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CNWRA WORK PLAN TO ASSIST NRC IN THE DEVELOPMENT OF ANALYSIS CODES AND METHODS IN TECTONICS

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I. BACKGROUND

Tectonic activity and resultant geologic structures (e.g., faults, fractures, joints and associated deformation) are fundamental concerns for any potential repository site and site region. Effective assessment of preclosure geologic hazards due to fault displacement and earthquake seismicity is dependent on validation of tectonic models. The geologic structure of a repository site may have significant influence on characteristics important to repository performance, site performance, determination of site suitability and containment and isolation of waste material. Modeling of structures and tectonic processes which occur at the site and in the site region, with a foundation in the construction of balanced geological cross sections, provides an essential means of evaluating potential geological models of the site region and the repository site.

Computational and graphical analyses, using existing computer codes when feasible, and developing conceptual models and numerical methods when necessary, will be required to evaluate the technical validity and viability of potential compliance determination and demonstration methods. The work activities proposed for this task are necessary to provide the desired technical assistance to support input of tectonic/structural data into iterative performance assessment, scenario development and investigation of potentially disruptive geological phenomena, examination of coupled processes, and design of surface and subsurface facilities. The proposed work will support Systematic Regulatory Analysis (SRA) in Task 2 by providing necessary technical foundation for development of Compliance Determination Methods (CDMs) and Technical Review Components (TRCs). Iterative Performance Assessment (IPA) is directly supported by development of scenarios of repository-scale deformation, and by providing methods and software systems for critical evaluation of coupled tectonic, magmatic and groundwater flow processes. This work plan will also support IPA, by providing a confirmatory hydrostratigraphic framework model of Yucca Mountain.

It is not anticipated that the Department of Energy (DOE) will provide the Nuclear Regulatory Commission (NRC) with software systems and analytical methods appropriate for interactive review and evaluation of tectonic process and models from a regulatory perspective. Rather, the DOE is more likely to provide structural geologic and tectonic models in support of specific conclusions and interpretations. Such models are not easily evaluated or verifiable by inspection. By accomplishing the work proposed here, it is the intent of the Center for Nuclear Waste Regulatory Analyses (CNWRA) to provide the NRC with a set of techniques and software tools that are highly tailored for use by the technical staff conducting prelicensing and license application review.

II. TASK DESCRIPTION

Assistance in the development of analysis codes and methods for tectonics is identified as Subtask 3.2 in the Geologic Setting (GS) Program Element section of the CNWRA FY91-92 Operations Plans for the Division of High-Level Waste Management (DHLWM) (Change 2, September, 1991).

NRC staff will require the capability to comprehensively review and evaluate structural/tectonic models of the site and geologic setting of a proposed repository for high-level waste. CNWRA staff will support NRC in the attainment and maintenance of this capability by acquisition of the computer hardware and software systems, identification and integration of existing methods, and development and documentation of specially tailored methods for computer-assisted analysis of 2D and 3D models of geologic structure. CNWRA staff will develop techniques, by incorporating certain types of new and existing models, that can be used by NRC staff in the assessment of natural hazards due to earthquakes and surface faulting and in the assessment of other processes that may be coupled to tectonic processes or influenced by geologic structures (e.g., fracture and fault control of ground-water flow, deformation and stress changes on the scale of the repository block associated with faulting).

Work performed in this task will provide NRC and CNWRA staff with essential capabilities to review and evaluate model results, analyses, and interpretive conclusions presented by a license applicant. Staff will gain the necessary technical computing capabilities to quickly and interactively test conclusions drawn by the DOE on issues related to tectonic deformation and coupling of tectonic processes with magmatic and groundwater flow processes.

A. TASK ORGANIZATION

The activities to be performed in accomplishment of this subtask are subdivided into five separate phases as follows:

PHASE 1: Analysis of cross section tectonic models of Yucca Mountain.

PHASE 2: Repository-Block-Scale deformation modeling.

PHASE 3: Development of a 3D structural-hydrostratigraphic framework model of Yucca Mountain.

PHASE 4: Structural evolution of and structural geologic controls on the Yucca Mountain ground-water flow system.

PHASE 5: Analysis of faulting and dike intrusion at Yucca Mountain.

B. TASK ACTIVITIES AND DELIVERABLES

PHASE 1: Analysis of Cross Section Tectonic Models of Yucca Mountain.

The work activities proposed for this phase are necessary to provide NRC staff with information and capabilities for reviewing the tectonic models of Yucca Mountain and vicinity which should a required part of a license application. This work is necessary to provide an integration of geological data into iterative performance assessment and scenario development. The balanced models can be used to assess specific conclusions or interpretations presented by the license applicant, or can be used as 'templates' for direct comparison to tectonic models used by the applicant. Errors and inconsistencies in applicant models can thereby be identified quickly. Direct application of the balancing methods by the regulatory analyst can in turn lead to mutually acceptable solutions to problems related to tectonics.

Work performed in this phase will build the necessary methodological foundation to support development of scenarios of repository-block-scale deformation and IPA.

Activity 1.1: Complete the pilot analysis of the Scott and Bonk (1984) cross sections

The initial balanced analyses of the Scott and Bonk (1984) cross sections of Yucca Mountain (Young and Stirewalt, 1990) will be refined and completed. The three dip sections (A-A', B-B' and C-C') will be correlated to available borehole data and then to the strike section (E-E') so that the network of sections is consistent with respect to thickness of geologic units and dip of the marker horizons. Key modeling parameters (shear angle, deformed and undeformed state markers and initial fault angles) need to be fine tuned between sections so that variation in depth to detachment and fault trajectories can be minimized or adequately explained. In addition, section D-D' will be modeled. This activity illustrates the desired level of capability to review tectonic models.

The deliverable for this activity is a set of balanced cross section models of Yucca Mountain based on the initial sections of Scott and Bonk. Five sections will be delivered to NRC: 1) A-A'; 2) B-B'; 3) C-C'; 4) D-D'; and 5) E-E' (Intermediate Milestone 3702003310-011).

Activity 1.2: Integrate structural interpretation of reflection seismic data

NRC and CNWRA staff will require the capability to review and evaluate structural interpretations of reflection seismic data. This is the single most significant source of large-volume subsurface data likely to be available in the site region. This capability needs to be integrated with the other structural modeling activities in this phase. Reflection seismic data from the Amargosa Valley, immediately to the south of Yucca Mountain, will be interpreted based on the work done in Activity 1.1 above. Balanced deeper-level fault trajectories will be computed and a balanced cross section model constructed from the data.

A balanced structural interpretation of the Amargosa Valley reflection seismic data of the U.S. Geological Survey will be delivered to NRC (Intermediate Milestone 3702003310-012).

Activity 1.3: Determine slip history of faulting at Yucca Mountain by sequential restoration of balanced cross section models

The slip history of key faults in Yucca Mountain will have important implications for evaluation of potential natural hazards due to fault rupture and earthquake seismicity, and to consideration of future conditions and events. The slip history of the Paintbrush Canyon, Bow Ridge, Ghost Dance and Solitario Canyon faults will be determined by backstripping individual ash-flow sequences from the balanced models and then subtracting the slip required to accommodate deposition of the flow sequence. As far as is possible, dip data on flattened lithophysae, pumice fragments and other layered or stratified rock fabric will be used to determine changes in fault block dip (rotation) with time. Results of this activity will be reported in Major Milestone 3702003310-015.

Activity 1.4: Develop and test alternative tectonic models of faulting at Yucca Mountain (e.g., domino vs listric)

Existing conceptual models of faulting for the Great Basin region and Yucca Mountain area will be examined. The major classes of fault models will be tested using the sections constructed in Activity 1.1 above. (Intermediate Milestone 3702003310-014). A general model of faulting will be developed for the Yucca Mountain area.

Activity 1.5: Construct a series of balanced cross section models incorporating all available surface and subsurface geologic and geophysical data

A series of balanced cross section models of Yucca Mountain will be constructed from the sections produced in Activity 1.1 and from additional cross sections, areal geologic data and geophysical data available in the literature or from DOE. These sections will be specified in terms of a hydrogeologic stratigraphy to be agreed upon by GS and Performance Assessment (PA) staff. The intent is to produce a highly integrated structural geologic/tectonic interpretation of Yucca Mountain and to illustrate and document the modeling and analysis methods needed to test the geologic validity of tectonic models that may be used to demonstrate compliance by the license applicant.

A report on PHASE 1 (Activities 1.1 through 1.5) will be delivered to NRC. The report will focus on application of structural geologic modeling methods to review and evaluation of tectonic models that may be submitted by license applicant. Results of modeling and analyses, regulatory implications and the structural and tectonic framework of Yucca Mountain will be thoroughly discussed (Major Milestone 3702003310-015).

Activity 1.6: Provide training and instruction to NRC staff on the use of structural geologic analysis as a regulatory review and analysis tool

A schedule for training and instruction will be jointly developed by CNWRA and NRC staff. Training will be on computer facilities maintained at the CNWRA in San Antonio, Texas, and will be given by CNWRA staff and consultants (Intermediate Milestone 3702003320-016).

PHASE 2: Repository-Block-Scale Deformation Modeling.

Work in this phase will support IPA, through scenario development and analysis of coupled processes. CNWRA staff will link the kinematic results from the balanced models to finite element computation of deformation mechanics to determine magnitudes and distribution of stresses and strains resulting from faulting, fault-associated deformation, and potential uplift and doming due to magmatic intrusion. Changes in in-situ stress and fracture fabric, and associated influence on ground-water flow patterns will be examined. This phase will focus on the fault block bounded on the east by the Bow Ridge fault and on the west by the Solitario Canyon fault. Work in this phase will be coordinated with the Repository Design, Construction, and Operations (RDCO) program element.

Activity 2.1: Compute forward kinematic models of deformation due to incremental slip on major bounding faults at Yucca Mountain

A selected balanced model (from PHASE 1) of Yucca Mountain will be forward modeled to simulate the future accumulation of slip on the major fault systems. New hanging-wall fault block geometry will be determined for the block within which a proposed repository may be mined. Results of this activity will be used in Activity 2.2, and reported in Major Milestone 3702003320-024.

Activity 2.2: Model stress and strain field resulting from the forward models in Activity 2.1

The change in shape (strain) of the proposed repository fault block will be used to determine boundary conditions in terms of displacement for finite element modeling of the internal stress and strain field. Alternative dynamic models will test the sensitivity of the solution to the behavioral characteristics of the geologic materials (e.g., elastic vs elastic-plastic, etc.).

Results of this activity will be used in Activity 2.3 and reported in Major Milestone 3702003320-024.

Activity 2.3: Determine deformation effects on in-situ faults and fractures and map potential new faults and fractures

The behavior of faults and fractures internal to the fault block will be determined based on an assumed rheology and new loading conditions calculated by superposition of the in-situ stress state and the stress field due to fault movement.

Activity 2.4: Develop scenarios of repository-block-scale deformation

Scenarios of repository-block-scale deformation due to movement along adjacent faults will be described (Major Milestone 3702003320-024).

PHASE 3: Development of 3D Structural-Hydrostratigraphic Framework Model of Yucca Mountain.

NRC and CNWRA staff will require 2D and 3D structural and hydrostratigraphic framework models within which to set hydrologic flow and transport and other types of performance assessment models. CNWRA staff will acquire the requisite data and develop the appropriate framework models.

Activity 3.1: Obtain Digital Elevation Model (DEM) data and develop digital terrane model of Yucca Mountain

This activity essentially produces a digital model of the topography of Yucca Mountain. Results of this activity will be integrated with Activities 3.2, 3.3 and 3.4, and reported in Major Milestone 3702003320-034.

Activity 3.2: Obtain bore hole data on subsurface geologic markers and create subsurface structural models of key surfaces

Activity 3.3: Integrate interpreted fault surfaces with multi-surface geologic model

Activity 3.4: Integrate surface and subsurface bore hole and geologic data into 3D solid geometric model

A multi-surface structural/hydrostratigraphic model of Yucca Mountain will be produced for display and analysis on the Silicon Graphics Iris system of the CNWRA. Vertical and horizontal sections and 3D grids will be extracted from the model based on specifications by staff from the PA program element. The hydrostratgraphic framework sections can be used in IPA flow and transport models. (Major Milestone 3702003320-034).

PHASE 4: Structural Evolution of and Structural Geologic Controls on the Yucca Mountain Ground-Water Flow System.

Activity 4.1: Review literature on local and regional ground-water flow system of Yucca Mountain

A report will be submitted to the NRC (Intermediate Milestone 3702003310-041).

Activity 4.2: Integrate digital elevation model of water table and potentiometric surfaces with balanced cross section models

Activity 4.3: Compute ground-water flow paths in restored-state sections from Activity 1.3

A report on the structural evolution of the Yucca Mountain ground-water flow system will be delivered to NRC. The report will focus on structural geologic controls on ground-water flow with special emphasis being given to potential structural influence and genesis of the so-called anomalous ground-water gradient to the north of Yucca Mountain (Intermediate Milestone 3702003310-043).

PHASE 5: Analysis of Faulting and Dike Intrusion at Yucca Mountain.

Activity 5.1: Analyze alternative models of fault and dike interaction

Activity 5.2: Develop scenarios of coupled faulting and dike intrusion

A report on scenarios of interaction between faults and dike systems that may feed potential volcanic eruptive events at Yucca Mountain will be delivered to NRC. The report will focus on the spatial and temporal relationships between fault inception and movement, dike intrusion and the potential for fault-associated eruptive events (Intermediate Milestone 3702003320-002).

III. ESTIMATED LEVEL OF EFFORT

Cost and general scope of the work plan are included in the CNWRA FY92-93 Operation Plans for the NRC/DHLWM.

IV. SCHEDULE/MILESTONES

The following schedule is dependent on several factors. The duration of review periods and the scope of the required response to address comments may affect revisions of the schedule. Priority reactive work requiring the same staff and expertise may necessitate schedule revisions. Schedule revisions may also result from modifications required in Regulatory Requirements (RRs)/Regulatory Elements of Proof (REOPs) based on the resolution of uncertainties concerning the relationships between 10 CFR 60.112 and 10 CFR 60.122. It is anticipated that appropriate staff will be allocated for a joint NRC/CNWRA working group on tectonics. Development and

approval of appropriate procedures by the NRC and the CNWRA, and timely acquisition of necessary hardware and software systems will be important in holding to the schedule.

INTERMEDIATE MILESTONES

WORK ITEM	COMPONENT	TITLE	DATE
310-011	Activity 1.1	Complete the pilot analysis of the Scott and Bonk cross sections	Mar. 02, 1992
310-012	Activity 1.2	Integrate structural interpretation of reflection seismic data	Apr. 06, 1992
310-014	Activity 1.4	Develop and test alternative tectonic models of faulting at Yucca Mountain	Sept. 07, 1992
320-016	Activity 1.6	Provide training and instruction to NRC staff on the use of structural geologic analysis as a regulatory review and analysis tool	Mar. 1-5, 1992
310-041	Activity 4.1	Review literature on local and regional ground-water flow system of Yucca Mountain	Jun. 29, 1992
310-043	Activity 4.3	Compute ground-water flow paths in restored-state sections from Activity 1.3	Apr. 26, 1993
320-052	Activity 5.2	Develop scenarios of coupled faulting and dike intrusion	Nov. 05, 1993

MAJOR MILESTONES

WORK ITEM	COMPONENT	TITLE	DATE
310-015	Activity 1.5	Construct a series of balanced cross section models incorporating all available surface and subsurface geologic and geophysical data	Feb. 08, 1993
320-024	Activity 2.4	Develop scenarios of repository-block-scale deformation	Feb. 05, 1994
320-034	Activity 3.4	Integrate surface and subsurface bore hole and geologic data into 3D solid geometric model	Sept. 30, 1994

V. TECHNICAL CONTACTS

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VI. REFERENCES

Scott, R.B. and Bonk, J. 1984. Preliminary Geologic Map of Yucca Mountain, Nye County, Nevada, with Geologic Sections. U.S. Geological Survey Open-File Report 84-494.

Young, S. R. and Stirewalt, G. 1990. Evaluation of Computer-Assisted Cross Section Balancing Methods for Analysis of Subsurface Fault Geometry in the Vicinity of Yucca Mountain, Nevada: A Pilot Study; NRC Activity 3702-002-305-472.