preventative and mitigative measures discussed in Tab 2 function as designed during the accident scenario.

As discussed in (1) Chapters 2 and 3 of the existing WIPP FSAR WP 02-9 and the FY-95 Annual Update DOE/WIPP-Draft-2065, (2) the Draft Project Technical Baseline for Regulatory Compliance WP 02-RC1,[11] and (3) Final Environmental Impact Statement DOE/EIS-0026,[12] UC-70,[13] the Design Basis Tornado (DBT) is the most severe credible tornado (183 mi/hr) that could occur at the WIPP site, based on a 1,000,000-yr. recurrence period.

The DBT was developed by a site specific study SMRP No. 155, "A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico,"[15] Department of Geophysical Sciences, T. Fujita, University of Chicago, February 1978 and its Supplement of August 1978.

CH11 UNDERGROUND ROOF FALL

During the underground HAZOP the roof fall was qualitatively determined to be in the Unlikely range (Unlikely $10^{-2} \geq p > 10^{-4}$), listed below are significant mitigating systems and controls that are in place to mitigate the release of hazardous materials from the WIPP underground.

General preventive and mitigative

- CMR initiated shift to filtered exhaust
- Frequent visual and instrumented inspections and assessments
- Ground control program
- Instrumented and monitored extensively
- MSHA inspections
- Predictive monitoring program
- Room checked before emplacement

It is difficult to quantify stability or to project the safe life of an underground opening without qualification. The condition of the underground facility is regularly assessed and appropriate measures (remediation) are taken to ensure that excavation performance is as intended and required. This iterative evaluation process is supported by the existing underground monitoring system (with over 1,000 instruments), augmented by regular periodic inspections, and provides long-term warning of any potential instability that may develop. An extensive program is in place to upgrade the geomechanical instrumentation (using state of the art systems developed by the U.S. Bureau of Mines), and to evaluate ground support materials and methods that provide improved performance while simultaneously reducing cost and maintenance effort. In the case of Site and Preliminary Design Validation (SPDV) Rooms 1 and 2, warning was well in excess of one year. An expert review panel assembled for review of Panel 1, Room 1, determined that the engineered monitoring system provides adequate warning of ground stability problems before they present an imminent hazard (DOE/WIPP 91-057,[16] DOE/WIPP 93-033[17]). The existing system provides more than adequate warning of instability and allows time for appropriate action. Geomechanical activities of WIPP are well documented and subject to rigorous quality assurance.

It should be noted that after the monitoring system indicated developing instability in SPDV Room 1 and 2, either could have been safely supported using established ground control practices or the falls could have been mitigated by mining the roof beam using well proven mining industry techniques. Prior to a room being filled, a complete assessment of excavation condition and stand-up time of the support systems will ensure that no room or access failures will occur prior to the time that the room or panel is scheduled to be closed (Draft Waste Emplacement and closure Plan Outline for a Panel Hazardous Waste Management Unit, January 1995).[18]

Occasionally ground control beyond light inspection and scaling may be required for a particular room. During waste handling operations, frequent inspections and assessments will be performed to ensure room performance is as anticipated or appropriate actions will be taken.

If for whatever reasons the roof fall of a waste filled panel/room is predicted, appropriate actions include the placement of room/panel seal system (Draft Waste Emplacement and closure Plan Outline for a Panel Hazardous Waste Management Unit, January 1995).[18] The panel/room closure system will act to prevent the releases of any hazardous materials as a result of the roof collapse (DOE/WIPP 94-2057, Conceptual Design for Operational Phase Panel Closure Systems).

For conservatism the qualitative frequency of occurrence (Unlikely $10^{-2} \geq p > 10^{-4}$) determined by the HAZOP is used.

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APPENDIX - E
Source Term/Dose Calculations

Table E-1 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH1) DRUM FIRE IN THE WHB

Drum Inventory (PE-Ci)	Waste Containers/ event	# of impacted drums @ max loading	Material at risk (PE-Ci)	Combustible DR	Noncombustible DR	Combustible ARF	Noncombustible ARF	Combustible RF	Noncombustible RF	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	1										
80.0		1	80	4.0E-01	6.0E-01	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.0E-06	1.9E-08
										Total	1.9E-08
Unmitigated											
80.0		1	80	4.0E-01	6.0E-01	5.0E-04	6.0E-03	1.0E+00	1.0E-02		1.9E-02
										Total	1.9E-02

$Q = [(MAR_C*DR_C*ARF_C*RF_C)+(MAR_{NC}*DR_{NC}*ARF_{NC}*RF_{NC})]*LPF$ (LPF considered for mitigation only)

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

$[(MAR_C*DR_C*ARF_C*RF_C)+(MAR_{NC}*DR_{NC}*ARF_{NC}*RF_{NC})]*LPF$ (LPF considered for mitigation only)

Table E-2 CHEMICAL SOURCE TERM ANALYSIS FOR (CH1) DRUM FIRE IN THE WHB

Compound	Material at Risk (mg)	DR Combust.	DR Noncombust	ARF Combust	ARF Noncombust	RF Combust	RF Noncombust	Source Term Combust. (mg)	Source Term Noncombust. (mg)	Combined Source Term (mg)	LPF HEPA	Total Source Term (mg)
Asbestos	3.0E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.0E+01	1.1E+01	7.1E+01	N/A	7.1E+01
Beryllium	2.3E+04	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	4.6E+00	8.3E-01	5.5E+00	N/A	5.5E+00
Cadmium	3.3E+02	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.6E-02	1.2E-02	7.8E-02	N/A	7.8E-02
Lead	9.1E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.8E+02	3.3E+01	2.1E+02	N/A	2.1E+02
Butyl Alcohol	3.3E+05	0.40	.060	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.6E+01	1.2E+01	7.8E+01	N/A	7.8E+01
Carbon Tetrachloride	6.9E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.4E+02	2.5E+01	1.6E+02	N/A	1.6E+02
Mercury	3.9E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	7.8E+01	1.4E+01	9.2E+01	N/A	9.2E+01
Methyl Alcohol	8.8E+02	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.8E-01	3.2E-02	2.1E-01	N/A	2.1E-01
Methylene Chloride	4.4E+04	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	8.8E+00	1.6E+00	1.0E+01	N/A	1.0E+01
Polychlorinated Biphenyl (PCB)	9.4E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.9E+02	3.4E+01	2.2E+02	N/A	2.2E+02
Trichloroethylene	4.3E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	8.6E+01	1.6E+01	1.0E+02	N/A	1.0E+02

No Credit is taken for mitigation of chemicals by HEPA filtration

$Q=[(MAR_C*DR_C*ARF_C*RF_C)+(MAR_{NC}*DR_{NC}*ARF_{NC}*RF_{NC})$

where: Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

Fibers/cc = (Asbestos concentration mg/m^3)(1 Fiber/1.3×10^7mg)($1m^3/1.0 \times 10^6$cc)

Table E-3 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH1) DRUM FIRE IN THE WHB

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	1.9E-08	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.9E-06	1.3E-07
SWBs							
Unmitigated							
Drums	1.9E-02	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.9E+00	1.3E-01
SWBs							

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:
Q= the source term (Ci)
X/Q= Site specific air dispersion factor (s/m3)
BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)
DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

BLE E-4 CHEMICAL CONSEQUENCE ANALYSIS FOR (CH1) DRUM FIRE IN THE WHB

Compound	Source Term Q (mg)	Release Rate (sec)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary (mg/m3)	Concentration Site Boundary (mg/m3)	Most Restricted Criteria for Extremely Unlikely Case (mg/m3)	TOX-2 Criteria (mg/m3)	Ratio (Conc./Limit) @ Exclusive Use Area Boundary	Ratio (Conc./Limit) @ Site Boundary
Asbestos	7.1E+01	900	5.96E-04	4.05E-05	3.63E-04 f/cc	2.47E-05 f/cc	0.2 f/cc	1 f/cc	3.6E-04	2.5E-05
Beryllium	5.5E+00	900	5.96E-04	4.05E-05	3.6E-06	2.5E-07	0.002	0.01	3.6E-04	2.5E-05
Cadmium	7.8E-02	900	5.96E-04	4.05E-05	5.2E-08	3.5E-09	0.002	0.01	5.2E-06	3.5E-07
Lead	2.1E+02	900	5.96E-04	4.05E-05	1.4E-04	9.7E-06	0.15	0.75	1.9E-04	1.3E-05
Butyl Alcohol	7.8E+01	900	5.96E-04	4.05E-05	5.2E-05	3.5E-06	150	150	3.5E-07	2.3E-08
Carbon Tetrachloride	1.6E+02	900	5.96E-04	4.05E-05	1.1E-04	7.3E-06	31	155	7.0E-07	4.7E-08
Mercury	9.2E+01	900	5.96E-04	4.05E-05	6.1E-05	4.1E-06	0.1	0.1	6.1E-04	4.1E-05
Methyl Alcohol	2.1E-01	900	5.96-04	4.05E-05	1.4E-07	9.4E-09	266	266	5.2E-10	3.5E-11
Methylene Chloride	1.0E+01	900	5.96E-04	4.05E-05	6.9E-06	4.7E-07	174	870	7.9E-09	5.4E-10
Polychlorinated Biphenyl	2.2E+02	900	5.96E-04	4.05E-05	1.5E-04	1.0E-05	0.5	2.5	5.9E-05	4.0E-06
Trichloroethylene	1.0E+02	900	5.96E-04	4.05E-05	6.8E-05	4.6E-06	1092	1092	6.2E-08	4.2E-09

No Credit is taken for mitigation of chemicals by HEPA filtration

C = (Q*X/Q)/RR

Where: C = Concentration
Q = Source Term
RR = Release Rate
X/Q = Dispersion Coeificient

TABLE E-5 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH2) CRANE DROP IN THE WHB

Drum Inventory (PE-Ci)	Waste Containers/ event	# of impacted drums @ max loading	Material at risk (PE-Ci)	DR	ARF	RF	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	14 Drums/ 2SWBs							
80.0		7	560	2.5E-01	1.0E-03	1.0E-01	1.0E-06	1.4E-08
							Total	1.4E-08
130.0		1	130.0	1.0E-01	1.0E-03	1.0E-01	1.0E-06	1.3E-09
							Total	1.3E-09
Un-mitigated								
80.0		7	560	2.5E-01	1.0E-03	1.0E-01		1.4E-02
							Total	1.4E-02
130.0		1	130.0	1.0E-01	1.0E-03	1.0E-01		1.3E-03
							Total	1.3E-03

Q = MAR*DR*ARF*RF*LPF

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-6 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH2) CRANE DROP IN THE WHB							
	Source Term Q (PE-Ci)	Exclusieve Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	1.4E-08	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.4E-06	9.6E-08
SWBS	1.3E-09	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.3E-07	8.9E-09
Unmitigated							
Drums	1.4E-02	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.4E-00	9.6E-02
SWBs	1.3E-03	5.96E-04	4.05E-05	3.33E-04	5.1E+08	1.3E-01	8.9E-03

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:
Q= the source term (Ci)
X/Q= Site specific air dispersion factor (s/m3)
BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)
DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-7 CHEMICAL SOURCE TERM/CONSEQUENCE ANALYSIS FOR (CH2) CRANE DROP IN THE WHB

Compound	Material at Risk/drum (ppmv)	Molecular Weight (g/mole)	Mole fraction (1.0E-06/PPMV)	Unit conversion (1.0E+3mg/g)	Material at Risk/drums (mg)	Material at Risk/SWBs (mg)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary-Drums (mg/m3)	Concentration Site Boundary-Drums (mg/m3)	Concentration @ Exclusive Use Area Boundary-SWBs (mg/m3)	Concentration Site Boundary-SWBs (mg/m3)
Unmitigated												
Methylene chloride	497.93	84.9	1.0E-06	1.0E+03	295.92	380.47	5.96E-04	4.05E-05	1.8E-01	1.2E-02	2.3E-01	1.5E-02
Carbon tetrachloride	408.0	153.8	1.0E-06	1.0E+03	439.25	564.75	5.96E-04	4.05E-05	2.6E-01	1.8E-02	3.4E-01	2.3E-02

# of waste containers at Risk drums/SWBs (14/2)
Drum equivalents for SWBs (64/7.4)=8.65, this ratio is multiplied by the number of SWBs involved in the event to calculate an equivalent concentration in a SWB
# of impacted drums @ Drum inventory (7)
# of impacted drum equiv. for SWBs @ drum inventory (9)
C = (MAR*X/Q)/RR
where:
C=Concentration in mg/m3
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (mg)
RR=release rate - The RR is the amount of material released as a function of time (assumed to be released in one second)
X/Q=Dispersion coefficient (s/m3)

TABLE E-8 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH3) PUNCTURE AND DROP BY FORK LIFT IN THE WHB

Drum Inventory (PE-Ci)	Waste Containers/ event	# of impacted drums @ max loading		Material at risk (PE-Ci)	DR	ARF	RF	LPF HEPA	Source Term (Q) (PE-Ci)
		Dropped	Punctured						
Mitigated	28 Drums/ 4 SWBs								
80.0		2		160.0	2.5E-01	1.0E-03	1.0E-01	1.0E-06	4.0E-09
80.0			2	160.0	1.0E-01	1.0E-03	1.0E-01	1.0E-06	1.6E-09
								Total	5.6E-09
130.0		2		260	1.0E-01	1.0E-03	1.0E-01	1.0E-06	2.6E-09
								Total	2.6E-09
Unmitigated									
80.0		2		160.0	2.5E-01	1.0E-03	1.0E-01		4.0E-03
80.0			2	160.0	1.0E-01	1.0E-03	1.0E-01		1.6E-03
								Total	5.6E-03
130.0		2		260	1.0E-01	1.0E-03	1.0E-01		2.6E-03
								Total	2.6E-03

Q = MAR*DR*ARF*RF*LPF

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-9 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH3) PUNCTURE AND DROP BY FORK LIFT IN THE WHB

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	5.6E-09	5.96E-04	4.05E-05	3.33E-04	5.1E+08	5.7E-07	3.9E-08
SWBS	2.6E-09	5.96E-04	4.05E-05	3.33E-04	5.1E+08	2.6E-07	1.8E-08
Unmitigated							
Drums	5.6E-03	5.96E-04	4.05E-05	3.33E-04	5.1E+08	5.7E-01	3.9E-02
SWBS	2.6E-03	5.96E-04	4.05E-05	3.33E-04	5.1E+08	2.6E-01	1.8E-02

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:

Q= the source term (Ci)

X/Q= Site specific air dispersion factor (s/m3)

BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)

DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-10 CHEMICAL SOURCE TERM/CONSEQUENCE ANALYSIS FOR (CH3) PUNCTURE AND DROP BY FORK LIFT IN THE WHB

Compound	Material at Risk/drum (ppmv)	Molecular Weight (g/mole)	Mole fraction (1.0E-06/PPMV)	Unit conversion (1.0E+3mg/g)	Material at Risk/drums (mg)	Material at Risk/SWBs (mg)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary-Drums (mg/m3)	Concentration Site Boundary-Drums (mg/m3)	Concentration @ Exclusive Use Area Boundary-SWBs (mg/m3)	Concentration Site Boundary-SWBs (mg/m3)
Unmitigated												
Methylene chloride	497.93	84.9	1.0E-06	1.0E+03	169.10	718.66	5.96E-04	4.05E-05	1.0E-01	6.8E-03	4.3E-01	2.9E-02
Carbon tetrachloride	408.0	153.8	1.0E-06	1.0E+03	251.00	1066.76	5.96E-04	4.05E-05	1.5E-01	1.0E-02	6.4E-01	4.3E-02

# of waste containers at Risk drums/SWBs (28/4)
Drum equivalents for SWBs (64/7.4)=8.65, this ratio is multiplied by the number of SWBs involved in the event to calculate an equivalent concentration in a SWB
# of impacted drums @ Drum inventory (4)
# of impacted drum equiv. for SWBs @ drum inventory (17)
C = (MAR*X/Q)/RR
where:
C=Concentration in mg/m3
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (mg)
RR=release rate - The RR is the amount of material released as a function of time (assumed to be released in one second)
X/Q=Dispersion coefficient (s/m3)

TABLE E-11 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH4) DROP OF WASTE CONTAINER FROM FORK LIFT IN THEWHB

Drum Inventory (PE-Ci)	Waste Containers/event	# impacted drums @ max loading (dropped)	Material at risk (PE-Ci)	DR	ARF	RF	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	28 Drums/ 4 SWBs							
80.0		4	320.0	2.5E-01	1.0E-03	1.0E-01	1.0E-06	8.0E-09
							Total	8.0E-09
130.0		2	260.0	1.0E-01	1.0E-03	1.0E-01	1.0E-06	2.6E-09
							Total	2.6E-09
Unmitigated								
80.0		4	320.0	2.5E-01	1.0E-03	1.0E-01		8.0E-03
							Total	8.0E-03
130.0		2	260.0	1.0E-01	1.0E-03	1.0E-01		2.6E-03
							Total	2.6E-03

Q = MAR*DR*ARF*RF*LPF

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-12 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH4) DROP OF WASTE CONTAINER FROM FORK LIFT IN THE WHB

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	8.0E-09	5.96E-04	4.05E-05	3.33E-04	5.1E+08	8.1E-07	5.5E-08
SWBS	2.6E-09	5.96E-04	4.05E-05	3.33E-04	5.1E+08	2.6E-07	1.8E-08
Unmitigated							
Drums	8.0E-03	5.96E-04	4.05E-05	3.33E-04	5.1E+08	8.1E-01	5.5E-02
SWBS	2.6E-03	5.96E-04	4.05E-05	3.33E-04	5.1E+08	2.6E-01	1.8E-02

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:
Q= the source term (Ci)
X/Q= Site specific air dispersion factor (s/m3)
BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)
DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-13 CHEMICAL SOURCE TERM/CONSEQUENCE ANALYSIS FOR (CH4) DROP OF WASTE CONTAINER FROM FORK LIFT IN THE WHB

Compound	Material at Risk/ drum (ppmv)	Molecular Weight (g/mole)	Mole fraction (1.0E-06/ PPMV)	Unit conversion (1.0E+3mg/g)	Material at Risk/ drums (mg)	Material at Risk/SWBs (mg)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary-Drums (mg/m3)	Concentration Site Boundary-Drums (mg/m3)	Concentration @ Exclusive Use Area Boundary-SWBs (mg/m3)	Concentration Site Boundary-SWBs (mg/m3)
Unmitigated												
Methylene chloride	497.93	84.9	1.0E-06	1.0E+03	169.10	718.66	5.96E-04	4.05E-05	1.0E-01	6.8E-03	4.3E-01	2.9E-02
Carbon tetrachloride	408.0	153.8	1.0E-06	1.0E+03	251.00	1066.76	5.96E-04	4.05E-05	1.5E-01	1.0E-02	6.4E-01	4.3E-02

# of waste containers at Risk drums/SWBs (28/4)
Drum equivalents for SWBs (64/7.4)=8.65, this ratio is multiplied by the number of SWBs involved in the event to calculate an equivalent concentration in a SWB
# of impacted drums @ Drum inventory (4)
# of impacted drum equiv. for SWBs @ drum inventory (17)
C = (MAR*X/Q)/RR
where:
C=Concentration in mg/m3
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (mg)
RR=release rate - The RR is the amount of material released as a function of time (assumed to be released in one second)
X/Q=Dispersion coefficient (s/m3)

TABLE E-14 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH7) DRUM FIRE IN THE UNDERGROUND

Drum Inventory (PE-Ci)	Waste con-tainers /event	# of impacted drums @ max loading	Material at risk (PE-Ci)	Combus-tible DR	Noncom-bustible DR	Combus-tible ARF	Noncom-bustible ARF	Combus-tible RF	Noncom-bustible RF	LPF Plateout	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	1											
80.0		1	80.0	4.0E-01	6.0E-01	5.0E-04	6.0E-03	1.0E+00	1.0E-02	5.0E-01	1.0E-06	9.4E-09
										Total		9.4E-09
Un-mitigated												
80.0		1	80.0	4.0E-01	6.0E-01	5.0E-04	6.0E-03	1.0E+00	1.0E-02	5.0E-01		9.4E-03
										Total		9.4E-03

$Q = [(MAR_C*DR_C*ARF_C*RF_C)+(MAR_{NC}*DR_{NC}*ARF_{NC}*RF_{NC})]*LPF_{plateout}*LPF_{HEPA}$ (LPF_{HEPA} considered for mitigation only)

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioacctive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-15 CHEMICAL SOURCE TERM ANALYSIS FOR (CH7) DRUM [illegible]RE IN THE UNDERG[illegible]

Compound	Material at Risk (mg)	DR Combust.	DR Noncombust		ARF Noncombust	RF Combust	RF Noncombust	Source Term Combust. (mg)	Source Term Noncombust. (mg)	Combined Source Term (mg)	LPF Plateout	Total Source Term (mg)
Asbestos	3.0E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.0E+01	1.1E+01	7.1E+01	5.0E-01	3.6E+01
Beryllium	2.3E+04	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	4.6E+00	8.3E-01	5.5E+00	5.0E-01	2.7E+00
Cadmium	3.3E+02	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.6E-02	1.2E-02	7.8E-02	5.0E-01	3.9E-02
Lead	9.1E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.8E+02	3.3E+01	2.1E+02	5.0E-01	1.1E+02
Butyl Alcohol	3.3E+05	0.40	.060	5.0E-04	6.0E-03	1.0E+00	1.0E-02	6.6E+01	1.2E+01	7.8E+01	5.0E-01	3.9E+01
Carbon Tetrachloride	6.9E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.4E+02	2.5E+01	1.6E+02	5.0E-01	8.2E+01
Mercury	3.9E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	7.8E+01	1.4E+01	9.2E+01	5.0E-01	4.6E+01
Methyl Alcohol	8.8E+02	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.8E-01	3.2E-02	2.1E-01	5.0E-01	1.0E-01
Methylene Chloride	4.4E+04	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	8.8E+00	1.6E+00	1.0E+01	5.0E-01	5.2E+00
Polychlorinated Biphenyl (PCB)	9.4E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	1.9E+02	3.4E+01	2.2E+02	5.0E-01	1.1E+02
Trichloroethylene	4.3E+05	0.40	0.60	5.0E-04	6.0E-03	1.0E+00	1.0E-02	8.6E+01	1.6E+01	1.0E+02	5.0E-01	5.1E+01

No Credit is taken for mitigation of chemicals by HEPA filtration

$$Q=[(MAR_C*DR_C*ARF_C*RF_C)+(MAR_{NC}*DR_{NC}*ARF_{NC}*RF_{NC})]*LPF_{plateout}$$

where: Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioacctive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the resplrable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

Fibers/cc = (Asbestos concentration mg/m^3)(1 Fiber/1.3×10^{-7}mg)($1m^3/1.0 \times 10^6$cc)

TABLE E-16 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH7) DRUM FIRE IN THE UNDERGROUND

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (300 meters) X/Q (s/m3)	Site Boundary (3029 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drum	9.4E-09	7.73E-04	3.99E-05	3.33E-04	5.1E+08	1.2E-06	6.4E-08
Unmitigated							
Drum	9.4E-03	7.73E-04	3.99E-05	3.33E-04	5.1E+08	1.2E+00	6.4E-02

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:
Q= the source term (Ci)
X/Q= Site specific air dispersion factor (s/m3)
BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)
DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-17 CHEMICAL CONSEQUENCE ANALYSIS FOR (CH7) DRUM FIRE IN THE UNDERGROUND

Compound	Source Term Q (mg)	Release Rate (sec)	Exclusive Use Area Boundary (350 meters) X/Q (s/m3)	Site Boundary (2982 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary (mg/m3)	Concentration Site Boundary (mg/m3)	Most Restricted Criteria for Extremely Unlikely Case (mg/m3)	TOX-2 Criteria (mg/m3)	Ratio (Conc./Limit) @ Exclusive Use Area Boundary	Ratio (Conc./Limit) @ Site Boundary
Asbestos	3.6E+01	900	5.9E-04	41E-05	1.8E-04f/cc	1.2E-05 f/cc	0.2 f/cc	1 f/cc	1.8E-04	1.2E-05
Beryllium	2.7E+00	900	5.9E-04	4.1E-05	1.8E-06	1.2E-07	0.002	0.01	1.8E-04	1.2E-05
Cadmium	3.9E-02	900	5.9E-04	4.1E-05	2.6E-08	1.8E-09	0.002	0.01	2.6E-06	1.8E-07
Lead	1.1E+02	900	5.9E-04	4.1E-05	7.1E-05	4.8E-06	0.15	0.75	9.5E-05	6.5E-06
Butyl Alcohol	3.9E+01	900	5.9E-04	4.1E-05	2.6E-05	1.8E-06	150	150	1.7E-07	1.2E-08
Carbon Tetrachloride	8.2E+01	900	5.9E-04	4.1E-04	5.4E-05	3.7E-06	31	155	3.5E-07	2.4E-08
Mercury	4.6E+01	900	5.9E-04	4.1E-05	3.1E-05	2.1E-06	0.1	0.1	3.1E-04	2.1E-05
Methyl Alcohol	1.0E-01	900	5.9E-04	4.1E-05	6.9E-08	4.7E-09	266	266	2.6E-10	1.8E-11
Methylene Chloride	5.2E+00	900	5.9E-04	4.1E-05	3.5E-06	2.3E-07	174	870	4.0E-09	2.7E-10
Polychlorinated Biphenyl	1.1E+02	900	5.9E-04	4.1E-05	7.4E-05	5.0E-06	0.5	2.5	2.9E-05	2.0E-06
Trichloroethylene	5.1E+01	900	5.9E-04	4.1E-05	3.4Ee-05	2.3e-06	1092	1092	3.1E-08	2.1E-09

No Credit is taken for mitigation of chemicals by HEPA filtration

C = (Q*X/Q)/RR

Where: C = Concentration
Q = Source Term
RR = Release Rate
X/Q = Dispersion Coeificient

TABLE E-18 SOURCE TERM ANALYSIS FOR (CH9) DROP OF WASTE CONTAINERS FROM FORK LIFT IN THE UNDERGROUND

Drum Inventory (PE-Ci)	Waste Containers/ event	# of impacted drums @ max loading (dropped)	Material at risk (PE-Ci)	DR	ARF	RF	LPF Plateout	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	7 Drums/1 SWBs								
80.0		7	560.0	2.5E-01	1.0E-03	1.0E-01	5.0E-01	1.0E-06	7.0E-09
							Total		7.0E-09
130.0		1	130.0	1.0E-01	1.0E-03	1.0E-01	5.0E-01	1.0E-06	6.5E-10
							Total		6.5E-10
Unmitigated									
80.0		7	560.0	2.5E-01	1.0E-03	1.0E-01	5.0E-01		7.0E-03
							Total		7.0E-03
130.0		1	130.0	1.0E-01	1.0E-03	1.0E-01	5.0E-01		6.5E-04
							Total		6.5E-04

Q = MAR*DR*ARF*RF*LPF

where:
Q= the source term (Ci)
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioacctive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-19 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH9) DROP OF WASTE CONTAINERS FROM FORK LIFT IN THE UNDERGROUND

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (300 meters) X/Q (s/m3)	Site Boundary (3029 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	7.0E-09	7.73E-04	3.99E-05	3.33E-04	5.1E+08	9.2E-07	4.7E-08
SWBS	6.5E-10	7.73E-04	3.99E-05	3.33E-04	5.1E+08	8.5E-08	4.4E-09
Unmitigated							
Drums	7.0E-03	7.73E-04	3.99E-05	3.33E-04	5.1E+08	9.2E-01	4.7E-02
SWBS	6.5E-04	7.73E-04	3.99E-05	3.33E-04	5.1E+08	8.5E-02	4.4E-03

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:

Q= the source term (Ci)

X/Q= Site specific air dispersion factor (s/m3)

BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)

DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-20 CHEMICAL SOURCE TERM/CONSEQUENCE ANALYSIS FOR (CH9) DROP OF WASTE CONTAINERS FROM FORK LIFT IN THE UNDERGROUND

Compound	Material at Risk/drum (ppmv)	Molecular Weight (g/mole)	Mole fraction (1.0E-06/PPMV)	Unit conversion (1.0E+3mg/g)	Material at Risk/drums (mg)	Material at Risk/SWBs (mg)	Exclusive Use Area Boundary (300 meters) X/Q (s/m3)	Site Boundary (3029 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary-Drums (mg/m3)	Concentration Site Boundary-Drums (mg/m3)	Concentration @ Exclusive Use Area Boundary-SWBs (mg/m3)	Concen-tration Site Boundary-SWBs (mg/m3)
Unmitigated												
Methylene chloride	497.93	84.9	1.0E-06	1.0E+03	295.92	380.47	7.73E-04	3.99E-05	2.3E-01	1.2E-02	2.9E-01	1.5E-02
Carbon tetrachloride	408.0	153.8	1.0E-06	1.0E+03	439.25	564.753	7.73E-04	3.99E-05	3.4E-01	1.8E-02	4.4E-02	2.3E-02

# of waste containers at Risk drums/SWBs (14/2)
Drum equivalents for SWBs (64/7.4)=8.65, this ratio is multiplied by the number of SWBs involved in the event to calculate an equivalent concentration in a SWB
# of impacted drums @ Drum inventory (7)
# of impacted drum equiv. for SWBs @ drum inventory (9)
C = (MAR*X/Q)/RR
where:
C=Concentration in mg/m3
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (mg)
RR=release rate - The RR is the amount of material released as a function of time (assumed to be released in one second)
X/Q=Dispersion coefficient (s/m3)

TABLE E-21 RADIOLOGICAL SOURCE TERM ANALYSIS FOR (CH11) ROOF FALL IN THE UNDERGROUND

Drum Inventory (PE-Ci)	Waste Containers/ event	# of impacted drums @ max loading (dropped)	Material at risk (PE-Ci)	DR	ARF	RF	LPF Plateout	LPF HEPA	Source Term (Q) (PE-Ci)
Mitigated	42 Drums/ 5 SWBs								
80.0		21	1680.0	2.5E-01	1.0E-03	1.0E-01	5.0E-01	1.0E-06	2.1E-08
							Total		2.1E-08
130.0		5	650	1.0E-01	1.0E-03	1.0E-01	5.0E-01	1.0E-06	3.3E-09
							Total		3.3E-09
Unmitigated									
80.0		21	1680.0	2.5E-01	1.0E-03	1.0E-01	5.0E-01		2.1E-02
							Total		2.1E-02
130.0		5	650	1.0E-01	1.0E-03	1.0E-01	5.0E-01		3.3E-03
0.0							Total		3.3E-03

Q = MAR*DR*ARF*RF*LPF

where:
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source
DR=Damage Ratio - the DR is that fraction of the MAR actually impacted by the accident condition.
ARF=Airborne Release Fraction - The fraction of radioactive material that is suspended in air.
RF=Respirable Fraction - fraction of the airborne radioactive particles that are in the respirable size range, i.e.less than 10um in aerodynamic equivalent diameter.
LPF=Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident. (i.e. HEPA Filtration, Plateout)

TABLE E-22 RADIOLOGICAL CONSEQUENCE ANALYSIS FOR (CH11) ROOF FALL IN THE UNDERGROUND

	Source Term Q (PE-Ci)	Exclusive Use Area Boundary (300 meters) X/Q (s/m3)	Site Boundary (3029 meters) X/Q (s/m3)	BR (m3/s)	DCF (rem/Ci)	Exclusive Use Area Boundary CEDE (rem)	Site Boundary CEDE (rem)
Mitigated							
Drums	2.1E-08	7.73E-04	3.99E-05	3.33E-04	5.1E+08	2.8E-06	1.4E-07
SWBS	3.3E-09	7.73E-04	3.99E-05	3.33E-04	5.1E+08	4.3E-07	2.2E-08
Unmitigated							
Drums	2.1E-02	7.73E-04	3.99E-05	3.33E-04	5.1E+08	2.8E-00	1.4E-01
SWBS	3.3E-03	7.73E-04	3.99E-05	3.33E-04	5.1E+08	4.3E-01	2.2E-02

Effective Dose Equivalent (CEDE) = Q * X/Q * BR * DCF

where:
Q= the source term (Ci)
X/Q= Site specific air dispersion factor (s/m3)
BR=Breathing rate (standard man) (m3/s) International Commission on Radiological Protection (ICRP) No. 23 (Light activity 20.0 liters/min or 3.33 E-04 m3/s)
DCF=Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public (Pu-239 Class W CEDE Inhalation 5.1E+02rem/uCi or 5.10E+08 rem/Ci)

TABLE E-23 CHEMICAL SOURCE TERM/CONSEQUENCE ANALYSIS FOR (CH11) ROOF FALL IN THE UNDERGROUND

Compound	Material at Risk/drum (ppmv)	Molecular Weight (g/mole)	Mole fraction (1.0E-06/PPMV)	Unit conversion (1.0E+3mg/g)	Material at Risk/drums (mg)	Material at Risk/SWBs (mg)	Exclusive Use Area Boundary (300 meters) X/Q (s/m3)	Site Boundary (3029 meters) X/Q (s/m3)	Concentration @ Exclusive Use Area Boundary-Drums (mg/m3)	Concentration Site Boundary-Drums (mg/m3)	Concentration @ Exclusive Use Area Boundary-SWBs (mg/m3)	Concentration Site Boundary-SWBs (mg/m3)
Unmitigated												
Methylene chloride	497.93	84.9	1.0E-06	1.0E+03	887.76	1817.79	7.73E-04	3.99E-05	6.9E-01	3.5E-02	1.4E+00	7.3E-02
Carbon tetrachloride	408.0	153.8	1.0E-06	1.0E+03	1317.76	2698.27	7.73E-04	3.99E-05	1.0E+00	5.3E-02	2.1E+00	1.1E-01

# of waste containers at Risk drums/SWBs (21/5)
Drum equivalents for SWBs (64/7.4)=8.65, this ratio is multiplied by the number of SWBs involved in the event to calculate an equivalent concentration in a SWB
# of impacted drums @ Drum inventory (21)
# of impacted drum equiv. for SWBs @ drum inventory (43)
C = (MAR*X/Q)/RR
where:
C=Concentration in mg/m3
MAR= Material At Risk - the maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (mg)
RR=release rate - The RR is the amount of material released as a function of time (assumed to be released in one second)
X/Q=Dispersion coefficient (s/m3)

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WASTE ISOLATION PILOT PLANT TECHNICAL SAFETY REQUIREMENTS

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Prepared for

United States Department of Energy

Westinghouse Electric Corporation
Waste Isolation Division

TECHNICAL SAFETY REQUIREMENTS
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TECHNICAL SAFETY REQUIREMENTS

1 Use and Application

This document provides the WIPP Technical Safety Requirements (TSR) in accordance with the requirements of DOE Order 5480.22, *Technical Safety Requirements*.[1] DOE Order 5480.22[1] provides detailed criteria for the selection of TSR Safety Limits (SLs), Limiting Control Settings (LCSs), Limiting Conditions for Operations (LCOs), Surveillance Requirements (SRs), and Administrative Controls (ACs).

Based on the WIPP Safety Analysis Report (SAR)[2] Chapter 5, Hazards and Accident Analyses, SLs, LCSs, LCOs, and SRs are not required for the WIPP facility as discussed below. As discussed in SAR[2] Chapter 5, Design Class I Systems, Structures or Components (SSCs) are not required for the WIPP to mitigate any accidental radiological and nonradiological consequence to acceptable levels. WIPP TSR in the form of ACs are derived in this chapter. These ACs provide TSR covering the WIPP defense-in-depth approach developed in SAR[2] Chapter 5.

1.1 Definitions

----------NOTE----------

The definitions provided in this section are specifically applicable to the TSR and they are displayed in all capital letters throughout this TSR Document. Also, some definitions refer the reader to a specific section of this document to help provide a more complete description than can be provided in a summarized definition read out of context.

Term	Definition
MODE	A MODE of operation defines the operating condition of the WIPP facility at a given time. See Section 1.2, MODES.
OPERABLE/ OPERABILITY	A system, subsystem, train, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified design function(s), and when all necessary attendant equipment, instrumentation, controls, electrical power sources, cooling or seal water, lubrication or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its specified function(s) are also capable of performing their related support function(s). General Principles of OPERABILITY are: 1. A system is considered OPERABLE as long as their exists assurance that it is capable of performing its specified design function(s). 2. A system can perform its specified design function(s) only when all of its necessary support systems are capable of performing their related support functions. 3. Assuring the capability to perform a design function is an ongoing and continuous process.

4. When all systems designed to perform a certain design function are not capable of performing that design function(s), a loss of function condition exists. Facility operation with such a condition may not continue.

5. When a system is determined to be incapable of performing its intended design function(s), the declaration of inoperability shall be immediate.

6. Any exception to an immediate determination of OPERABILITY must be justified.

OPERATIONAL LIMITS	Those limits that are required to ensure the safe operation of a nuclear facility. Specifically, these limits include LCSs and LCOs.
TECHNICAL SAFETY REQUIREMENTS	TSR are those requirements that define the conditions, safe boundaries, and the management or administrative controls necessary to ensure the safe operation of a nuclear facility and to reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposures due to inadvertent criticality. TSR consist of safety limits, OPERATIONAL LIMITS, surveillance requirements, administrative controls, use and application instructions, and the basis thereof.
VIOLATION	A deviation from a TSR that is reportable. Since SLs, OPERATIONAL LIMITS, and SRs are not defined for the WIPP, failure to comply with an AC requirement constitutes a TSR Violation. (See Section 5.6, TSR VIOLATIONS.)
WASTE	Contact-Handled (CH) Transuranic (TRU) WASTE materials disposed in WIPP-approved CH containers.

1.2 Facility Modes

Operations at the WIPP consist mainly of waste handling, in-process storage, and disposal operations. The following description of the operational MODES provides a definition of the varying levels of operations. Prior to receiving waste, the facility is required to be in one of the MODES of operation.

1.2.1 Waste Handling Mode

The facility or sections of the facility are operating in their intended function (waste handling, in-process storage and/or disposal operations are being conducted). The Waste Handling Building (WHB) and/or the Underground is configured for waste handling, in-process storage and/or disposal, and all applicable TSR ACs for the appropriate areas have been met.

Prior to entering the Waste Handling MODE, the following systems shall be OPERABLE: (1) WHB and/or Underground Ventilation Systems, (2) WHB and/or Underground Effluent Monitoring Systems, (3) Backup Electrical System, (4) Waste Hoist (when required to transport waste), and (5) waste handling equipment, including support equipment or systems as required (during waste handling operations only). These systems may be shutdown for maintenance or activities scheduled on the Plan of the Day, provided no waste handling operations are in progress in affected areas.

1.2.2 Waste Storage/Disposal Mode

Waste handling operations are not being conducted in the WHB or in the Underground. WHB and/or the Underground is configured for waste in-process storage or disposal, and all applicable TSR ACs for the appropriate areas have been met. The facility will always be in the Waste Storage/Disposal MODE or Waste Handling MODE.

No waste handling operations are allowed during Waste Storage/Disposal MODE. Maintenance, and inspection activities are allowed. The Underground Ventilation System, WHB Ventilation System (when in-process waste is present), Underground Effluent Monitoring System, WHB Effluent Monitoring System (when in-process waste is present), and backup Electrical System should be operable except for maintenance, and inspection activities

1.3 Safety Limits (SLs)

As defined in DOE Order 5480.22,[1] SLs are limits on process variables associated with those physical barriers, generally passive, that are necessary for the intended facility function and that are found to be required to guard against the uncontrolled release of radioactivity and other hazardous material. "Process Variables" refers to observable, measurable parameters such as temperature and pressure. "Passive physical barriers" refers to those barriers that constitute the primary process material boundary.

Based on the analysis presented in SAR[2] Chapter 5, no SLs are identified for the WIPP facility.

1.4 Limiting Control Settings (LCSs)

As defined in DOE Order 5480.22[1], LCSs are settings on safety systems that control process variables to prevent exceeding SLs. More precisely, an LCS is the set point for an instrument or device monitoring a process variable that, if exceeded, initiates actions to prevent exceeding an SL.

The WIPP facility has no SLs identified, therefore, no LCSs are required.

1.5 Limiting Conditions for Operations (LCOs)

DOE Order 5480.22,[1] Attachment 1, Section II.2.3.h, provides that "LCOs should be written only for systems and equipment which meet one (or more) of the following descriptions", and prescribes five selection criteria, h.(1) through h.(5). The order also emphasizes that "Maintaining the LCOs at the minimum number necessary will emphasize the importance of the LCOs and better ensure the compliance with them." All five criteria clearly tie the LCOs to the facility accident or transient analyses.

The LCO selection criteria interpretations define TSR content based on key nuclear safety analysis requirements. Specifically, three of the five TSR LCO selection criteria are understood to restrict TSR LCOs to only those requirements that are under the direct control of the facility's operators and are of primary importance for; **prevention** (Criterion h.(1)), **mitigation** (Criterion h.(2)) and **initial conditions** (Criterion h.(3)) of credible, unmitigated accident scenarios. Additionally, Criterion h.(4) involves the application of criteria h.(1), h.(2), and h.(3) to experiments and experimental facilities, and Criterion h.(5) to systems and equipment that are used for handling fissile material.

The specifics of each criterion as applied to the WIPP facility are as follows:

Criterion h.(1) - Prevention:

A basic concept in the protection of the public is the prevention of accidents that have the potential for an uncontrolled release of radioactive material. Criterion h.(1) is intended to ensure that TSR be selected to identify instrumentation that is used to detect, and to indicate in the control room or other control location, a significant degradation of the physical barriers which prevent the uncontrolled release of radioactive or other hazardous materials. For example, instrumentation installed to detect significant degradation of a reactor coolant pressure boundary enables the operator to correct the degraded condition prior to accident initiation or to place the facility in a condition that reduces the likelihood of the accident.

Instrumentation at the WIPP, such as the Continuous Air Monitors (CAMs), Effluent Monitors, Area Radiation Monitors (ARMs), and installed instrumentation to control differential pressure, are not required to prevent accidents as analyzed in the SAR[2] from occurring, or to facilitate the Central Monitoring Room (CMR) operator placing the facility in a condition reducing the likelihood of an accident from occurring. Therefore, Criterion h.(1) has no application to the WIPP.

Criterion h.(2) - Mitigation:

Criterion h.(2) provides that "Structures, systems, and components that are relied upon in the Safety Analyses to function or actuate to prevent or mitigate accidents, or transients that either involve the assumed failure of, or present a challenge to, the integrity of a physical barrier that prevents the uncontrolled release of radioactive materials ... intended to include only those structures, systems, and components that are part of the primary success path of a safety sequence analysis and those support and actuation systems necessary for them to function successfully."

The "primary success path of a safety sequence analysis" is defined as "the sequence of events assumed by the Safety Analyses, which leads to the conclusion of a transient or accident with consequences that are acceptable. Hence, any structure, system, or component in that assumed sequence should be included in the LCO."

Consistent with the primary intent of DOE Order 5480.22[1] establishing requirements for the protection of the public, the SAR[2]: 1) evaluates the unmitigated radiological and non-radiological consequences to members of the off-site public as the result of an accident, 2) compares the radiological and non-radiological consequences to established accident acceptance criteria, and 3) if the consequences of the accident exceed the established accident consequence acceptance criteria, defines SSCs and associated TSR LCOs mitigating or reducing those consequences to acceptable levels below the established criteria.

The unmitigated off-site radiological and non-radiological consequences and acceptance criteria, as documented in SAR[2] Chapter 5, Tables 5.2-3, and 5.2-4 are used as the basis for applying this criterion.

Application of DOE Order 5480.22[1] TSR LCO Selection Criterion h.(2) to the WIPP:

The WIPP SSCs that are assumed to function in the SAR[2] accident analysis mitigating an accident's radiological and non-radiological consequences to acceptable levels (to within the accident acceptance criteria) satisfy Criterion h.(2).

The unmitigated radiological and non-radiological accident consequences were estimated and compared to the acceptance criteria in SAR[2] Chapter 5. The unmitigated radiological and non-radiological accident consequences are below the consequence acceptance criteria therefore; 1) mitigating SSCs are not required, and 2) TSR LCOs are not required.

Tables 5.2-3 and 5.2-4 of SAR[2] Chapter 5 list the analyzed accidents and the mitigated and unmitigated off-site radiological consequences. All of the radiological and non-radiological accident consequences are well below the off-site acceptance criteria.

Criterion h.(3) - Initial Condition:

Process variables as initial conditions of accidents or transients that are monitored and controlled during operations so the parameter remains within the analysis bounds satisfy this selection criterion. The WIPP is not a process facility, therefore process variables are not considered in the SAR[2] accident analysis as initial conditions for accidents. Thus, Criterion h.(3) is not applicable to the WIPP.

Criterion h.(4)

Criterion h.(4) involves applying criteria h.(1), h.(2), and h.(3) to experimental activities involving radioactive or other hazardous materials. There are currently no planned experimental or test activities at the WIPP. Therefore, Criterion h.(4) is not applicable to the WIPP.

Criterion h.(5)

Criterion h.(5) applies to fissile material handling facilities and is only related to inadvertent criticality protection. Inadvertent criticality is not a credible hazard at the WIPP. Inadvertent criticality is controlled through the ACs Criticality Program in conjunction with the Waste Characteristics program which conforms to the WIPP Waste Acceptance Criteria (WAC).[3] Therefore, Criterion h.(5) is not applicable to the WIPP.

1.6 Surveillance Requirements (SRs)

As defined in DOE Order 5480.22,[1] SRs relate to testing, channel calibration, channel operational testing, or inspection to maintain the operability, quality, and safety of SSCs and their support systems. SRs are defined as the requirements necessary to maintain facility operation within the SLs, LCSs, and LCOs. Selection criteria for SRs are defined in DOE Order 5480.22.[1]

Without SLs, LCSs, and LCOs for the WIPP facility, SRs are not required.

1.7 Administrative Controls (ACs)

As discussed in Section 2.4 of Attachment 1 of DOE Order 5480.22,[1] ACs impose necessary requirements controlling operation of the facility to meet all TSR requirements. Without SLs, LCSs, LCOs, and SRs, WIPP specific ACs impose administrative and operational requirements supporting the WIPP defense-in-depth concept.

Supporting the first layer of defense in depth (the prevention of accidents) as defined in SAR[2] Section 5.1.6, WIPP TSR ACs are established as follows:

- To maintain the design, quality, testability, inspectability, OPERABILITY, maintainability, and accessibility of the facility, TSR ACs are required relating to: (1) configuration and document control, (2) maintenance, and (3) quality assurance.

- To ensure that the facility operations are conducted by trained/certified personnel, TSR ACs are required relating to: (1) facility operations chain of command and responsibilities, (2) facility staffing requirements, (3) procedures, (4) staff qualifications, (5) conduct of operations, and (6) training.

- To ensure the administrative accident prevention measures are maintained, TSR ACs are required relating to: (1) waste characteristics (WIPP WAC),[3] (2) waste container integrity, and (3) criticality safety.

Supporting the second and third layers of defense in depth, WIPP TSR ACs are identified which establish programs for radiation protection (including radiation monitoring equipment and airborne radioactivity monitoring), and emergency management.

2 Safety Limits

No SLs are defined for the WIPP facility.

3/4. Operational Limits and Surveillance Requirements

No LCSs or LCOs are defined for the WIPP facility.

Because no OPERATIONAL LIMITS have been defined for the WIPP facility, no SRs are needed.

5 Administrative Controls

5.1 Facility Operations Chain of Command and Responsibilities

Facility Manager (FM)

The FM shall be responsible for overall WIPP facility operation. The FM shall delegate in writing the succession to this responsibility during his/her absence. The Manager of the Operations Department of the Management and Operations Contractor (MOC) is the FM for the WIPP facility operation.

The Operations Department section managers are responsible for reporting plant status to the FM, and resolving issues as they arise.

Facility Shift Manager (FSM)

The FSM shall be responsible for operation of facility equipment and systems during normal and emergency situations. The FSM directs shift personnel through approved plans, procedures, and instructions. The FSM is the senior manager on shift during periods other than normal working hours and reports to the FM through the organizational structure.

5.2 Facility Staffing Requirements

The MOC organizational structure, responsibilities, and staffing qualifications are described in Chapter 8 of the SAR.[2] The minimum required operating staff to maintain the facility in a safe condition is specified below. The minimums are based on conducting waste handling operations in series (e.g., completing surface waste handling activities before beginning underground waste handling activities) from a single TRUDOCK position. The personnel performing surface waste handling activities may perform underground waste handling activities providing surface waste handling activities are completed. When parallel waste handling activities are occurring at two or more TRUDOCK positions, additional staff is required to provide the minimum concurrent coverage for surface and underground waste handling activities. In addition to the minimum operating staff, adequate staffing will be available to implement and maintain the TSR ACs when required.

5.2.1 Waste Storage/Disposal Mode Staffing Requirements

Facility Shift Manager

Central Monitoring Room Operator

Surface Roving Watch

Emergency Safety Technician

5.2.2 Waste Handling Mode Staffing Requirements

5.2.2.1 Surface Staffing Requirements

Staffing requirements from Waste Storage/Disposal Mode plus:

Waste Handling Supervisor

Facility Operations Shift Engineer

Health Physics Technician (one for the controlled area)

Health Physics Technician (one per TRUDOCK position in operation)

Waste Handling Technician (two per TRUDOCK position in operation)

5.2.2.2 Underground

Staffing requirements from Waste Storage/Disposal Mode plus:

Waste Handling Supervisor

Facility Operations Shift Engineer

Health Physics Technician (one for the controlled area)

Health Physics Technician (one for each waste handling area)

Waste Handling Technician (two for each waste handling operation)

Underground Facility Operations Engineer

Underground Roving Watch

5.3 Facility Staff Qualifications

Each member of the WIPP facility operation staff and technical support personnel shall meet or exceed the minimum qualifications as prescribed in job descriptions established and maintained under the direction of the manager of Human Resources.

5.4 Nuclear Review Board (NRB)

The NRB shall have a documented Charter and Scope as follows:

- Provide policy guidance in areas involving nuclear and/or occupational safety, and surety of TRU waste handling/disposal operations,
- Conduct formal reviews of activities or issues having nuclear/occupational safety or environmental significance.

5.5 Reportable Occurrence Action

Procedures shall be established, implemented, and maintained for the administration of reportable occurrence actions.

5.6 TSR Violations

Since SLs, LCSs, LCOs, and SRs are not required for the WIPP, failure to comply with an AC requirement directly applicable to: (1) the TRU waste handling process, and (2) facility conditions directly supporting the waste handling process, constitutes a TSR VIOLATION. A procedure shall be established, implemented, and maintained for the reporting of TSR AC VIOLATIONS.

If a TSR AC is violated, the following actions shall be performed:

1. Place the facility in the Waste Storage/Disposal MODE.

2. Report the VIOLATION in accordance with the above required reporting procedure.

3. Prepare a recovery plan describing steps that will reinstate compliance with the TSR AC.

4. Perform and document a technical evaluation, if appropriate, of the TSR AC VIOLATION to determine if an Unreviewed Safety Question exists.

5.7 Revisions to the TSR

All proposed changes to the TSR shall be submitted to the DOE for approval prior to implementation of the revision. Such submittals shall include the bases for the proposed revision.

5.8 Programs

5.8.1 Configuration Control

A Configuration Control Program and associated procedures shall be established, implemented, and maintained to control designs, modifications, and procurement to ensure that the WIPP facility remains consistent with the design features assumed in the SAR.[2]

5.8.2 Document Control

A Document Control Program and associated procedures shall be established, implemented, and maintained to control WIPP documents. The program shall establish minimum review and approval requirements, change control, and minimum record retention requirements for the WIPP.

5.8.3 Maintenance

A Maintenance Program and associated procedures shall be established, implemented, and maintained to ensure that routine, corrective, and preventative maintenance, inspection, testing, and calibration activities are controlled.

5.8.4 Quality Assurance Program

A Quality Assurance Program and associated procedures shall be established, implemented, and maintained.

The Quality Assurance program should contain elements that describe or provide reference to organizational structure, functional responsibilities, levels of authority, and interfaces. The description should include the onsite and offsite organizational elements that function within the scope of the program.

The basic elements of the Quality Assurance program should encompass, as applicable, work such as planning; training and personnel development; preparing, reviewing, approving, and verifying designs; qualifying suppliers; preparing, reviewing, approving, and issuing instructions, procedures, schedules, and procurement documents; purchasing; verifying supplier work; identifying and controlling hardware and software; manufacturing; managing and operating facilities; calibrating and controlling measuring and test equipment; conducting investigations and acquiring data; performing maintenance, repair, and improvements; performing assessments; and controlling records.

5.8.5 Procedures

Procedures shall be established, implemented, and maintained for WIPP TRU waste handling and disposal related activities. A system shall be developed and established to control such procedures in support of the WIPP facility operation, including the mechanism of review, approval, revision, control, and temporary changes.

5.8.6 Training

A Training Program for the WIPP facility operation staff and technical support personnel shall be established and maintained.

5.8.7 Conduct of Operations

The Conduct of Operations program shall contain elements of organization and administration of facility operations to ensure that a high level of operations is achieved through effective implementation and control of operations activities. The program shall provide for the establishment, implementation, and maintenance of the required procedures.

Effective implementation and control of operating activities are primarily achieved through established written standards for operations, periodic monitoring and performance assessment, and holding personnel accountable for their performance.

The basic elements of the Conduct of Operations program should include, as applicable, guidance for: operations organization and administration; shift routines and operating practices; control area activities; communications; control of on-shift training; control of equipment and system status; lockouts and tagouts; independent verification; log keeping; operations turnover; timely orders to operators; operations procedures; operator aid postings; and equipment and piping labeling.

The concern for the protection and safety of the worker, the public, and the environment shall be a major input to the Conduct of Operations program.

5.8.8 Emergency Management

An Emergency Management Program and associated procedures shall be established, implemented, and maintained that provides preparedness, training, and operational response capabilities to minimize consequences to workers and the public from accidents involving WIPP operations.

5.8.9 Radiation Protection

A Radiation Protection program and associated procedures shall be established, implemented, and maintained to ensure personnel radiation protection for all operations involving personnel radiation exposure.

The basic elements of the Radiation Protection program should encompass, as applicable, the specifications of: policy considerations and general facility design features employed to maintain radiation exposures ALARA; radiological control zoning and access control; radiation shielding; ventilation systems; differential pressure; radiation monitoring equipment including area radiation and airborne radioactivity monitoring; and effluent monitoring systems.

5.8.10 Waste Container Integrity

Procedures shall be established, implemented, and maintained to ensure WASTE container integrity from the time a WASTE container is no longer sealed inside an authorized transport package (DOT Type B) until it has been emplaced in the underground disposal area.

The basic elements of this program should include the following requirements:

- Transport packaging (TRUPACT-IIs) loaded with materials intended for disposal at the WIPP facility shall not be opened outside the designated WIPP Controlled Area (CA).

- WASTE containers intended for disposal at the WIPP shall not leave the boundaries of the CA unless they are inside a sealed TRUPACT-II. If a WASTE container is outside the CA and is not sealed inside a TRUPACT-II, it shall immediately be returned to the CA or sealed inside a TRUPACT-II.

- CH WASTE containers (drums or boxes) received at the WIPP for disposal shall be isolated from the WASTE handling process if they are found to exceed any of the following criteria:

  1) The removable surface contamination limits of the WIPP WAC[3]

  2) The surface contact dose rate limits of the WIPP WAC[3]

  3) A known or suspected breach of container integrity

- Decontamination to below the allowed surface activity levels, shielding to below 200 mrem/hr contact dose rate, or sealing inside another container to meet the listed criteria (overpacking), as appropriate, shall be performed prior to returning the containers to the WASTE handling process.

5.8.11 Criticality Safety

A Criticality Safety program and associated procedures shall be established, implemented, and maintained to ensure the prevention of accidental criticality at the WIPP facility. The basic elements of this program shall include the following criticality safety configuration requirements which apply at all times:

CH WASTE package configuration:

- Fissile loading shall not exceed 200 grams per 55-gallon drum.
- Fissile loading in WASTE boxes approximately equal to or greater in size than the TRUPACT-II SWB design shall not exceed 325 grams per box.
- Drum arrays shall not exceed 16 drums wide or 3 drums high. Drum arrays may be of any length.
- Box arrays shall not exceed seven boxes wide or three boxes high. Box arrays may be of any length.
- WASTE drums shall be stacked only in the vertical position (longest dimension vertical).
- WASTE boxes shall be stacked only in the normal horizontal position (longest dimension horizontal).

5.8.12 Waste Characteristics

A Waste Characterization Program shall ensure that only wastes that are compatible with the design, operation and long-term performance of the WIPP facility are shipped to WIPP and that any exceptions are weighed against all applicable baseline documents prior to their authorization for shipment.

Procedures shall be established, implemented, and maintained to ensure that the following WIPP WAC[3] requirements apply to all WASTE that is to be shipped to the WIPP are implemented:

- The WASTE accepted for placement in the WIPP facility must conform with the WIPP WAC[3] unless an exception to the WAC has been approved as a result of examination in relation to the SAR.[2] Specific criteria used in the development of the safety analysis are as follows:

  - Waste Containers
    1. Containers shall be noncombustible and meet DOT Type A packaging requirements.
    2. Limit acceptable containers to 55-gallon drums and standard waste boxes (SWBs).

  - Liquids
    1. Only residual liquids; as a guideline, residual liquid in well-drained internal containers to be restricted to approximately 1 volume % of the internal container; aggregate amount of residual liquid <1 volume % of external container.

  - Pyrophoric Materials
    1. No non-radionuclide pyrophorics permitted. Radionuclides in pyrophoric form are limited to $<1\%$ by weight in each waste package.

- Explosives and Compressed Gases
  1. No explosives or compressed gases are permitted.

- TRU Mixed Wastes
  1. TRU wastes shall contain no hazardous wastes unless they exist as co-contaminants with transuranics.
  2. Characteristic ignitable (D001), corrosive (D002), and reactive (D003) wastes are not acceptable at WIPP.

- Specific Activity of Waste
  1. Waste shall be greater than 100 nanocuries of TRU per gram of waste, exclusive of added shielding, rigid liners, and the waste containers, including alpha contaminated wastes handled.

- Nuclear Criticality (Pu-239 FGE)
  1. Accepted package limits, including two times the error, are:
     a. <200g/55-gallon drum
     b. <325g/SWB

- Pu-239 Equivalent Activity
  1. Waste packages shall not exceed 80.0 Ci and 130 Ci of Pu-239 equivalent activity (PE-Ci) for drums and SWBs, respectively.

- Surface Dose Rate
  1. Drums or SWBs shall not exceed 200 mrem/hr surface reading, or 10 mrem/hr at 2 m.

- Gas Generation
  1. All waste packages shipped shall be vented with one or more filters.

- Data Package/Certification
  1. A data package with certification shall be transmitted prior to shipment.

- In addition to the SAR, all exceptions shall be evaluated against the WIPP facility Operational, Health, and Safety Requirements; the Final and Supplement Environmental Impact Statements; agreements with the state of New Mexico; the No-Migration Determination; the Performance Assessment; RCRA requirements; and any applicable regulations before approval to ship is granted.

- Radioactive mixed WASTE shall be managed in accordance with the applicable regulations of the U.S. Environmental Protection Agency and the state of New Mexico.

- All WASTE containers to be shipped to the WIPP facility shall be vented.

5.8.13 Unreviewed Safety Questions

An Unreviewed Safety Question program and associated procedures shall be established, implemented, and maintained that maintains the facility consistent with the SAR and design features.

6 References

1 DOE Order 5480.22, Technical Safety Requirements, September 15, 1992.

2 WIPP Safety Analysis Report, DOE/WIPP 2065.

3 WIPP-DOE-069, Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 4, December 1991.

APPENDIX A

BASES

APPENDIX A BASES

This appendix is utilized to provide summary statements of the reasons for the OPERATIONAL LIMITS and the associated SRs. No OPERATIONAL LIMITS or associated SRs have been identified for the WIPP. Accordingly, no BASES statements are presented in this appendix.

APPENDIX B

DESIGN FEATURES

APPENDIX B DESIGN FEATURES

The provisions of the DESIGN FEATURES are present in the DOE-approved WIPP SAR, Chapter 4. As stated in DOE Order 5480.22, Attachment 1, paragraph 2.6, this DESIGN FEATURES appendix is not needed.