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June 2007

Performance Confirmation Test Plan for Seismicity Monitoring

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Performance Confirmation Test Plan for

Seismicity Monitoring

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Sandia National Laboratories

Performance Confirmation Test Plan for SEISMICITY MONITORING

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CHANGE HISTORY

Revision Number	ICN Number	Date of Change	Description of Change
00	00	06/29/2007	Initial issue A portion of the scope of this test plan was initiated during site characterization and is continued under auspices of the performance confirmation program.

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FIGURE

TABLES

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ACRONYMS

DOE	U.S. Department of Energy
ECRB	Enhanced Characterization of the Repository Block (drift)
FEPs	features, events, and processes
FWP	field work package
GMPE	ground motion probability evaluation
IP(s)	implementing procedure(s)
ITBC	Important to Barrier Capability
LA	license application
M	magnitude of a seismic event
NRC	U.S. Nuclear Regulatory Commission
PC	Performance Confirmation
PCTP	Performance Confirmation Test Plan
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
PI	principal investigator
PSHA	Probabilistic Seismic Hazard Analysis
QA	quality assurance
QARD	Quality Assurance Requirements and Description
RPC	Records Processing Center
SGBDSN	Southern Great Basin Digital Seismic Network
SIP	Site Investigation Plan
TCO	Test Coordination Office
TDMS	Technical Data Management System
TSPA	total system performance assessment
TTF	Thermal Test Facility
TWP	technical work plan
UNR	University of Nevada–Reno
YMP	Yucca Mountain Project
YMRP	Yucca Mountain Review Plan, Final Report

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1. WORK SCOPE

1.1 INTRODUCTION

1.1.1 Background

Seismic monitoring is one of 20 testing and monitoring activities currently included in the *Performance Confirmation Plan* (BSC 2004 [DIRS 172452]). Collectively, these activities make up the performance confirmation (PC) program described in the plan. Each activity will have one or more separate test plans called a PC Test Plan (PCTP). The PC program was started during site characterization (consistent with regulation 10 CFR Part 63 [DIRS 180319]),), is responsive to 10 CFR 63.132(a) and (b), and may continue until permanent closure of the repository (10 CFR 63.131(b) [DIRS 180319]).

The activity description in *Performance Confirmation Plan* (BSC 2004 [DIRS 172452]) describes the seismicity monitoring activity as follows:

> "This activity includes monitoring regional seismic activity. It also includes observation of subsurface and surface fault displacement after significant local or regional seismic events. Candidate parameters that may be measured include: event detection, event magnitude, event location, strong-motion data collection and analysis, and seismic attenuation investigations (within 50 km). This activity addresses disruptive influence that could impact the lifetime of the Engineered Barrier System as a result of seismic events. This long-term field data collection activity provides direct measurements that represent the temporal and spatial scale over the area of the repository during the monitoring. Seismic monitoring began during site characterization. The existing seismic monitoring system (the Southern Great Basin Digital Seismic Network-SGBDSN) may be maintained through closure of the repository."

Over 100 years of relevant seismic historical data is available. The current seismic monitoring effort is a continuation of an ongoing study that was initiated in the 1980s. The study data, supplemented by historical data, have been used to develop a probabilistic seismic hazard analysis (PSHA), which in turn has been used to prepare drift degradation analyses to support design and performance analyses for the repository. Based on this work, there is predicted to be a low potential that there will be significant rockfall or rock instability due to seismic activity during the repository monitoring period of approximately 100 years.

10 CFR 63.102(m) states in part that "a performance confirmation program will be conducted to evaluate the adequacy of assumptions, data and analyses that led to the findings that permitted construction…..". To support, in part, the above conclusion, the PC plan purpose states that, "Seismic parameters for nominal earthquakes (i.e., location, size, style, and number) will continue to be collected continuously during construction and operation of the repository using automated equipment. Field observation data will be collected for any fault displacements that occur after any significant local or regional seismic event." In the absence of an extreme event or events during the planned monitoring period, data collected as a part of the performance confirmation program will provide evidence of trends in repository behavior in response to

seismic events over a range of annual exceedance probability conditions. Trend analyses will make a significant contribution to the "...evaluation of the adequacy of assumptions, data and analyses..." noted above.

An original set of PC activities was identified, as an effective means of obtaining data relevant to repository performance, during the course of a multi-attribute decision analysis process described in Revision 2 of *Performance Confirmation Plan* (BSC 2003 [DIRS 166219]). Modifications to the original activity set were subsequently made during technical and management reviews (documented in revisions to *Performance Confirmation Plan* (BSC 2004 [DIRS 172452])).

1.1.2 Summary

This seismicity monitoring activity has two primary goals. The first goal is to collect, analyze, and report on seismic activity in the vicinity (especially within a 50km radius) of the repository (including observation of any measurable fault displacement after local or regional seismic events). This will provide data to help confirm the validity of the probabilistic seismic hazard analysis (CRWMS M&O 1998. *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada.* September 23, 1998 [DIRS 103731].

The second goal is to alert the Project to conditions (seismic activity levels) under which damage, if any, in the underground facilities will be evaluated following significant seismic events. This evaluation will provide data intended to confirm that predictions regarding underground stability in response to seismic events are valid and also that the ability to retrieve waste from the repository has been preserved. Information from this activity will be evaluated in combination with that obtained from other PC program activities to achieve PC goals. Relationships with other PC program activities (i.e., drift inspection, subsurface mapping, construction effects monitoring) will be described and explained when identified in this test plan.

It should be noted that seismic monitoring instrumentation will be installed in and/or near to repository surface facilities. Current planning is to install both surface-based and subsurface seismic monitoring instrumentation. The purpose of that instrumentation is to provide seismic data needed to support surface facility operations and satisfy NRC requirements. While the scope of this PC Test Plan is focused on subsurface performance, it is important that the subsurface and surface data systems be coordinated to avoid conflicting requirements and provide for effective use of the data. The seismic monitoring network operated by the University of Nevada-Reno (discussed in the following sections) is a regional network which includes repository area instruments. The above surface-based monitoring may provide additional data at the local site that could be of value in data analysis under this test plan.

Data from this PC activity (as well as data obtained from the other currently defined PC activities) will be evaluated in the context of overall repository performance. Observed ground motion and fault displacement will be compared to values used in design, safety and performance analyses.

In response to the regulatory requirements discussed below, this PCTP defines monitoring scope, parameters, and methods. It also includes data evaluation criteria with reporting and action processes. If conditions or observations found during the monitoring activity are outside the expected ranges defined herein (expected ranges selected as "non-problem" ranges), appropriate evaluations and reporting to the U.S. Department of Energy (DOE) are required. If conditions are found that are outside the condition limits defined herein (condition limits selected as potential "challenge" ranges to predicted performance), reporting to the DOE and the U.S. Nuclear Regulatory Commission (NRC) are required in accordance with the interface embodied in AP-REG-009, *Reportable Geologic Condition*, and as described herein.

The monitoring of seismic activity is currently performed by the University of Nevada–Reno (UNR). In addition to the operation of the seismic network, UNR has a shared principal investigator (PI) responsibility with the Lead Laboratory. On-site activities, including the inspections of underground openings and related on-site functions, are the responsibility of the Lead Laboratory. On-site activities will also include seismic network maintenance by UNR.

Portions of this activity began during site characterization, including the use of data obtained from the Southern Great Basin Digital Seismic Network (SGBDSN) operated by UNR. A discussion of seismicity at Yucca Mountain is provided in *Characterize Framework for Seismicity and Structural Deformation at Yucca Mountain, Nevada* (BSC 2004 [DIRS 168030]).

A brief description of the Yucca Mountain seismic monitoring carried out using the SGBDSN is given in Section 2. Operation of the SGBDSN is performed in accordance with *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]). Location coordinates for the current seismic monitoring stations of the SGBDSN are provided in DTN: MO0207UCC012DV.010 [DIRS 166427].

Data are currently monitored continuously and archived at the UNR laboratory. Data from that monitoring form part of the database for this PC activity. Current planning is to continue using the SGBDSN system for this activity. It is anticipated that the seismic monitoring activity may be performed throughout the preclosure period for the repository.

1.2 OVERALL TECHNICAL/ PERFORMANCE REQUIREMENTS/OBJECTIVES

PCTPs are created in support of the DOE as a license applicant to the NRC. Whereas site characterization activities provided the bases for modeling assumptions supporting the LA, the PCTPs support a regulatory requirement to evaluate the continued adequacy of the information used to demonstrate compliance with the performance objectives in the regulation. A functional framework for implementation requires a specific management structure (Section 1.6) and a detailed technical pathway from the PC work through design analyses used in the license application (LA) and analysis and model reports supporting the total system performance assessment (TSPA). Relevance to performance assessment is discussed in Section 2.5.

1.2.1 Technical and Performance Requirements

Requirements for the PC program are contained in regulation 10 CFR 63 [DIRS 180319]. The purpose and objectives of the program are defined in 10 CFR 63.102(m). Detailed requirements for the PC program are specified in 10 CFR 63, Subpart F. Guidance for the PC program is also provided in *Yucca Mountain Review Plan, Final Report* (YMRP) (NRC 2003 [DIRS 163274]). A description of the PC program is required in the safety analysis report as part of the LA

(10 CFR 63.21(c(17)). Regulatory performance objectives for the overall repository are stated in 10 CFR 63, Subpart E.

This activity addresses (with regard to seismic events) 10 CFR 63.131 and 63.132, which require that the PC program provide data that indicate that natural and engineered systems are functioning as intended and that (seismic) design parameters are confirmed. Several other PC program activities will provide relevant data as described in the following sections.

In addition, 10 CFR 63.111 requires preservation of the option to retrieve waste until completion of a PC program and the Commission review of the information is obtained from such a program. This activity will be responsive, in part, to this requirement by confirming seismic event tunnel stability analysis (*Drift Degradation Analysis* (BSC 2004 [DIRS 166107)). The engineering design analyses in *Ground Control for Emplacement Drifts for LA* (BSC 2004 [DIRS 170292]) and *Ground Control for Non-Emplacement Drifts for LA* (BSC 2004 [DIRS 168178]) support the LA. These analyses form the basis for the underground excavated opening support system that is designed to withstand preclosure seismic events with no structural support failure.

1.2.2 Objectives

The overall objective of this seismicity monitoring activity is to respond to the requirements of 10 CFR 63.131(a)(1) and (2) and 10 CFR 63.132(a) and (b) by monitoring and documenting seismic events and observing the behavior of repository underground elements (barrier system elements) in response to those events. The scope of work for this activity is to monitor seismic activity in the vicinity of the repository and perform inspections of selected underground openings following a significant seismic event or events. More specifically, the data and information gathered under this PC activity will be used to achieve the following objectives:

- Confirmation that seismic activity is within the predicted input parameter ranges used in the PSHA. The confirmation will ensure that information used for predicting the magnitude and frequency of events, as part of the PSHA process, is valid. Results of the PSHA are the basis for inputs to site-response modeling that provides ground motions used in design and TSPA analyses. Confirmation may continue throughout the preclosure period.

- Confirmation that observed ground motion spectra are within the predicted input parameter ranges used in design. This will ensure that seismic loads used in design analyses are appropriate and sufficient. Confirmation may continue throughout the preclosure period.

- Confirmation (in part) of model predictions of seismic site response as recorded in analysis and model reports that were used for the LA. The monitoring results will be compared to model predictions and to the assumptions, data, and analyses supporting the models. Indications of impact on model input data and predictions will be reviewed by the PC organization for further action as described herein.

- Data will be combined with observations of the condition of the underground openings following significant seismic events. Observation of no significant damage from these events will provide confirmation, in part, of design predictions and the preservation of the infrastructure necessary to retrieve stored material until permanent closure. Observations of tunnel degradation and condition of engineered systems elements will be part of the information needed to address whether design system performance has been maintained following significant events.

- Measurement of the amplitude of underground accelerations for significant seismic events that will demonstrate the conditions that the tunnel experienced. Even though conditions might be less than expected to cause rockfall, rockfall might still occur and the level of shaking is the critical parameter for understanding what occurred.

- Identification of fault displacements, including evidence of surface displacement, as soon as practicable following significant seismic events. Measurable fault displacement(s) within the waste emplacement area following a seismic event(s) is not expected since fault displacement(s) are associated with extreme (very low probability) seismic events.

Monitoring of seismic activity is expected to provide initial confirmation of normal or expected activity levels, and inspections of underground elements following significant events should provide confirmation of the predicted behavior of those elements in response to the events. (Inspections of underground openings will be conducted in accordance with *Technical Work Plan for: Construction Effects Monitoring* (BSC 2006 [DIRS 177500]) and a future test plan for drift inspections.)

The seismic monitoring program will be routinely tracked and the results included in regular performance confirmation annual reports. Observational information collected following significant seismic events will be documented in the annual reports. Data and observations outside of expected ranges will receive special attention and will be evaluated as described in Section 2.4. Results that depart appreciable from the seismic information used for the license application, will be reported in accordance with AP-16.1Q, *Condition Reporting and Resolution,* and/or AP-REG-009, as discussed in subsequent sections of this test plan.

1.3 CATEGORY OF ACTIVITY

This test plan does not involve the development of new models. Analyses and calculations will be performed that are categorized as Routine Analysis/Calculation per SCI-PRO-002, *Planning for Science Activities.*

1.4 MAJOR ACTIVITIES

1.4.1 Primary Tasks

The primary tasks covered by this test plan are as follows:

Seismic Network Operations--The existing area/regional seismic monitoring network (SGBDSN) is operated by UNR. The operation of the SGBDSN is covered by SIP-UNR-

027. This document, along with other sub-tier procedures, will be transitioned to the Lead Laboratory document system in accordance with applicable quality assurance (QA) procedures. Table 2-1 lists the parameters to be monitored under this test plan. The task includes:

- Continuous seismic monitoring and maintenance of the seismic network
- Data collection and data management, including data submission to the Records Processing Center (RPC) and the Technical Data Management System (TDMS)
- Data analysis and screening of seismic activity and earthquake spectra for unexpected events
- Participation with the Lead Laboratory for data analysis, evaluation, reporting, and courses of action to address unexpected events
- **On-site Operations**—Field Work Packages (FWPs) will be used to implement tasks requiring on-site activities. The tasks associated with on-site monitoring and inspections (i. e., non-network activities) following a significant seismic event and covered by this PCTP are listed in Tables 2-3 and 2-4.

1.4.2 Possible Future Operations

Additional types of monitoring procedures, monitoring instrumentation, or different data collection techniques may be incorporated to ensure that data continue to be sufficient to confirm the licensing basis, respond to changes in requirements, and take advantage of improved technologies. In the event that future data links to the UNR system are added on site, controlled procedures will be developed as required. Consistent with this PCTP, this activity will implement appropriate technological advancements as part of continued viability and enhanced reliability of the system. System upgrades would not change the acquisition of the fundamental PC information.

1.5 FEATURES, EVENTS, AND PROCESSES

The method selected to address regulatory requirements for repository performance is to ascribe performance to a set of three barriers (i. e., upper natural barrier system, engineered barrier system, and lower natural barrier system). Each barrier has been evaluated as to its performance in terms of associated features, events, and processes (FEPs). The characteristics of each FEP in terms of effects on barrier performance have been identified for performance evaluation purposes. See Section 2.5 for further discussion of the relevance of FEPs to performance assessment.

1.6 ORGANIZATIONAL RESPONSIBILITIES

This PC activity requires integration and support from several project entities and off-site organizations. As previously stated in Section 1.1, seismic network operations (as well as shared PI functions) are the responsibility of UNR. On-site activities and related work elements, including shared PI functions, are the responsibility of the Lead Laboratory. Specific interfaces will be further defined in future implementing documents, including FWPs, which will provide details on field interactions, data handoffs, and coordination aspects of the field work.

The Lead Laboratory Performance Confirmation organization is responsible for implementing the PC program as described in the *Performance Confirmation Plan* (BSC 2004 [DIRS 172452]). The PC organization assumes overall project management for the program and provides the central interface between the PIs, performance assessment modelers, Test Coordination Office (TCO), and the DOE. The PC organization is responsible for preparing and approving this PCTP, has a shared (with UNR) PI responsibility, and is charged with ensuring communication and agreement between the above organizations, arranging for the technical review of the field results as they become available, and updating testing and monitoring strategies, as necessary. The PC organization is responsible for notifying the DOE in accordance with AP-REG-009 if informed by the PIs that field results are found outside expected ranges or condition limits (as defined herein). UNR shares the PI responsibilities for this activity with the Lead Laboratory Disruptive Events Group. In addition to their responsibility for the operation of the seismic monitoring network (which includes evaluation and analysis of seismic data and on-site network maintenance), UNR shares responsibility with the Disruptive Events Group for assisting in the preparation of this PCTP, including the establishment of expected range limit values, condition limit values, and the development of reporting protocols.

Entities currently having responsibilities associated with field activities include the PI(s), Performance Assessment Department, Licensing Department, Test Coordination Department, and Site Manager. The principal off-site organization is UNR as described herein. Additional off-site organizations could include Nye County, University of Nevada–Las Vegas, U.S. Bureau of Reclamation, and U.S. Geological Survey (for interpretation of fault displacement data and water level measurements associated with significant seismic events). Geotechnical personnel from various organizations will provide mapping of the subsurface under a separate (future) test plan or technical work plan (TWP). Mapping data will supplement the evaluation of the data collected in this test plan. These personnel may also be called upon for identification or interpretation of geologic conditions described in the PC plan. The Lead Laboratory will designate entities to be responsible for measurement and reporting of fault offsets, convergence pin measurements, and drift inspections following seismic events.

Other PCTPs (e. g., Construction Effects Monitoring, Drift Inspection) will be used to describe field measurements and observations. The Test Coordination Department is currently responsible for the overall field oversight and work management, coordination, and monitoring of field test activities. This includes the installation and maintenance of test equipment and the department would be available to assist UNR with the installation of seismic-related equipment.

Presently, all site-required interfaces, including access and craft support, are provided by the Site Manager. Site management is composed of multiple departments that are responsible for providing site infrastructure/access, logistics, craft labor, and emergency response to support testing. Site management support specific to testing activities is requested, planned, scheduled, and conducted in accordance with OP-PRO-9101, *Work Control Process*, and consistent with baseline budget and resource levels integrated within a Test Coordination Department work package.

Repository engineering, repository construction, and repository operations will have responsibilities in the future related to this work scope as this monitoring is planned to run throughout the construction and operations period. A PC integration group will be developed, consistent with the PC plan, to review PC data and evaluate the overall status of the program. In addition, the group will be designed to ensure continuity and integration with other testing and monitoring programs. The integration group will evaluate whether the incremental results within PC are interrelated, technically adequate, properly documented, and properly evaluated. This evaluation will ensure that barrier and system performance is assessed in the context of all relevant PC information. The integration group will also assist the PC organization with reviews of the effectiveness of existing measurement techniques and possible applications of new technologies. The integration group, using a workshop approach, will facilitate the use of new technologies and the improvement of the PC knowledge base.

1.7 QUALITY ASSURANCE

This activity is subject to the requirements of *Quality Assurance Requirements and Description* (QARD) (DOE 2006 [DIRS 177092]). This PCTP for seismicity monitoring was prepared in accordance with SCI-PRO-002. The UNR currently operates in the Yucca Mountain program as a Qualified Supplier, which utilizes a QA program that adequately complies with QARD (DOE 2006 [DIRS 176927]). If the UNR is contracted with the Lead Laboratory, they will implement the Lead Laboratory Quality Assurance Program.

2. SCIENTIFIC APPROACH/TECHNICAL METHODS

2.1 ACTIVITY PURPOSE AND BASIS FOR SELECTION

2.1.1 Activity Purpose

The objectives of this activity are described in Section 1.2. The purpose of this activity is to monitor and document seismic events and the response of repository underground elements to those events.

A major purpose is to provide data to confirm the validity of the Probabilistic Seismic Hazard Analysis (PSHA) (*Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada.* September 23, 1998 [DIRS 103731]). The PSHA for Yucca Mountain developed a series of hazard curves that gives the annual probability of exceeding a level of ground motion. The hazard curve is a monotonically decreasing function of a ground motion intensity measure, such as peak acceleration, peak velocity, or a spectral amplitude. Combining the results of the PSHA with ground motion site-response modeling provides ground motion inputs used for design and performance assessment analysis. An important purpose of this Seismic Monitoring Test Plan is to provide the means for recognizing whether any new information, resulting from ongoing earthquakes, would significantly affect the PSHA hazard curve that form the foundation for ground motions used for the repository design.

The users/customers of results of this activity include the DOE, NRC, Lead Laboratory operations, repository project management (including operations and safety), design, and others. Relationships with affected organizations are discussed in Section 1.6.

The parameters to be monitored are identified in Tables 2-2 and 2-3. A description of the individual monitoring requirements, monitoring instructions, predictions of expected results, evaluations of actual results, and responses to actual results are provided herein. The basis for selection of these parameters is described in the following section.

2.1.2 Basis for Selection

This seismicity monitoring activity was originally selected as a part of a multi-attribute decision analysis process described in *Performance Confirmation Plan* (BSC 2003 [DIRS 166219], Appendix B). The activity was retained during the course of a series of technical and management reviews (documented in subsequent revisions to the PC plan) and determined to be a relevant and effective method for evaluating elements of repository performance (e.g., it can provide inputs to drift degradation analyses).

Seismicity monitoring will provide data on local and regional seismic activity and spectra that will be important in assessing the assumptions, data, and analyses used to design the surface and underground facilities and evaluate the performance of the repository. The repository design and performance analyses have used risk-informed seismic parameter choices, such as PGA and PGV values, associated with relatively low probability of occurrence seismic events (1×10^{-3} and 5×10^{-4} per year and lower). Seismic monitoring results during the preclosure period are expected to confirm the consistency of seismic activity and spectra with those assumptions and data (i.e., events with expected ranges as defined herein). The monitoring may also provide, over the extended preclosure period (e.g., about 100 years), an opportunity to look for trends in frequency, magnitude, and location of seismic events in the repository region that differ from the assumptions and data used to design the repository.

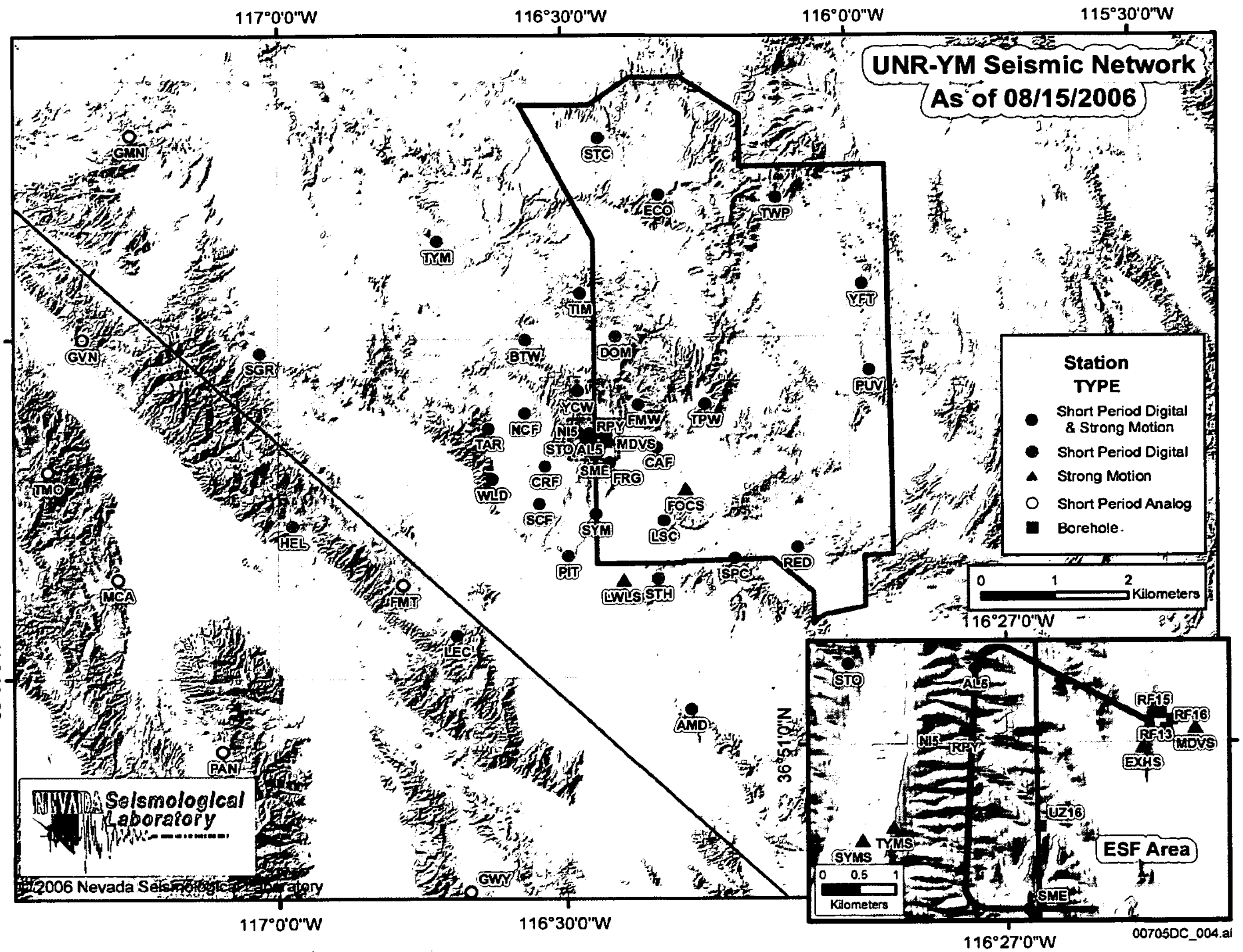
2.1.3 Parameter Measurement Justification

The data collected as part of the scope of this PCTP are needed for comparisons with the licensing design bases and assumptions with regard to seismicity and spectra. These comparisons will tend to confirm that the collected data are either consistent with the information used in the designs and systems modeled in the TSPA to support the LA or appear to be inconsistent with that information, in which case further evaluation will be required. Measurement and evaluation of the seismic data collected (i.e., event frequency, locations, magnitudes, PGV values, and PGA values), along with underground opening stability observations and any collected fault displacement information, will also be used to assess postclosure seismic predictions.

2.2 SCIENTIFIC/TECHNICAL METHODS

A seismicity monitoring program was started as part of the site characterization program. The methods and instrumentation utilized have remained relatively consistent, which provides added confidence in the methods to be used in PC. With implementation of this PC plan, specific elements of that monitoring program have been formally incorporated into the current PC program in support of an LA.

The locations of the SGBDSN monitoring stations are shown in Figure 2-1. Station location coordinates are provided in Table 2-1. Consistent with SIP-UNR-027 [DIRS 170249] and best practice, earthquake locations and magnitudes will also use available contributing stations from the region around Yucca Mountain.



Source: UNR Seismological Laboratory Website.

Figure 2-1. SGBDSN and Contributing Seismic Monitoring Station Locations

Table 2.1a. SGBDSN Digital Stations with Weak-Motion Sensors:

Station	Latitude	Longitude	Elevation	Comment
AMD	36.4526	-116.2809	0.7754	[1]
BTW	36.9978	-116.5665	1.3910	[1]
CRF	36.8118	-116.5340	1.0320	[1]
DOM	37.0021	-116.4086	1.7110	[1]
FMW	36.9021	-116.3688	1.1460	[1]
HEL	36.7246	-116.9750	0.7470	[1]
LEC	36.5627	-116.6896	1.1130	[1]
NCF	36.8899	-116.5682	1.1510	[1]
PIT	36.6798	-116.4937	0.8500	[1]
PUV	36.9494	-115.9633	1.2530	[1]
RED	36.6895	-116.0930	1.1430	[1]
SGR	36.9805	-117.0327	1.5600	[1]
STC	37.2939	-116.4358	1.9600	[1]
STH	36.6457	-116.3375	1.0500	[1]
TAR	36.8680	-116.6322	1.2500	[1]
TIM	37.0667	-116.4694	1.8710	[1]
TPW	36.9016	-116.2519	1.5730	[1]
TWP	37.2047	-116.1234	1.5760	[1]
TYM	37.1441	-116.7208	1.4570	[1]

Table 2.1b. SGBDSN Stations with Both Weak and Strong-Motion Sensors

Station	Latitude	Longitude	Elevation	Comment
CAF	36.8391	-116.3377	1.1100	[1]
FRG	36.8169	-116.4195	1.1550	[1]
LSC	36.7307	-116.3255	1.2380	[1]
RPY	36.8515	-116.4563	1.3010	[1]
SCF	36.7568	-116.5440	0.9090	[1]
SPC	36.6746	-116.2030	1.0640	[1]
STO	36.8603	-116.4742	1.3590	[1]
SYM	36.7416	-116.4460	0.9950	[1]
YCW	36.9224	-116.4756	1.4980	[1]
WLD	36.7927	-116.6257	0.9300	[1]
AL5S	36.8596	-116.4547	1.3660	[2] Surface above ESF station AL5
NI5S	36.8523	-116.4619	1.4070	[2] Surface above ESF station NI5
SMES	36.8286	-116.4468	1.4390	[2] Surface above ESF station SME

NOTE: ESF = Exploratory Studies Facility

Table 2.1c. SGBDSN Stations in the ESF Tunnel with Both Weak and Strong-Motion Sensors

Station	Latitude	Longitude	Elevation	Comment
AL5	36.8596	-116.4547	1.0660	[1]
NI5	36.8523	-116.4619	1.1070	[2] Removed 2007 due to ESF closure
SME	36.8286	-116.4468	1.1390	[2] Removed 2007 due to ESF closure

Table 2.1d. SGBDSN Free-Field Strong Motion Stations

Station	Latitude	Longitude	Elevation	Comment
EXHS	36.8495	-116.4294	1.1780	[3]
LWLS	36.6445	-116.3976	0.8250	[3]
MDVS	36.8519	-116.4214	1.1120	[3]
SYMS	36.8377	-116.4723	1.3280	[3]
TYMS	36.8394	-116.4675	1.5060	[3]
FOCS	36.7779	-116.2867	1.0420	[3] Location until 4/2007; relocation pending

Table 2.1e. SGBDSN Borehole Strong-Motion Stations

Station	Latitude	Longitude	Elevation	Comment
RF13	36.8529	-116.4249	1.1190	[4] Surface and two depths.
RF15	36.8537	-116.4267	1.1220	[4] Surface and two depths.
RF16	36.8517	-116.4258	1.1190	[4] Surface and two depths.

Table 2.1f. SGBDSN Borehole Station, weak-motion sensors.

Station	Latitude	Longitude	Elevation	Comment
UZ16	36.8393	-116.4450	1.2120	[2] Surface and down-hole 3-C sensors

Table 2.1g. Contributing Digital Stations with weak-motion sensors operated by UNR, owned by others

NTS M&O – National Security Technologies				
Station	**Latitude**	**Longitude**	**Elevation**	**Comment**
ECO	37.2108	-116.3296	2.2320	[1] Echo Peak Northern NTS
YFT	37.0762	-115.9735	1.3540	[1] Yucca Flat; Northeastern NTS

NOTES:

[1] *Locations of Stations in the Southern Great Basin Digital Seismic Network* (MO0207UCC012DV.010 [DIRS 166427].

[2] TCO

[3] *Preliminary Data Gathering with the UNR/YMP Strong-Motion Network*, Scientific Notebook MOL.19980203-0705.

[4] Depths description in *Initial Borehole Accelerometer Array Observations Near the North Portal of the ESF* (von Seggern 2005 [DIRS 170522]). Locations in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

2.2.1 Monitoring Parameter Tables

As required in 10 CFR 63, PC should verify that information used in the LA remains valid. For the seismic design, the link between the monitoring of earthquakes and the design is the Probabilistic Seismic Hazard Analysis (PSHA). This analysis provides a hazard curve by combining a seismicity model (giving the locations, magnitudes, and rates of earthquakes) with a ground motion model, expressed as the probability of exceeding a ground motion conditional on an earthquake with magnitude M at a prescribed distance to the site. Thus, if monitoring the seismicity detects a reason to change either the seismicity model or ground motion model, the most efficient way to evaluate the effect of the change is to recompute the hazard curve, as illustrated schematically in Figure 2-2.

The PSHA calculates r thousands of alternative hazard curves in order to account for the full range of epistemic uncertainty. These calculations have been combined to produce a consolidated (condensed) set of hazard curves suitable for design and performance evaluations. This PC activity will not repeat the entire PSHA, however. Instead, it will select a few relatively simple representative models. If trends observed in the seismicity (using Activity Evaluations) or ground motions (using Spectrum Evaluations), when propagated through these representative models, indicate that the hazard curves might change significantly, then this evidence will be brought to the attention of the Lead Laboratory by the PIs. This will be accomplished through the use of Project Special Internal Reports. These special reports will be prepared by UNR and will be especially focused on confirmation of the PSHA-derived information. The purpose of the Project Special Internal Reports is to alert the Lead Laboratory (including the Performance Confirmation Integration Group) which will have initial responsibility to review the data for consideration/recommendation of whether the entire PSHA needs to be reevaluated.

As noted above, Figure 2-2 illustrates the context of how monitoring of the seismicity and spectra relate to PC. The methodology for the Activity Evaluations and Spectrum Evaluations are described in Section 2.2.1.1 (Table 2-2a) and Section 2.2.1.2 (Table 2-2b).

Tables 2-2a and 2-2b provide a listing of the seismicity and ground motion spectrum parameters to be monitored for the PSHA confirmation. Figure 2-3 (in Section 2.4) illustrates how these evaluations fit into the reporting cycle. The remainder of the reporting cycle is illustrated in Figure 2-4. Tables 2-3 and 2-4 list the ground motion parameters to be monitored within the immediate vicinity of the repository using seismic data provided by the SGBDSN for confirmation of the effects of seismic motions on the repository. (The SGBDSN currently includes multiple strong motion monitoring stations within 15 km of the repository. Data from all of the stations will be of value in evaluating specific events and also in performing trend analyses of local seismic activity over long periods of time).

Probabilistic Seismic Hazard Analysis

Seismicity Model

$$n(\mathbf{x}, M)$$

Occurrence rate in space ($\mathbf{x}$) of earthquakes as a function of magnitude (M).

Monitoring for performance confirmation will detect if there is a need to change the seismicity model.

Earthquake Ground Motions Model

$$\Phi(v|r, M)$$

Probability of exceeding an intensity measure (v, e.g. peak acceleration, peak velocity, or spectrum) at a site (x_0) as a function of magnitude, source to site distance ($r=|x-x_0|$), and site conditions.

Monitoring for performance confirmation will detect if there is a need to change the earthquake ground motion model.

$$E(v) = \int_{space} \int_{M} n(\mathbf{x}, M)\Phi(v|r, M)\,dM\,d\mathbf{x}$$

The seismicity model and earthquake ground motion model are combined using standard probability theory to generate a synthetic exceedance rate curve.

A large enough change in the seismicity model or the earthquake ground motion model might cause the hazard curve to be shifted significantly.

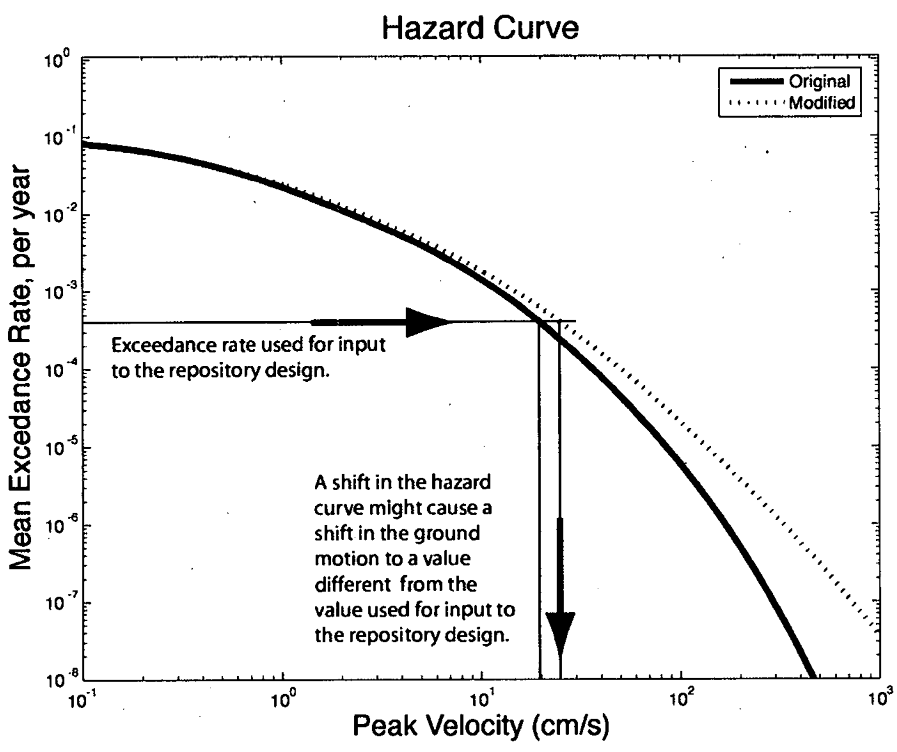


Figure 2-2. Illustration of the Context for Confirmation of the Validity of the Probabilistic Seismic Hazard Analysis

Table 2-2a. Earthquake Occurrence Evaluations

Parameters	Activity	Special Internal Reporting Range
Earthquake Magnitudes, Locations (Level 1 Review)	Event has probability of less than 5% according to PSHA seismicity model.	Identify in Annual Report
Earthquake Magnitudes, Locations (Level 2 Review)	Seismologist analysis concludes that the PSHA seismicity model for this source is consistent with these events.	Identify in Annual Report
Earthquake Magnitudes, Locations (Level 3 Review)	Seismologist modifies source zone and hazard curve for PSHA to be consistent with this event or trend.	Recomputed hazard curve is not more than 1% greater at the annual probability of 10^{-3} than original. Identify in Annual Report
Ground Motion Type, Frequency, or Location	Compare with historical catalog.	Event is inconsistent with 99.9% of the SGBDSN catalog. Project Special Internal Report prepared by PI(s).

Table 2-2b. Earthquake Spectra Evaluations

Parameters	Expected Range	Special Internal Reporting Level
Earthquake Spectrum (Level 1 Review)	Spectrum has probability of greater than 95% according to PSHA seismicity model.	Identify in Annual Report
Earthquake Spectrum (Level 2 Review)	Seismologist analysis concludes that the PSHA ground motion model for this source is consistent with these events.	Identify in Annual Report
Earthquake Spectrum (Level 3 Review)	Seismologist creates modified ground motion for PSHA to be consistent with this event or trend.	Recomputed hazard curve not more than 1% greater at the annual probability of 10^{-3} than original. Identify in Annual Report If more than 1% greater, Project Special Internal Report prepared by PI(s).

2.2.1.1 Earthquake Occurrence Parameter Tables

Table 2.2a outlines the process steps for an Activity Evaluation to distinguish between low probability events that are consistent with the probability distributions used in the PSHA and those that are outside of the normal range. The column on the left side of Figure 2-3 illustrates a three-level evaluation:

1. Associate detected earthquakes with the earthquake source zones that went into PSHA.

2. Is the detected location, magnitude, or frequency of the earthquake/sequence probability greater than 5% per year, based on the available earthquake source models that went into PSHA? If so, it is Level 0 event and continued analysis is not necessary. If the detected location, magnitude, or frequency of the earthquake/sequence probability is less than 5% per year this is a Level 1 event that requires further analysis. In any year, a small number of earthquakes are expected that will fit the Level 1 criteria.

3. For Level 1 events, compare with the basis for the probability distributions used in the PSHA. Earthquakes that might have caused a change in the PSHA input will be designated Level 2 events.

4. After a Level 2 event has been identified, generate a modified seismicity model, taking into account the new information, and calculate a new simplified PSHA with this modified seismicity model. (The "modified seismicity model" will simply be the use of a small number of selected existing PSHA input elements that are most relevant to the recorded event in terms of magnitude, location and frequency. For example, this might entail the use of a single area model and one or more of the local fault models, rather the entire set of area models and the entire set of both local and remote fault models used in the PSHA development.) If the hazard curve shows a significant change (>1% increase in the hazard curve at the annual probability of 10^{-3}), this will be declared a Level 3 event.

5. Level 3 events will be brought forward immediately (via Project Special Internal Reports) to the attention of the Lead Laboratory for further evaluation and reporting as shown in Figure 2-3 and as described in Section 2.7. All events analyzed at Level 1 and higher will be noted as such by UNR for inclusion in the Lead Laboratory annual reporting.

2.2.1.2 Earthquake Spectrum Monitoring Parameters

The PSHA used a model for the spectrum of the seismogram as part of its input to the LA. Peak acceleration and peak velocity are correlated with the spectrum. For larger events, the spectrum recorded from earthquakes in the YMP vicinity can be compared with the model. The spectrum of observations will be evaluated to determine if it differs from the PSHA input. For additional comparison purposes, more recent model development information is contained in *Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV.* MDL-MGR-GS-000003 REV 01 (BSC 2004 [DIRS 170027]).

Spectra will be evaluated using criteria that parallel those described in Section 2.2.1.1. Level 0 spectral observations would be consistent with the GMPEs, and Level 1 would represent observations that have low probability (less than 5%) of occurring according to the GMPEs used for the PSHA. Level 2 would represent observations of a trend that might have caused the ground motion panel to modify their GMPEs. Level 3 would represent observations where preliminary, simplified calculations indicate that the modified GMPEs that incorporate new data could cause the hazard curves to differ by more than 1% at the annual probability of 10^{-3} from the curves used for the performance assessment.

2.2.1.3 Monitoring Events to Confirm Underground Stability

Table 2-3 provides a listing of the strong ground motion amplitudes to be monitored using seismic data provided by the SGBDSN and the related underground conditions in the repository area to be monitored. Data from all SGBDSN stations will be of value in evaluating specific events and also in performing trend analyses of local seismic activity over long periods of time.

Table 2-4 provides locations for monitoring underground opening stability (using convergence pin methods) and fault displacement (using offset measurement methods). These locations have been identified in connection with previous site testing and are locations judged to be the most susceptible to deformation or that offer easy accessibility after a seismic event. As stated in the Table 2-3 note, if baseline data do not already exist for these locations, measurements will be taken and entered into the TDMS as soon as practicable to establish a baseline for comparison with future data. Parameters 2, 3, and 4 (Table 2-3) will be monitored as soon as practicable after significant seismic events that exceed expected range values.

As underground development of the repository proceeds, additional accelerometer locations will be selected based on the recommendations of the PIs and PC organization. These additional locations will be identified so as to be representative of the overall repository footprint and varying conditions that may be encountered. In addition, accelerometers will be installed in the underground in support of surface facility operations to comply with regulatory requirements. These will be connected to an environmental/meteorological monitoring panel on the surface. The number and locations of these devices will be selected in the future and any relationship with performance confirmation instrumentation will be determined at that time.

2.2.2 Expected Range and Condition Limit Values

2.2.2.1 Current Baseline Information

Table 2-3 includes technical baseline information based on seismic event frequency, location, and magnitude compiled in advance of the LA. These values reflect analyses performed to date and data obtained from seismic monitoring during site characterization. Sections 6.4 and 4.1 in the *Seismic Consequence Abstraction* (BSC 2005 [DIRS 173247]) contain seismic scenario input data for the TSPA-LA. Section 6.4 provides a description of how seismic events of various exceedance probabilities (e.g., 10^{-4} to 10^{-8}) are included in the TSPA annual dose calculations. Section 4.1 provides a listing of the relationship between PGV values and annual exceedance probability.

Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV (BSC 2004 [DIRS 170027]) provides design or target response spectra for relevant annual exceedance probability ground motions at the waste emplacement level. In that document, data are shown in Tables 6.3-2, 6.3-4, 6.3-6, 6.3-8, 6.3-10, 6.3-12, 6.3-14, 6.3-16, and 6.3-18. The Executive Summary (Table E-1) provides the relationship between PGA values and annual exceedence probability. The document also provides, in Tables 6.2-8 and 6.2-9, earthquake magnitude and distance information for earthquakes controlling the annual ground motion exceedance probability. Evaluations of the repository emplacement drift damage thresholds associated with seismic annual exceedance probability events are provided in *Drift Degradation Analysis* (BSC 2004 [DIRS 166107], Section 6.4.2.2.1).

2.2.2.2 Expected Range Values

Yucca Mountain is in a fairly active seismic state. However, based on historical and instrumental data accumulated over the last 100 years, the local seismic environment can be described as one with relatively infrequent events of moderate and larger magnitude. Data collection conducted during site characterization has produced results that are consistent with this description. Previously, a 0.02g value was used as a trigger value for internal event notification from UNR to the DOE. The value was adopted from a report on the Northeast Jackass Flat Earthquake (Smith 1997 [DIRS 176337]). That event (about an M 4 at a distance of about 15 km from the repository) produced a surface PGA of 0.0134g, which is substantially less than the PGA for a 1×10^{-3} mean annual probability of exceedance event (surface PGA of 0.37).

The current design basis for subsurface ground support in the repository uses conditions associated with a 5×10^{-4} annual exceedence probability event (*Ground Control for Emplacement Drifts for LA* (BSC 2004 [DIRS 170292]). Earthquakes contributing the most to this level of ground motion hazard have magnitude M 5.4 at a distance of 5 km (for response spectra frequencies of 5 to 10 Hz) and magnitude M 7.8 at a distance of 74 km (for response spectral frequencies of 1 to 2 Hz) (see *Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV* (BSC 2004 [DIRS 170027], Tables 6.2-8a through f).

Current analyses indicate a potential damage threshold (minor rockfall for unsupported ground in the weakest [Category 1] rock) for ground motion with a 5×10^{-4} annual exceedence probability (*Drift Degradation Analysis* (BSC 2004 [DIRS 166107], Section 6.4.2.2.1). These analyses suggest that the 5×10^{-4} event conditions would be conservative threshold values (for subsurface facilities) that are consistent with the design basis.

For comparison, the surface facilities designs use Design Basis Ground Motions DBGM-1 (1×10^{-3} event conditions) and DBGM-2 (5×10^{-4} event conditions). Waste handling operations are likely to be halted as a result of a seismic event resulting in site ground motions significantly below the DBGM design values to allow for an assessment of repository functionality.

Tentatively, the waste package, pallet, and drip shield may be evaluated for conditions associated with a 1×10^{-6} annual exceedence probability event. This is much more conservative than the basis for ground support design and for the purposes of expected range value selection the ground support basis will govern.

Based on the above, and to be consistent with repository facility operational planning, expected range values (i.e., PGA and PGV) associated with a 1×10^{-3} annual exceedence probability event have been selected as the Expected Range. . The subsurface facility is conservatively designed for more severe conditions. Events exceeding the Expected Range should provide valuable information on facility response based on the post-event inspections called for in Tables 2-3 and 2-4.

2.2.2.3 Condition Limit Values

Development of Earthquake Ground Motion for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV (BSC 2004 [DIRS 170027], Executive Summary Table E-1 and Tables 6.2-8 a through f) provide a distribution of magnitudes and distances representing earthquakes contributing to the ground motion hazard for various annual exceedence frequency seismic events, along with associated PGV values. As noted above, conditions associated with a 1×10^{-6} annual exceedence probability event may be used for evaluation of the engineered barrier systems components.

Because of the importance of engineered barrier system components to performance, the selection of condition limit values that challenge or exceed the design basis for these items would leave little or no (predicted) performance margin. Also, conditions at this event level would subject the ground support design to several times the design load values.

Events at the 1×10^{-6} annual exceedance frequency level would be, by definition, extremely rare, compared to historical seismic behavior at the site. Lower level events (e. g. with 1×10^{-5} or 1×10^{-4} annual probabilities) would also be rare relative to site historical data. A condition limit value of 5×10^{-4} would, however, be at a low enough level so that an analysis of seismic event trends at the site (or in the region) over the approximately 100-year evaluation period (at the time of repository closure) might reveal some tendency towards that extreme an event(s). This value would be reasonably conservative relative to underground design (design basis of 5×10^{-4}) and would provide a substantial margin for the engineered barrier system components (1×10^{-6} as noted above). On this basis, conditions associated with an annual exceedance probability of 5×10^{-4} would seem to be reasonable and are selected for Condition Limit values.

Notwithstanding the condition limit values discussed above, ground motions associated with a 10^{-2} annual probability event have been selected for Project Special Internal Reporting (discussed in Section 2.2.1 above). This level is chosen because a one hundred year earthquake is below selected design and performance bases but is sufficiently rare as to be valuable in reviewing data for trends and for evaluating facility response. Special reporting, and possibly special inspections as determined by the PIs and the PC integration group (Section 1.6), will be performed to confirm that the repository performed as expected.

Table 2-3. Seismicity Monitoring Parameters

Parameters	Expected Range	Condition Limits
1. Monitor local seismic response acceleration at waste emplacement level (local responses will be obtained from multiple strong motion monitoring stations in the repository area). (Note 1) Data will also include event magnitudes and locations.	Expected range at waste emplacement level is a PGA of less than 0.13g (horizontal and 0.12g vertical). (Source a) and (Note 4)	PGA at the emplacement level greater than 0.19g (horizontal) or 0.23g (vertical). (Source a)
2. Convergence pin measurements at locations selected by PIs. (Note 2)	No observable effects (outside of measurement accuracy range) for seismic events registering less than 0.13g. (Sources a, b)	Any convergence exceeding expected range values (Table 1-1, TWP-MGR-GE-000006 [DIRS 177500]). (Source c)
3. Observation of fault displacements in excess of 1cm (exceeding measurement accuracy) at previously identified underground fault locations. (Note 3) after Expected Range or greater seismic events.	No measurable fault displacement is expected for accelerations less than 0.13g. (Source d)	Measurement of any fault displacement exceeding 2.cm at any currently monitored locations (and any appropriate future locations that may be identified).
4. Observation of condition of underground openings (visual inspection of rock face and/or emplacement drift liner at selected locations). These observations will be conducted under TWPs and test plans for Construction Effects Monitoring and/or Drift Inspections and will be performed if unexpected results are obtained in one or more of items 1 through 3 above.	No significant rockfall (Source d) is expected for accelerations less than 0.13g.	Visible damage of rock face (rock fall and/or excessive raveling) and/or visible damage or distress of emplacement drift liner (liner segment distortion/failure or segment locking pin failures) at the selected locations.

Sources: a *Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV (BSC 2004 [DIRS 170027[(*Executive Summary Table E-1).

b *Seismic Consequence Abstraction* (BSC 2005 [DIRS 173247]).

c *Technical Work Plan for: Construction Effects Monitoring* , (BSC 2006 [DIRS 177500], Table 1-1).

d *Drift Degradation Analysis* (BSC 2004 [DIRS 166107].

NOTES: 1. Seismic stations are part of the SGBDSN operated by UNR, which also provides regional seismic data.

2. Table 2-4 contains a listing of existing convergence pin measurement locations for underground openings. These locations were developed as a part of site characterization activities associated with ESF and ECRB testing and monitoring and are, therefore, representative of a limited portion of the repository footprint. Additional (representative) convergence pin locations will be identified as repository development proceeds (selected existing pin locations will continue to be monitored).

1.1 3. Table 2-4 also contains a list of existing fault displacement convergence pin measurement locations. These locations were developed as a part of site characterization activities. Additional locations (representative of the repository footprint) will be identified as repository development proceeds.

1.2 4. Expected Range and Condition Limit values at the emplacement level were selected from *Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain , NV* (BSC 2004 [DIRS 170027], Executive Summary Table E-1). These values are associated with events at the 5×10^{-4} and 1×10^{-3} probability level, respectively, from earthquakes with magnitude 5.0 or greater.

Table 2-4. Underground Opening Stability and Fault Measurement Locations

Convergence Pin Locations	Station[a]	Fault	Station[a]
North Portal	ESF 00 + 05 ESF 00 + 09	Bow Ridge	ESF 01 + 96 ESF 02 + 00
ECRB	ESF 00 + 25	Drill Hole	ESF 18 + 30 ESF 20 + 35
Alcove 5	ESF 28 + 28	Ghost Dance	ESF 57 + 48
Thermal Test Facility (TTF)	ESF 00 + 41	Solitario Canyon	ECRB 24 + 72 (if readily accessible)
TTF/Access Observation Drift	TTF 01 + 30	Imbricate Faults	ESF 71 + 29
TTF/Heated Drift	TTF 00 + 09		
Alcove 6	ESF 37 + 37		
Alcove 7	ESF 50 + 64		
ESF	ESF 76 + 96		

[a] These locations were selected by the TCO as most susceptible to deformation or that offer data quickly (are readily accessible) after a seismic event.

NOTE: Tunnel convergence and MPBX data collected to date (baseline data) for these locations are provided in SN0405F3312393.015 [DIRS 177261]. For locations where baseline data are not available, a set of measurements will be taken as soon as practicable to establish a baseline for comparison with future monitoring measurements.

2.2.3 Measurement Methods for Seismic Events and Underground Damage Evaluations

2.2.3.1 Seismic Event Monitoring

Seismic activity will be evaluated based on data from the existing SGBDSN operated by UNR as described in Sections 1.4 and 2.1. These data will include data provided by multiple strong motion monitoring stations located at or near the current ESF. Data are monitored continuously (on-line data recording) and transmitted from the repository to the UNR seismology laboratory for data reduction, evaluation, and storage. Data will also be available from the regional seismic monitoring stations in the existing network. These data may be supplemented by data from the surface-based and subsurface monitoring systems installed in support of repository operations (see Sections 1.1.2 and 2.3).

1. Confirmed acceleration readings at any of the UNR strong-motion sites that are greater than 0.13g (Expected Range value per Table 2-3) at the waste emplacement level will be internally communicated to the DOE. Upon receipt of such acceleration numbers from UNR, the program outlined in Section 2.2.3.2 would be initiated.

2.2.3.2 Seismic Event Damage Evaluations

Inspections and investigations of possible damage to the underground openings and any evidence of fault displacements will be accomplished in ways that depend on the timing of any seismic event and the state of repository construction and operations at the time of each event. Investigations of possible damage to underground openings will be performed in accordance with the PCTPs for construction effects monitoring (*Technical Work Plan for: Construction*

Effects Monitoring. TWP-MGR-GE-000006 REV 00 [DIRS 177500]) drift inspection (to be prepared). Fault displacement evaluation will be per this test plan. Access to the Main Drift (ESF) and Alcoves to perform these inspections is currently controlled by applicable Yucca Mountain site plan documents.

Construction of the entire set of repository openings and completion of waste emplacement in those openings will require about 25 years or longer, based on current planning. During this construction/waste emplacement period, the underground facility will be in a combined state of active emplacement operations and new construction.

For active nuclear operational areas (either waste emplacement drifts already filled or drifts where waste emplacement is in progress), access for inspections and investigations will be governed by waste handling operational controls. Following completion of waste emplacement, the entire facility will be in a monitoring mode and under waste handling operational controls. Construction management controls will apply in areas under construction and where construction is complete but nuclear operations have not yet commenced.

Nuclear Operations Areas–Emplacement Drifts: Damage evaluations will be conducted using remote means in accordance with the drift inspection test plan.

Turnouts, Mains, and Ramps: Damage evaluations will be conducted in accordance with the drift inspection test plan either by visual observations, similar to those for emplacement drifts, or by using convergence pin/MPBX deformation measurements in areas where ground support systems (e.g., rock bolts and mesh and/or grouting) will allow access to such instruments.

Construction Areas–Emplacement Drifts, Turnouts, Mains, and Ramps: Damage evaluations will be conducted in accordance with the construction effects monitoring test plan.

2.2.4 Measurement Locations for Underground Damage Evaluations

There are at least three sets of locations where measurements and/or observations may be conducted following significant seismic events. These three locations are 1) site characterization locations, 2) locations that exhibit unusual characteristics (unusual lithophysae, stratigraphic contact areas, fault zone areas), and 3) areas identified during the course of performing other PC activities (e.g., unexpected rock properties, evidence of ground support distress).

Based on future information from other sources (i.e., analysis and model report updates), there may be additional locations where data should be taken. Also, monitoring data may suggest that existing monitoring locations could be changed to obtain more useful data. These will be determined by the PIs with concurrence of the PC organization.

Site characterization locations are where data have been taken during the site characterization testing and a data history has already been accumulated to provide a baseline for measurement comparisons. Areas warranting assessment are those that appear most susceptible to deformation or that offer data quickly (i. e. are readily accessible) after a seismic event. These locations are listed in Table 2-4. Visual inspections and the measurement of convergence pins will be performed at these locations as soon as practical after a significant seismic event.

Locations that exhibit relative weakness (raveling, minor rockfall) during construction of the underground openings will be documented and become candidates for later inspection following seismic events (unless they have already been addressed in construction operations and/or construction effects monitoring). Locations will be selected from the list of candidates developed by the Lead Laboratory with concurrence by the PC organization.

Locations indicated by other PC activity data (mapping of fractures/lithophysae) may be potential weakness areas and will be documented. The Lead Laboratory with PC organization concurrence will select locations from those identified for evaluation following significant seismic events.

2.2.5 Measurement Timing for Underground Damage Evaluations

Measurements and observations will be performed as soon after significant seismic events as is practicable and safe. Timing will depend on the specific locations selected as noted above and whether these locations are in construction zones or in nuclear operational zones.

2.2.6 Monitoring Method Implementation Documents

FWPs containing implementation details will be prepared in accordance with TST-PRO-006, *Testing Work Implementation and Control,* by the TCO for performance of the monitoring activities described in this test plan (refer also to Sections 4.1 and 8.5). The TCO will also prepare test work authorizations in accordance with TST-PRO-006 for control of conduct of the fieldwork.

The FWPs typically contain the following information:

Purpose and scope of the test

Roles and responsibilities of interfacing organizations

Project requirements for quality affecting and site disturbing testing activities

Planned tracer, fluid, and materials usage

Controls resulting from evaluations of potential impact from the activities on waste isolation and test-to-test interference

Environmental, safety and health controls

Identification and mitigation of hazards associated with the test to be performed

Records requirements for the test.

2.3 DATA COLLECTION, DATA REDUCTION, AND RECORDING OF RESULTS

2.3.1 Data Collection

2.3.1.1 Seismic Monitoring Data

Currently, performance confirmation data collection for the SGBDSN is accomplished by the UNR continuous data recording system (data are telemetered from instruments in the repository area to the Nevada Seismological Laboratory at UNR). Data handling is performed in accordance with the UNR Scientific Investigation Plan, *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]). An annual report that includes earthquake catalog data is prepared by UNR, and the catalog data are submitted to the TDMS. Memoranda covering specific seismic events are submitted to the DOE on an as-requested basis. All seismic event data will be transmitted to the TDMS per the requirements of TST-PRO-001, *Submittal and Incorporation of Data to the Technical Data Management System.* Representative continuous time-series data will be submitted to the RPC. All work is performed under a DOE-approved QA program.

Any on-site handling of data received from the UNR system will be performed to meet the high-level requirements of IM-PRO-002, *Control of the Electronic Management of Information*, and the more detailed requirements in implementing procedures (IPs) identified elsewhere in this test plan. As changes in the UNR/Yucca Mountain Project site interface are made and as technological advances are made in equipment and methods described herein, this plan will be revised to incorporate these changes to improve efficiency and data quality. This may include additional strong-motion stations in representative underground or surface locations.

Data collected from surface-based and subsurface seismic monitoring stations which have been installed to support repository operations will also be available and may be used to supplement or corroborate UNR seismic network data. This instrumentation, installed to support repository operations, will be installed and operated in accordance with approved procedures under the same DOE-approved QA program.

UNR will maintain seismic stations in accordance with the Seismic Network Operations Scientific Investigation Plan (SIP) and network operations procedures. Data collection, data reduction, and data recording for the seismicity continuous monitoring system will be in accordance with IPs identified in the site investigation plan (SIP). Indications of apparently erroneous data will be evaluated in accordance with these IPs.

2.3.1.2 On-Site Data

In cases where on-site measurements (e.g., convergence and/or fault displacement) produce apparently erroneous data, the measurement will be repeated as soon as practicable to confirm the values taken. Field technicians will check equipment and hardware as described in technical procedures to identify areas where data collection errors might have occurred. The PI and PC organization will determine if the data are acceptable after inspection of the data collection hardware and monitoring equipment.

The first and most likely source for an apparent unexpected condition is human error when taking a manual reading or entering data into data forms or databases. To minimize human error, the following will be implemented:

- Reference previously recorded data when taking a manual reading (mandatory)
- Have the data recorder read back the entry to the data reader (mandatory)
- Review database entries
- Develop an electronic data collection system.

2.3.2 Data Reduction

2.3.2.1 Seismic Monitoring Data (UNR)

Analysis of seismic data will be in accordance with the Seismic Network Operations SIP. The following steps will routinely be performed and confirmed by the UNR PI:

Confirmation that UNR data acquisition IPs have been followed

Confirmation that monitoring system calibrations are in accordance with UNR systems procedures

Conduct data reviews (Figures 2-2, 2-3, and 2-4).

2.3.2.2 On-site Data and Structural Measurements (Lead Laboratory)

For on-site (non-UNR) data (such as convergence pin measurements and other underground measurements), the initial responsibility for data analysis rests with the TCO. The following steps will routinely be performed and then confirmed by the PI and PC organization:

Confirmation that applicable data acquisition procedures have been followed

Confirmation that calibration of the relevant instrumentation system(s) is in accordance with applicable procedures

Conduct data reviews (Figures 2-2, 2-3, and 2-4).

2.3.3 Recording of Results

Detailed reporting protocols will be developed, particularly with regard to those intended for the DOE and NRC. Where appropriate, reports will be prepared in accordance with LS-PRO-001.

Currently, data reporting is expected to be as follows:

Data will be submitted to the TDMS.

Data and data evaluations performed under this test plan will be included in a regular annual report (including relevant elements of the seismicity monitoring prepared by UNR) prepared by the PC organization.

Internal and interim special reports will be prepared by the UNR and Lead Laboratory PIs and the PC organization, as needed, to support the PC program.

Unexpected results will be reported as discussed Section 2.4. An initial notification of unexpected results and conditions (e.g., a seismic event exceeding the identified expected ranges) will be automatically generated and sent to the DOE.

2.4 PROVISIONS FOR UNEXPECTED RESULTS, UNANTICIPATED CONDITIONS, OR OCCURRENCE OF OFF-NORMAL EVENTS

This activity must be responsive to the requirements associated with regulatory compliance, including those in 10 CFR Part 63 [DIRS 180319] and YMRP (NRC 2003 [DIRS 163274]) for normal repository control and reporting for test activities. This activity must also be responsive to unexpected results, unanticipated test conditions, and the occurrence of off-normal events. The overall approach to these functions is portrayed in Figure 2-3 and Figure 2-4. The process for reporting such events is discussed in Section 2.7.

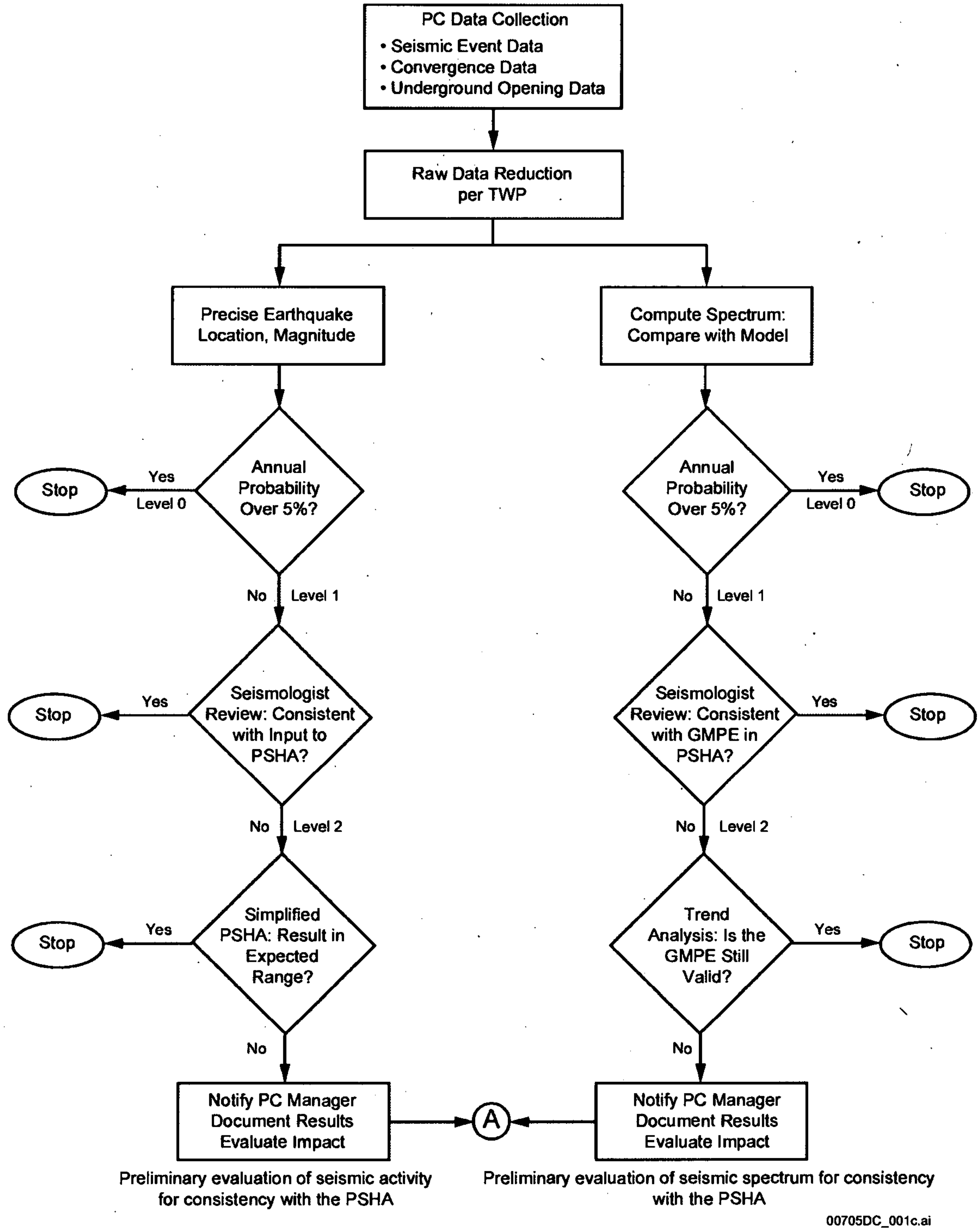
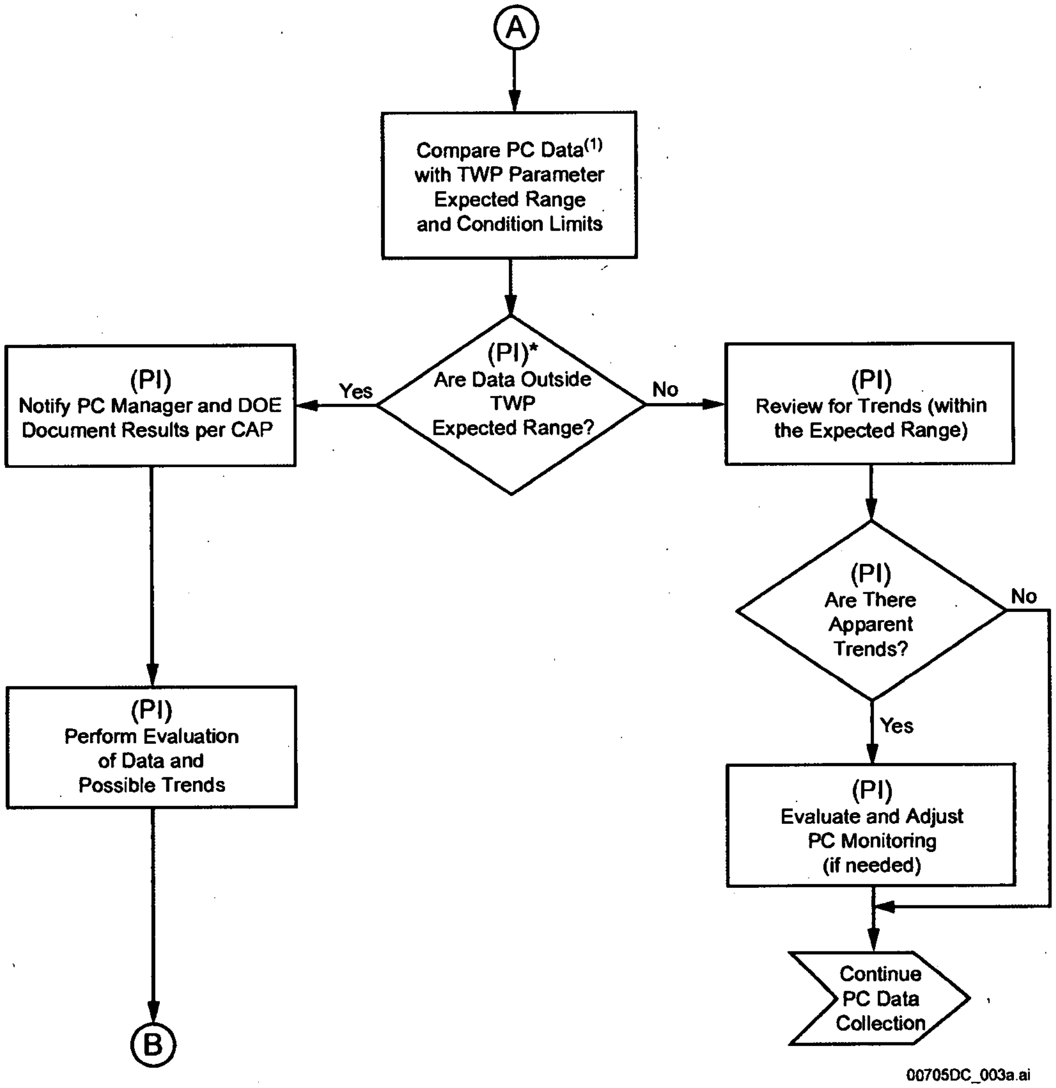


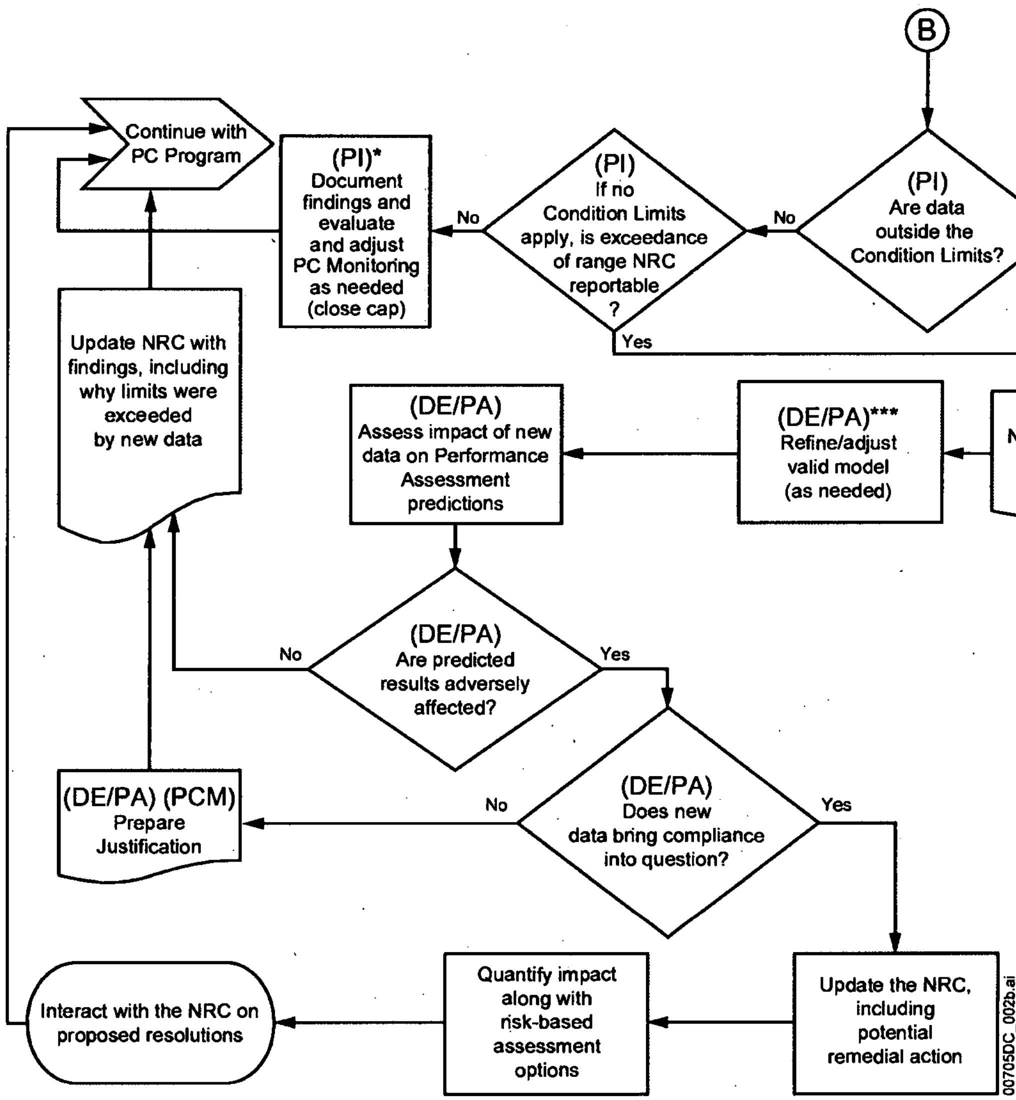
Figure 2-3 Seismic Monitoring Data Preliminary Evaluations

(See Figure 2-4 for a continuation of this Figure)



(1) Data comparisons may include statistical tests/comparisons as well as direct numerical comparisons per the PC Test Plans.

Figure 2-4 . Seismic Monitoring Data Collection, Review, and Reporting



*PI Principal Investigator
**PCM Performance Confirmation Manager
***DE/PA Design Engineering/Performance Assessment

Figure 2-4 . Seismic Monitoring Data Collection, Review, and Reporting (Continued)

2.5 RELEVANCE TO PERFORMANCE ASSESSMENT

Seismic activity can affect the capabilities of the upper natural barrier and the engineered barrier system. With respect to the interface between the upper natural barrier and the engineered barrier system, seismic activity can change the shape of emplacement drift openings. Such a change can alter the effect of capillary forces and, thus, affect seepage into the drifts (BSC 2006 [DIRS 176566], Section 6.2.6). Seismic monitoring, especially at underground locations, will collect data that potentially could be used to confirm modeling of drift degradation (BSC 2004 [DIRS 166107]), Sections 6.3 and 6.4). Drift degradation modeling is an input to postclosure seismic consequence analyses and abstractions for the TSPA (BSC 2005 [DIRS 173247], Section 6.8).

Seismic ground motion and fault displacement can also affect the performance of the engineered barrier system (BSC 2006 [DIRS 176566], Section 6.3.6). At sufficiently high levels, seismic ground motion can cause mechanical interactions between waste packages, between a waste package and an emplacement pallet, or between a waste package and a drip shield. Such interactions need to be evaluated because they could lead to stress corrosion cracking or other damage of engineered barrier system components.

Fault displacement also has the potential to affect the capability of the engineered barrier system. Monitoring of seismic ground motion allows detection of events that would trigger field inspections for drift stability and inspection for possible fault displacement within the emplacement area. Seismicity monitoring will provide data that can be used to confirm that the seismic information used for modeling seismic effects has not been exceeded.

For the lower natural barrier, seismic activity is not expected to affect the barrier's capability to prevent or substantially reduce the rate of movement of radionuclides to the accessible environment (BSC 2006 [DIRS 176566], Section 6.4.6). Seismic monitoring data are also relevant to confirming the ability of repository facilities to meet preclosure performance objectives. *Preclosure Seismic Design and Performance Demonstration Methodology for a Geologic Repository at Yucca Mountain Topical Report* (DOE 2006 [DIRS 178617]) identifies seismic hazard levels (mean annual probabilities of being exceeded) for design basis ground motion 1 and Design Basis Ground Motion 2. These design bases are used, as appropriate, for seismic design of important-to-safety structures, systems, and components. Seismic margin assessments are also carried out for a beyond design basis ground motion to demonstrate a high confidence that safety functions will be maintained. In addition, to show that preclosure performance objectives are met, a probabilistic seismic analysis using seismic hazard and structures, systems, and components fragility curves will be carried out. Ground motion data from seismic monitoring will allow comparisons between the design bases and observations.

2.6 OBSERVATIONS, MEASUREMENTS, AND DATA QUALITY OBJECTIVES

The overall objectives to be attained by performing the observations and measurements required by this test plan are described in Sections 2.1 and 2.2. Data quality is generally addressed in Section 2.3.

Data obtained under this PCTP can be of considerable importance in assessing repository operations and performance. While extreme seismic events are by definition unlikely, repository behavior in response to seismic events is one of the more influential factors in evaluating the repository. Data that are apparently outside of expected ranges and/or beyond condition limits will necessitate special reporting and evaluations (Section 2.7) and could be cause for operational changes and performance assessments. The data must, therefore, be timely and accurate.

Continuous monitoring of seismicity is provided by the SGBDSN system under *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]) and operating checks are incorporated into the supporting IPs. The system has inherent redundancy because there are multiple monitoring stations. On-site inspections and monitoring following significant seismic events will be conducted as soon as practicable after the events and will be performed using established procedures. Supporting quality checks will be implemented (Section 2.3). Reviews will be conducted by the PI, PC organization management, and subject matter experts, as appropriate (Section 1.6). These measures have been successfully implemented for many years.

2.7 PROCESS FOR REPORTING UNEXPECTED RESULTS/CONDITIONS

2.7.1 General Provisions

The PC program is designed to detect parameters that confirm or potentially deviate from an expected range of values. Predicting long-term performance for the repository at Yucca Mountain is a complex process, so some deviations from expectations will probably occur. A logical pathway to document, track, and manage deviations significant to performance evaluations starts with recording the condition in the corrective action program per AP-16.1Q, *Condition Reporting and Resolution*, followed by evaluations detailed in this test plan. Referring to Figure 2-4, if monitoring data fall outside the expected range, the PI notifies the PC organization and the DOE, and further evaluation of the monitoring results is required. If monitoring data fall outside the condition limits, notification to the PC organization , DOE, and, subsequently, NRC (by DOE) is required. Follow-up actions are shown in Figure 2-4.

Initial internal reporting (exclusive of internal special reports per Section 2.2.1) of conditions will be done in the corrective action program system. This test plan describes (Tables 2-3 and 2-4) each parameter, sources of monitoring parameter data, the monitoring parameter, and expected ranges . The table also identifies monitoring parameter condition limits (values that, if exceeded, would not necessarily cause performance to change but would require additional evaluation) and potentially adverse trends.

Through routine reporting, the NRC will be kept current on the progress of PC activities and their evaluations, and a protocol of standard reporting format and interval will be established with the NRC. The PC program will be subject to formal reporting of discovery of conditions that differ from those assumed in the LA. The reporting protocol will call attention to such conditions such as values outside of the expected ranges as described herein. For data outside of condition limits, an NRC notification (by the DOE), an evaluation(s) of the cause of the exceedance, an assessment of the potential significance of the deviation, and a determination of possible corrective actions will be conducted, also as noted herein.

In cases where the evaluation process requires sampling over time, it is possible to observe the time evolution of estimated parameter values and associated uncertainty bands. For seismicity monitoring, the evolution of frequency of seismic events, magnitude of events, and location (proximity to the repository) will all be reviewed for trends. The time series of reduced data can be analyzed to determine whether there is evidence of a trend that, if it were to continue, would eventually challenge assumptions supporting the LA and/or adversely impact repository operations. If such a trend is identified, action will be initiated to evaluate possible consequences (Figure 2-4).

2.7.2 Reporting Bases

Off-normal and unexpected events will be handled under standard project work control procedures and protocols as defined herein. Data that are outside the expected range(s) will require further evaluation by the PI, PC organization and, as appropriate, subject matter experts as noted above. Data that are outside the condition limits (exceeds condition limit values and/or show evidence of fault displacement or drift degradation) will require the same further evaluations, depending on the impact of the new observations.

2.8 MODELING AND SCIENTIFIC ANALYSIS

2.8.1 Models

This test plan does not require the development of new scientific models.

2.8.2 Analysis and Calculations

Analyses and calculations will be performed in connection with the data collection, data reduction, and evaluation of seismic monitoring data by UNR. UNR is currently a qualified supplier under the YMP QA Program and will use qualified software identified in SIP-UNR-027 and IPs to perform the analyses and calculations. The previously qualified software will be transitioned to the Lead Laboratory. Any future required changes or additions to the software will be qualified under Lead Laboratory procedures.

Analyses and calculations will also be performed by Lead Laboratory personnel in connection with the data collection, data reduction, and analysis of field measurements. These analyses and calculations are performed using currently qualified software identified in IPs. Any future required changes or additions will be qualified under Lead Laboratory procedures.

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3. INDUSTRY STANDARDS, FEDERAL REGULATIONS, DOE ORDERS, REQUIREMENTS,AND ACCEPTANCE/COMPLETION CRITERIA

3.1 INDUSTRY STANDARDS

Industry standards and codes will be applied to specific parameter monitoring methods and identified in the specific monitoring and test procedures and/or relevant FWPs (listed in Appendix B). Laboratory tests might be required to interpret results from monitoring under this test plan. If required, standards will be identified in relevant laboratory procedures covered in a revision to this test plan and/or PCTPs applicable to construction effects monitoring or drift inspections.

3.2 FEDERAL REGULATIONS, DOE ORDERS, OTHER REGULATORY REQUIREMENTS

Federal regulations, DOE orders, and other regulatory requirements will be captured in conformance with PI-PRO-005, *Requirements Management*.

3.3 PROVISIONS FOR ACCURACY, PRECISION, REPRESENTATIVENESS

Provisions for accuracy and precision, and sources of error or uncertainty in the data collection of the test and monitoring activities associated with this test plan, will be identified in the technical procedures used for field implementation and as discussed in Section 2.3.1. The representativeness of collected data will be evaluated by comparing the data with pretest predictions as discussed in Sections 2.4 and 2.7. In situations where the precision of the data precludes such comparisons and/or where the data do not appear to be representative of the conditions being monitored, the PI, in conjunction with the PC organization , will evaluate and select (if needed) alternative procedures, instrumentation, data collection, data reduction, and/or monitoring techniques (also discussed in Section 2.6).

3.4 ACCEPTANCE AND COMPLETION CRITERIA

High-level planning acceptance and completion criteria are provided in the PC organization annual work package task plans under WBS 1.5.03.12, Section E, Work Package: S31205 Seismicity Monitoring. This document defines high-level requirements allocated to the PC organization science activity and includes the high-level regulatory criteria (e.g., 10 CFR 63.111 and Subpart F) as well as the DOE deliverable requirements for seismicity monitoring relative to performance confirmation (other seismicity monitoring, e. g. for surface facilities is covered in other regulatory requirements). Lower level acceptance and completion criteria are covered in the data collection, data reduction, and data evaluation and reporting requirements for each test parameter. Details are provided in Sections 2.3 and 2.4 as well as Figure 2-1.

In summary, this activity requires the collection, reduction, recording, and analysis of seismicity data at the repository and in the repository region (especially within a 50-km radius). It further requires inspections of repository underground conditions whenever specified seismic acceleration thresholds are exceeded. Routine annual reporting and special reports to the DOE and NRC covering unexpected events are required (Section 2.7).

In addition, in accordance with 10 CFR 63.51, the license amendment for permanent closure of the repository "must include any PC data collected under the program required by Subpart F, and pertinent to compliance with Section 63.113" as a future requirement.

3.5 ALLOCATED REQUIREMENTS

This document defines high-level requirements allocated to the PC organization science activity and includes the high-level regulatory criteria (e.g., 10 CFR 63.111 (e) and Subpart F)

3.6 DERIVED REQUIREMENTS

There are no derived requirements for this TEST PLAN and this item is N/A.

4. IMPLEMENTING DOCUMENTS

4.1 IMPLEMENTING PLANS AND PROCEDURES

This test plan is the primary implementing document for this seismicity monitoring activity. *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]) is the implementing document for the collection of seismic monitoring data. Seismic data is currently submitted directly to the RPC and TDMS by UNR per the Site Investigation Plan.

Collection of data for on-site construction features following a seismic event (e.g., convergence monitoring data and/or fault displacement data) and associated data handling will be conducted in accordance with *Field Test Data Collection Systems* (YMP 2000 [DIRS 161209]). This is consistent with current data collection and handling procedures used for ESF data.

Additional information on implementing plans is provided in Section 2.2. A listing of applicable IPs is provided in Appendix B. Additional implementing documents will be provided in the FWPs and testing laboratory procedures and work plans.

4.2 ADDITIONAL IMPLEMENTING DOCUMENTS

The PC organization will be responsible for developing any newly required implementing documents.

4.3 NON-Q PROCEDURES

Any non-Q work under this TEST PLAN will be in accordance with *Augmented Quality Assurance Program* (DOE 2006 [DIRS 177173]). No such work has currently been identified.

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5. EQUIPMENT

5.1 MAJOR SYSTEMS AND EQUIPMENT

Specific systems and equipment for performance confirmation will be identified in the relevant FWPs and testing laboratory work plans and procedures for each test parameter. Seismicity monitoring systems and equipment are existing as part of the UNR SGBDSN (off-site) and do not require FWPs. FWPs will apply to on-site work. Applicable procedures are listed in Appendix B.

5.2 CALIBRATION REQUIREMENTS

5.2.1 SGBDSN Systems and Equipment

SGBDSN systems and equipment will be performed in accordance with *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]) and supporting procedures. Those systems and procedures are governed by a DOE-approved QA plan.

5.2.2 On-Site Systems and Equipment

Calibration of on-site (non-UNR) systems and equipment will be performed in accordance with TST-PRO-002, *Control of Measuring and Test Equipment*, and QA-PRO-1071, *Acceptance of Items and Services*.

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6. RECORDS

Records of all testing and monitoring work performed under this test plan (as identified in the IPs) will be developed, maintained, collected, and submitted to the RPC (PC) in accordance with DM-PRO-002, *Records Management*.

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7. QUALITY VERIFICATIONS

The PC program, including this seismicity monitoring activity, will be conducted in accordance with the requirements of *QARD* (DOE 2006 [DIRS 176927]) and in compliance with 10 CFR 63, Subpart F, Performance Confirmation, and Subpart G, Quality Assurance. No additional quality verifications, other than regularly scheduled audits and surveillances, are required during the implementation of this work except as defined herein.

Notification levels associated with out-of-expected range and condition limits are discussed in Sections 2.3 and 2.4. Any additional notification levels (items requiring special evaluations and DOE and NRC notifications) will be as identified in revisions to this TEST PLAN.

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8. PREREQUISITES, SPECIAL CONTROLS, ENVIRONMENTAL CONDITIONS, PROCESSES, OR SKILLS

8.1 QARD REQUIREMENTS

Work performed under this TEST PLAN will be in accordance with QARD (DOE 2006 [DIRS 177092]).

8.2 NON-Q WORK

All non-Q work under this TWP will be in accordance with *Augmented Quality Assurance Program (AQAP)* (DOE 2006 [DIRS 177173]). No such work has currently been identified.

8.3 PREREQUISITES

Before commencement of activities delineated in this plan, the following will be implemented:

- Approved FWPs and SIPs (UNR)
- Approved test work authorizations
- Quality-affecting instrument calibration

Approved field technical procedures for test implementation.

There are no requisite input items under development.

8.4 CONTROL OF ELECTRONIC MANAGEMENT OF INFORMATION

An evaluation has been performed in the development of this plan as required by IM-PRO-002. The process control evaluation is provided as Appendix D. Existing data collection and data handling controls required for electronic data protection are specified in the IPs identified in the FWP for field test data collection (YMP 2000 [DIRS 161209]) and in the plan for seismic data collection (von Seggern 2004 [DIRS 170249]).

8.5 ENVIRONMENTAL CONTROLS

Environmental controls required for the UNR seismicity monitoring system are covered in *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249], Section 11). Environmental controls for (on-site) field monitoring activities are covered in *Field Test Data Collection Systems* (YMP 2000 [DIRS 161209], Section 6) (listed in Appendix B).

8.6 SPECIAL TRAINING/PERSONNEL QUALIFICATIONS

Special training or personnel qualifications (over and above employee position standard training) will be detailed in the FWP and/or testing laboratory procedure for each monitoring and test parameter, as required.

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9. SOFTWARE

9.1 SOFTWARE IDENTIFICATION

Software used for seismicity data acquisition and data handling are referenced and listed in *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249], Sections 5.0 and 10.0). Software and procedures for field test data acquisition and data handling are addressed in *Field Test Data Collection Systems* (YMP 2000 [DIRS 161209], Sections 2.3 and 5.2.1). Campbell scientific software for downloading data (Campbell PC208) is listed in the software baseline report as PC208WV.3.2. Data analysis and evaluation will be performed using commercially available and/or previously qualified software. No new software is required to conduct this work, and if new software is needed it will be qualified and baselined prior to use..

9.2 SOFTWARE QUALIFICATION

Software for these TEST PLAN activities is qualified.

9.3 CONTINUOUS USE SOFTWARE

Software use and documentation for seismicity data handling are covered in *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249]). Several of the software items (von Seggern 2004 [DIRS 170249], Section 10.0) are continuous use software and are qualified, including the application of in-use checks to verify proper operation in accordance with von Seggern (2004 [DIRS 170249]) and procedures referenced therein. Documentation of these checks will be in accordance with the UNR QA program approved by DOE.

Continuous use software is not employed in the field test and monitoring (i.e., on-site, non-UNR) data handling. If continuous use software is employed in the future, use and documentation requirements will be detailed in monitoring parameter FWPs and testing laboratory procedures and will be in accordance with the requirements listed in Appendix B.

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10. ORGANIZATIONAL INTERFACES

Organizational interfaces are identified and described in Section 1.6.

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11. PROCUREMENT

Any required non-UNR procurement activities will be conducted in accordance with PM-PRO-001, *Procurement Documents.* UNR personnel will use applicable UNR procedures as identified in *Southern Great Basin Seismic Network Operations* (von Seggern 2004 [DIRS 170249], Section 10.0).

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12. REFERENCES

The following references are cited in this test plan (exclusive of IPs). IPs are listed in Appendix B.

180319 10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

157829 BSC (Bechtel SAIC Company) 2002. *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project.* ANL-MGR-GE-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20021004.0078.

166219 BSC 2003. Snell, R.D.; Beesley, J.F.; Blink, J.A.; Duguid, J.O.; Jenni, K.E.; Lin, W.; Monib, A.M.; Nieman, T.L.; and Hommel, S. 2003. *Performance Confirmation Plan.* TDR-PCS-SE-000001 REV 02 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20031124.0003.

168030 BSC 2004. *Characterize Framework for Seismicity and Structural Deformation at Yucca Mountain, Nevada.* ANL-CRW-GS-000003 REV 00 [Errata 001]. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20000510.0175; DOC.20040223.0007.

170027 BSC 2004. *Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV.* MDL-MGR-GS-000003 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041111.0006; DOC.20051130.0003.

166107 BSC 2004. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 03, Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040915.0010

170292 BSC 2004. *Ground Control for Emplacement Drifts for LA.* 800-K0C-SSE0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040712.0019; ENG.20050816.0015.

168178 BSC 2004. *Ground Control for Non-Emplacement Drifts for LA.* 800-KMC-SSD0-00700-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040302.0022; ENG.20050816.0022.

172452 BSC 2004. *Performance Confirmation Plan.* TDR-PCS-SE-000001 REV 05. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041122.0002.

173247 BSC 2005. *Seismic Consequence Abstraction.* MDL-WIS-PA-000003 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20050829.0005.

176566 BSC 2006. *Postclosure Nuclear Safety Design Bases.* ANL-WIS-MD-000024 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20060817.0005.

177500 BSC 2006. *TWP for Construction Effects Monitoring.* TWP-MGR-GE-000006 Rev 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20060531.0005.

103731 CRWMS M&O 1998. *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada.* Milestone SP32IM3, September 23, 1998. Three volumes. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981207.0393.

177173 DOE (U.S. Department of Energy) 2006. *Augmented Quality Assurance Program (AQAP).* DOE/RW-0565, Rev. 1. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20060626.0002.

178617 DOE 2006. *Preclosure Seismic Design and Performance Demonstration Methodology for a Geologic Repository at Yucca Mountain Topical Report.* YMP/TR-003-NP, Rev. 4. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: DOC.20061205.0004

177092 DOE 2006. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 18. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20060504.0008.

166427 MO0207UCC012DV.010. *Location of the Stations in the Southern Great Basin Digital Seismic Network.* Submittal Date: 7/26/2000.

163274 NRC (U.S. Nuclear Regulatory Commission) 2003. *Yucca Mountain Review Plan, Final Report.* NUREG-1804, Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 254568.

176337 Smith, K. 1997. LETTER REPORT, Strong Motion Data from the M 4.0 September 12, 1997 Northeast Jackass Flat Earthquake. Letter from K. Smith (UNRSL) to N. Biggar (YMP/M&O), September 29, 1997. ACC: MOL.20010705.0290.

177261 SN0405F3312393.015. *Tunnel Convergence and MPBX Data (With Results from 7/3/1999 Through 2/5/2004).* Submittal Date 4/18/2005.

170249 University and Community College System of Nevada. Von Seggern, D. 2004. *Southern Great Basin Seismic Network Operations.* SIP-UNR-027, Rev 0 [Reno] ACC: MOL.20040629.0239.

170522 von Seggern, D. 2005. *Initial Borehole Accelerometer Array Observations Near the North Portal of the ESF.* Task Number: ORD-FY04-006. TR-04-001 Rev. 0. Las Vegas, Nevada: U.S. Department of Energy, Nevada Seismolgical Laboratory. ACC: MOL.20050919.0341.

161209 YMP (Yucca Mountain Site Characterization Project) 2000. *Field Test Data Collection Systems.* Field Work Package FWP-ESF-96-001, Rev. 3. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20001228.0231.

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APPENDIX A

GLOSSARY

AOD—Access Observation Drift.

Accuracy—The degree to which a calculation, measurement, or set of measurements agree with a true value or an accepted reference value.

Barrier—Any material, structure, or feature that, for a period to be determined by the NRC, prevents or substantially reduces the rate of movement of water or radionuclides from the Yucca Mountain repository to the accessible environment, or prevents the release or substantially reduces the release rate of radionuclides from the waste. For example, a barrier may be a geologic feature, an engineered structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around the waste, provided that the material substantially delays movement of water or radionuclides.

Baseline—A set of information (developed from site characterization data, modeling assumptions or results, design bases and specifications, other relevant analogue or technical information) and analysis of that information on those parameters selected to be monitored, tested, evaluated, or observed during the performance confirmation program. The baseline is the standard to which comparisons are made, by parameter, to evaluate performance confirmation data. For the performance confirmation plan purposes, the baseline includes expected range, condition limits, and trend indicators (see baseline condition).

Condition limit—The discrete value(s) or trend(s) outside (upper or lower) the expected range that results in more detailed evaluation and potentially additional sampling (including adversely developing trends as defined in the performance confirmation test plans). The exceedance of a condition limit may cause a decision-maker to choose one of the alternative actions (e.g., conclusion of compliance or noncompliance). The condition limit is defined during the planning phase of a data collection activity (based on that parameter's importance to performance); it is not calculated from the sampling data. Condition limits for parameters will be discussed in the performance confirmation test plan for that activity.

Confirmation, or to confirm—In the context of the performance confirmation program, means to evaluate the adequacy of assumptions, data, and analyses that led to the findings that permitted construction of the repository and subsequent emplacement of the wastes.

Design bases—Information that identifies the specific functions to be performed by items and the specific values or ranges of values chosen for controlling parameters as reference bounds for design.

Disposal—The emplacement of radioactive waste in a geologic repository with the intent of leaving it there permanently.

Drift—The near-horizontal underground excavations from the shaft(s) or ramp(s) to the other excavations, such as alcoves and rooms. The term includes excavations for emplacement (emplacement drifts) and access (access mains).

Drip shield—A component of the engineered barrier system. The drip shield is above the waste package and is designed to (1) prevent seepage from dripping directly onto the surface of the waste package, and (2) to mitigate the effects of rockfall.

Emplacement—The placement and positioning of spent nuclear fuel or high-level radioactive fuel (i.e., waste packages) in prepared locations within excavations of a geologic repository.

Emplacement drift—A drift in which waste packages are placed.

Engineered barrier system—The waste packages, including engineered components and systems other than the waste package (e.g., drip shields), and the underground facility.

Expected range—A discrete set of values for a parameter within which collected data are expected to fall. The expected range values are established during the planning phase of a data collection activity and are selected based on assumptions, data, and analyses available prior to starting the collection of parameter data.

Experiment—A test under controlled conditions.

Exploratory Studies Facility—An underground facility at Yucca Mountain used for performing site characterization studies. The facility includes a 7.9-km (4.9-mi) main loop (tunnel), the 2.8-km (1.7-mi) Enhanced Characterization of the Repository Block Cross-Drift, and a number of alcoves used for site characterization tests such as the drift scale test.

Feature—A natural barrier structure, characteristic, process, or condition that functions to prevent or reduce the movement of water or prevent the release or substantially reduce the release rate of radionuclides.

Geologic repository—A system that is intended to be used for, or may be used for, the disposal of radioactive waste in excavated geologic media. A geologic repository includes the geologic repository operations area and the portion of the geologic setting that provides isolation of the radioactive waste.

Geologic repository operations area—A high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

Geologic setting—The geologic, hydrologic, and geochemical systems of the region in which a geologic repository is or may be located.

In situ—In its natural position or place. The phrase distinguishes between tests or experiments conducted in the field (e.g., in an underground excavation, in-place) from tests and experiments conducted in a laboratory.

Lithophysal—Pertaining to tuff units with lithophysae, small, bubble-like holes in the rock caused by volcanic gases trapped in the rock matrix as the ash-flow tuff cooled, often having concentric shells of finely crystalline alkali feldspar, quartz, and other materials that were formed by the entrapped gases that later escaped.

M—earthquake magnitude (Richter Scale).

Model—A representation of a system, process, or phenomenon, along with hypotheses required to describe the process or system or to explain the phenomenon, often mathematically. Model development typically progresses from conceptual models to mathematical models.

Monitoring—To keep track of systematically with a view to collecting information and to analyze or sample, especially on a regular or ongoing basis. In performance confirmation, monitoring is generally a long-term observation or sampling for a parameter or set of parameters.

Observation drift—A drift near a thermally accelerated emplacement drift from which conditions in the observed drifts can be monitored without adverse effects from radiation or temperature and with minimal disruption of the conditions in the observed drift.

Parameter—Scientific data, performance assessment data, or engineering technical information that represent physical or chemical properties, consisting of an assigned variable name and generally represented by a value or range of values. Select parameters that potentially are subject to varied interpretation and selection of multiple values, and subject to multiple use for various technical products within the project, reside in the Technical Data Management System.

Performance assessment—An analysis that: (1) identifies the features, events, processes (except human intrusion), and sequences of events and processes (except human intrusion) that might affect the Yucca Mountain disposal system and their probabilities of occurring during 10,000 years after disposal; (2) examines the effects of those features, events, processes, and sequences of events and processes upon the performance of the Yucca Mountain disposal system; and (3) estimates the annual dose incurred by the reasonably maximally exposed individual, including the associated uncertainties, as a result of releases caused by all significant features, events, processes, and sequences of events and processes, weighted by their probability of occurrence.

Performance confirmation—The program of tests, experiments, and analyses conducted to evaluate the accuracy and adequacy of the information used to demonstrate compliance with the postclosure performance objectives in Subpart E of 10 CFR 63.

Performance confirmation test plan—A test plan specifically developed to support the tests, experiments, and analyses of the performance confirmation program. Performance confirmation test plans are distinct from other types of test plans that will be generated for planning and executing tests that are used to verify conformance of an item to specified requirements, or to demonstrate satisfactory performance for service. Examples of such preclosure testing include prototype qualification tests, production tests, proof tests prior to installation, construction tests, and preoperational tests.

Permanent closure—Final backfilling of the underground facility, if appropriate, and the sealing of shafts, ramps, and boreholes.

Precision—A measure of mutual agreement among individual measurements of the same property.

Process model—A mathematical model that represents an event, phenomenon, process, or component, or series of events, phenomena, processes, or components. A process model may undergo an abstraction for incorporation into a system model.

Retrieval—The act of permanently removing radioactive waste from the underground location at which the waste had previously been emplaced for disposal.

Risk-informed, performance-based—An approach to decision-making whereby risk insights are considered together with other factors to establish requirements that better focus attention on design, operation, and performance issues commensurate with their importance to public heath and safety.

Sample (statistical)—In statistics, a set of data from the population.

Seepage—The flow of the groundwater in fractures or pore spaces of permeable rock to an open space in the rock; the percolation flux that enters an underground opening.

Seismic—Pertaining to, characteristic of, or produced by earthquakes or earth vibrations.

Seismic event—Seismic ground motion occurrence. (Could also include the effects of weapons testing and other man-made events.)

Significance—An effect is said to be significant if the value of the statistic used to test it lies outside defined limits; that is to say, if the hypothesis that the effect is not present is rejected. A test of significance is one that, by use of a test statistic, purports to provide a test of the hypothesis that the effect is absent. By extension, the critical values of the statistics are themselves called significant.

Site—That area surrounding the geologic repository operations area for which the DOE exercises authority over its use in accordance with the provisions of 10 CFR 63.

Site characterization—The program of exploration and research, both in the laboratory and field, that is undertaken to establish the geologic conditions and ranges of parameters of a particular site that are relevant to the implementing documents.

TTF—Thermal Test Facility.

Total system performance assessment—A risk assessment that quantitatively estimates how the proposed Yucca Mountain repository system performs in the future under the influence of specific features, events, and processes, incorporating uncertainty in the models and data. Its purposes are: (1) provide the basis for predicting system behavior and for testing that behavior against safety measures in the form of regulatory standards, (2) provide the results of total system performance assessment analyses and sensitivity studies, (3) provide guidance to site characterization and repository design activities, and (4) help prioritize testing and selection of the most effective design options.

Trend—A long-term movement in an ordered series, which may be regarded, together with the oscillation and random component, as generating the observed values.

Tuff—Igneous rock formed from compacted volcanic fragments created from pyroclastic (explosively ejected) flows with particles generally smaller than 4 mm in diameter; the most abundant type of rock at the Yucca Mountain site.

Uncertainty—A quantitative or qualitative measure of how well a mathematical model represents a system, process, or phenomenon, or the interval above and below the measurement, parameter, or result that contains the true value. There are two types of uncertainty: (1) stochastic (or aleatory) uncertainty caused by the random variability in a process or phenomenon, and (2) state-of-knowledge (or epistemic) uncertainty, which results from a lack of complete information about physical phenomena. State-of-knowledge uncertainty is further divided into: (i) Parameter uncertainty, which results from imperfect knowledge about the inputs to analytical models, (ii) Model uncertainty, which is caused by imperfect models of physical systems, resulting from simplifying assumptions or an incomplete identification of the system modeled, and (iii) Completeness uncertainty, which refers to the uncertainty as to whether the important physical phenomena, relationships (coupling), and events have been considered.

Underground facility—The underground structure, backfill materials, if any, and openings that penetrate the underground structure (e.g., ramps, shafts, and boreholes, including their seals).

Unsaturated zone—The zone between the land surface and the regional water table. Generally, fluid pressure in this zone is less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies the fluid pressure locally may be greater than atmospheric.

Variability—Refers to the observed difference attributed to heterogeneity or diversity in a population. Sources of variability are the results of natural random processes and stem from the differences among the elements of a population. Variability is not usually reducible by further measurement but can be better estimated by increased sampling based on the understood or assumed distribution in the parameter's physical attributes.

Variance—In performance confirmation, a difference between what is expected or predicted and what actually occurs. In statistics, the total variation displayed by a set of observations, as measured by the sums of squares of deviations from the mean, may in certain circumstances be separated into components associated with defined sources of variation used as criteria of classification for the observations. Such an analysis is called an analysis of variance, although in the strict sense it is an analysis of sums of squares. Many standard situations can be reduced to the variance analysis form.

Waste form—The radioactive waste materials and any encapsulating matrix.

Waste package—The waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container.

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APPENDIX B

IMPLEMENTING DOCUMENTS

B.1 PLANNING

SCI-PRO-002, *Planning for Science Activities*
LS-PRO-001, *Technical Reports*
PA-PRO-0202, *Expert Elicitation*
PI-PRO-005, *Requirements Management*
SCI-PRO-002, *Planning for Science Activities*
SIP-UNR-027, *Southern Great Basin Seismic Network Operations*

B.2 TEST CONTROLS

FWP-ESF-96-001, *Field Test Data Collection Systems*
IT-PRO-0009, *Control of the Electronic Management of Information*
IT-PRO-0011, *Software Management*
OP-PRO-9101, *Work Control Process*
PA-PRO-0313, *Technical Reports*
PA-PRO-0601, *Document Review*
TST-PRO-006, *Testing Work Implementation and Control*

B.3 RECORD CONTROLS

AP-17.1Q, *Records Management*
AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*
DM-PRO-001, *Document Control*
DM-PRO-002, *Records Management*

B.4 EQUIPMENT/INSTRUMENT CALIBRATION RECORDS

TST-PRO-002, *Control of Measuring and Test Equipment*
QA-PRO-1071, *Acceptance of Items and Services*

B.5 NONCONFORMANCES AND CORRECTIVE ACTIONS

AP-16.1Q, *Condition Reporting and Resolution*
AP-REG-009, *Reportable Geologic Condition*

B.6 PROCUREMENT

PM-PRO-001, *Procurement documents*

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APPENDIX C

PROCESS CONTROL EVALUATION FOR THE ELECTRONIC MANAGEMENT OF INFORMATION

Sandia National Laboratories	**Process Control Evaluation for the Electronic Management of Information** *Complete only applicable items.*	QA: QA Page 1of 2

A. Procedure/Work Activity Identification (check one)

☐ Procedure (identify process procedure number, title, and revision and ICN level being evaluated), or

☒ Work Activity (identify by work package number, Technical Work Plan, and technical product, including title and revision)

TWP-MGR-MM-000003 REV 00D

B1. Processes/Process Functions/Work Activities Evaluation

	Yes	No
1. Will, or does, the process/process function/work activity depend on a form of electronic media to store, maintain, retrieve, modify, update, or transmit information?	☒	☐
2. Will, or does, the process/process function/work activity manage, control, or use an electronic database, spreadsheet, set of files, or other holding system for information?	☒	☐
3. Will, or does, the process/process function/work activity transfer information electronically from one location to another? (The method may be File Transfer Protocol, electronic download, tape to tape, or disk to disk)	☒	☐
4. Will, or does, the process/process function/work activity produce any Sensitive Unclassified electronic information?	☐	☒

If the answers to Section B1 are all No, process in accordance with Step 6.1.2G.

B2. Processes/Process Functions/Work Activities Compliance Evaluation

	Yes	No	N/A
1. If any Sensitive Unclassified electronic information is produced, are the process controls in accordance with Sandia Corporate processes?	☐	☐	☒
2. Does the procedure or work activity document provide adequate controls to protect information from damage and destruction for its prescribed lifetime?	X	☐	
3. Does the procedure or work activity document provide adequate controls to ensure that information is readily retrievable?	X	☐	☐
4. Does the procedure or work activity document provide adequate controls to describe how information will be stored with respect to media, conditions, location, retention time, security, and access?	☒	☐	☐
5. Does the procedure or work activity document provide adequate controls to properly identify storage and transfer media as to source, physical and logical format, and relevant date?	☒	☐	☐
6. Does the procedure or work activity document provide adequate controls to ensure completeness and accuracy of the information input and any subsequent changes?	☒	☐	☐

Sandia National Laboratories	**Process Control Evaluation for the Electronic Management of Information** *Complete only applicable items.*	QA: QA Page 2of 2		
7.	Does the procedure or work activity document provide adequate access to controls to maintain the security and integrity of the information?	X	☐	☐
8.	Does the procedure or work activity document provide adequate controls to ensure that transfers are error free or within a defined permissible error rate (e.g., copying raw information from notebook to electronic information form, electronic media to another electronic media, or File Transfer Protocols)?	X	☐	☐

If the answers to Section B2 are all Yes, process in accordance with Step 6.1.2G. Mark "N/A" for those items that are not applicable to the specific process or work activity.

C. Results of Evaluation

Provide a summary of the as-is condition, proposed remedial actions, and expected completion date of document revision for each item in Section B2 that was indicated as No.

Responsible Manager	Date
[signature]	06/29/07