NUREG-1620
Rev. 1

Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act

Draft Report for Comment

U.S. Nuclear Regulatory Commission
Office of Nuclear Materials Safety and Safeguards
Washington, DC 20555-0001

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Manuscript Completed: January 2002
Date Published: January 2002

Division of Fuel Cycle Safety and Safeguards
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

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ABSTRACT

A U.S. Nuclear Regulatory Commission source and byproduct material license is required by 10 CFR Part 40 for the operation of uranium mills and the disposal of "tailings," wastes produced by the extraction or concentration of source material from ores processed primarily for their source material. Appendix A to Part 40 establishes technical and other criteria relating to siting, operation, decontamination, decommissioning, and reclamation of mills and of tailings at mill sites. The licensee's site reclamation plan documents how the proposed activities demonstrate compliance with the criteria in Appendix A to Part 40 and the information needed to prepare the environmental assessment on the effects of the proposed reclamation activities on the health and safety of the public and on the environment.

This standard review plan is prepared for the guidance of staff reviewers in the Office of Nuclear Material Safety and Safeguards in performing safety and environmental reviews of reclamation plans for uranium mill tailings sites covered by Title II of the Uranium Mill Tailings Radiation Control Act. It provides guidance for new reclamation plans, renewals, and amendments. The principal purpose of this standard review plan is to ensure the quality and uniformity of staff reviews and to present a well-defined base from which to evaluate changes in the scope and requirements of a review.

This standard review plan is written to cover a variety of site conditions and reclamation plans. Each section contains a description of the areas of review, review procedures, acceptance criteria, and evaluation findings.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

FIGURE

TABLES

EXECUTIVE SUMMARY

A U.S. Nuclear Regulatory Commission (NRC) source and byproduct material license is required in accordance with the provisions of Title 10 of the U.S. Code of Federal Regulations, Part 40 (10 CFR Part 40), "Domestic Licensing of Source Material," in conjunction with uranium or thorium milling, or with byproduct material at sites formerly associated with such milling. At the termination of a uranium mill license, the mill tailings impoundment and some land will be turned over to the U.S. Department of Energy (DOE), another Federal agency designated by the President, or the State in which the site is located for long-term care. Requirements applicable to a license consist of the regulations in 10 CFR Part 40, Appendix A to 10 CFR Part 40, and any license condition. The specific sections in this standard review plan that address the criteria of 10 CFR Part 40, Appendix A are shown in Appendix A of the review plan.

An application for a new license, license renewal, or an amendment to or termination of an existing license should contain, as appropriate, proposed specifications relating to the milling operations, and the information on the disposal of tailings or wastes resulting from such milling activities and information on decommissioning of the site. General guidance on (i) contents and filing of an application and (ii) producing an environmental report appears 10 CFR 40.31, "Application for specific licenses," and in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," respectively. The staff uses the information in the application to determine whether the proposed activities will be protective of public health and safety and be environmentally acceptable. General provisions for issuance, amendment, transfer, and renewal of licenses are described in 10 CFR Part 2, Subpart A. Guidance on considering environmental justice issues during licensing of Title II uranium or thorium mills is presented in NUREG–1748 (NRC, 2001).

This standard review plan provides the staff in the Office of Nuclear Material Safety and Safeguards with specific guidance on the review of reclamation plans and license amendments related to reclamation plans. The reclamation plan, submitted by an applicant (in the case of a new application) or a licensee (in the case of an amendment to a previously approved reclamation plan or termination of an existing license) should demonstrate compliance with the applicable criteria in Appendix A to 10 CFR Part 40. The principal purpose of the standard review plan is to present guidance to the NRC staff to ensure a consistent quality and uniformity in NRC reviews of reclamation plan. Each section in this standard review plan contains guidance on what is to be reviewed, the basis for the review, how the staff review is to be done, what the staff will find acceptable in a demonstration of compliance with the regulations, and the conclusions that are sought regarding compliance with the regulations in 10 CFR Part 40. This standard review plan is intended to cover only those aspects of the NRC regulatory mission related to the reclamation of mill tailings sites, including ground-water cleanup, at conventional uranium mills. As such, the standard review plan helps focus the staff review on determining if a tailings impoundment can be constructed, operated, and reclaimed in compliance with the applicable NRC regulations. The standard review plan is also intended to make information about regulatory matters widely available to improve communication, and to help interested members of the public and uranium recovery industry gain a better understanding of the staff review process. In any of these reviews, the staff will consider licensee-proposed alternatives to Appendix A criteria as described in the Introduction in Appendix A to 10 CFR Part 40. The review would cover the level of protection to the public health and safety and the environment and the level of stabilization and containment of the site. All site-specific licensing decisions based on Appendix A criteria or proposed alternatives will consider the risk to health and safety and the environment and the economic costs involved. Staff guidance for review of environmental reports and preparing environmental assessments is found in NUREG–1748 (NRC, 2001).

For license amendments, the review should focus on the changes proposed in the amendment [see NUREG–1748 (NRC, 2001) for guidance on reviewing historical aspects of site performance]. Reviewers should not review previously accepted actions if they are not part of the proposed amendment, unless the review of the amendment package identifies an impact on previously accepted actions.

For changes to previously approved reclamation plans, the licensee need only submit information pertinent to the proposed change. The licensee need not resubmit a complete reclamation plan covering all aspects of site reclamation, but should present information on the proposed changes to the previously approved plan and its updates as identified in the current NRC license. Reviewers should also analyze the inspection history and operation of the site to see if any major problems have been identified over the course of the license term that would have an effect on reclamation. The operating history of the facility is often a valuable source of information concerning the adequacy of site characterization, the acceptability of radiation protection and monitoring programs, and the sufficiency of other data that may influence staff determination of compliance. NUREG–1748 (NRC, 2001) presents guidance for review of these historical aspects of facility performance. If the changes are found to be acceptable, the license is then amended to identify the revised reclamation plan as the required design for reclamation.

License termination usually involves a confirmation that all applicable requirements have been met. This includes ensuring completion of stabilization work for the tailings consistent with the accepted reclamation plan and a determination that the licensee has complied with all standards applicable to land structures, and ground-water cleanup. As such, the information in this review plan will be used to help make the necessary conclusions concerning license termination in three ways. First, this standard review plan will present guidance on how the reclamation and ground-water cleanup plans will be reviewed to determine if they are in compliance with requirements of 10 CFR Part 40, Appendix A. Second, the standard review plan will help the reviewers determine if land and structures have been decommissioned consistent with the accepted design. Information for this review is found in a construction completion report, as supplemented by NRC inspection of construction. Finally, the standard review plan provides guidance on what needs to be done to determine if the ground-water cleanup program has achieved its objective of restoring any contaminated ground water to appropriate standards. Compliance with these three aspects of reclamation, taken together, forms the basis for the staff finding that the design and ground-water cleanup program meet applicable requirements, and that the design and cleanup program have been acceptably completed at the sites and that the licensee has, therefore, met the applicable requirements.

The staff will prepare the following reports to document the review: a technical evaluation report and an environmental assessment. The guidance in NUREG–1748 (NRC, 2001) will be used to prepare the environmental assessment. The provisions of 10 CFR 51.21 require preparation of an environmental assessment unless: (i) the staff finds, based on the environmental assessment, that NRC needs to prepare an environmental impact statement; (ii) another federal agency also involved in the action as a cooperating agency needs to prepare an environmental impact statement; (iii) if the effects on the quality of the human environment are likely to be highly controversial; or (iv) 10 CFR 51.22 categorically excludes the necessity to prepare an environmental assessment. Applications for new mills require NRC to prepare an environmental impact statement in accordance with 10 CFR 51.20(b)(18). This standard review plan is intended to guide the preparation of the technical evaluation report. NRC guidance for preparation of an environmental assessment is provided in NUREG–1748 (NRC, 2001).

It is important to note that the acceptance criteria noted in this standard review plan are for the guidance of the Office of Nuclear Material Safety and Safeguards staff responsible for the review of applications. Review plans are not substitutes for the Commission regulations, and compliance with a particular standard review plan is not required. Methods and solutions different from those set out in the standard review plan may be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a license by NRC. Use of this standard review plan does not obviate the need for professional judgement; it helps assure overall completeness and uniformity of the staff review.

GENERAL REVIEW PROCEDURE

A licensing review is not intended to be a detailed evaluation of all aspects of facility operations. Specific information about implementation of a program or construction of a design outlined in an application is obtained through the NRC review of procedures and operations done as part of the inspection function. The differences between licensing reviews and inspections are shown in Figure 1. For a new license application, the staff will review the proposed reclamation plan and ground water program for compliance with the criteria in Appendix A to 10 CFR Part 40. For a license renewal or an amendment to an existing license, the staff will only review proposed changes to the NRC-approved reclamation plan for compliance with criteria in Appendix A to 10 CFR Part 40. If the changes proposed have an adverse impact on the performance or functionality of some of the approved features at the site, then the staff will review those items for their compliance with regulations.

In the case of an amendment application concerning confirmation of site or ground-water cleanup or completion of construction, the reviewer will focus on ensuring that the applicable activities have been completed consistent with the approved review plan. Reviewers will not revisit accepted designs or plans unless the as-completed activity presents problems, such as degradation or reconformation.

Changes to existing licensed activities and conditions require the issuance of an appropriate license amendment. An application for such an amendment should describe the proposed changes in detail and should discuss the potential environmental and health and safety impacts. Amendment requests should be reviewed using the appropriate sections of this document for guidance. NUREG–1748 (NRC, 2001) contains guidance for examining the historical aspects of facility operations in connection with amendment reviews. The steps of the reclamation plan review are described in the paragraphs that follow.

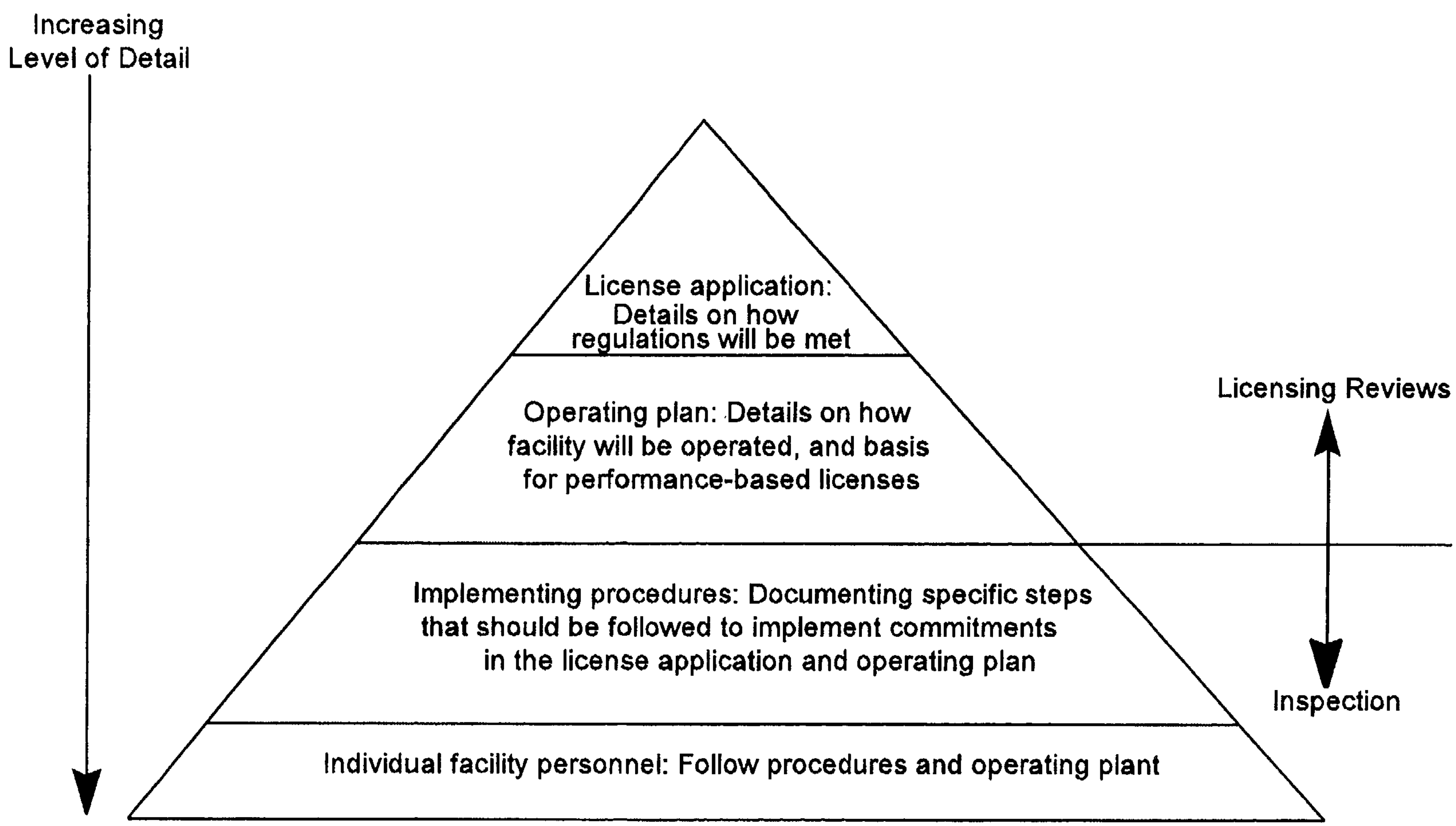

Figure 1. Schematic of NRC Licensing and Inspection Process and Applicability to Different License Documents

Acceptance Review

The staff will conduct an acceptance review of a new reclamation plan or changes to a previously approved plan to determine the completeness of the information submitted. The reclamation plan will be considered acceptable for docketing if the information in it is complete, reflects an adequate reconnaissance and physical examination of the regional and site conditions, and contains appropriate analyses and design information to demonstrate that the applicable regulatory criteria will be met. Completeness of the environmental report will be determined using the information requirements in 10 CFR 51.45 and the guidance in NUREG–1748 (NRC, 2001). The staff should complete the acceptance review and transmit the results to the applicant within 30 days of the receipt of the application, along with a projected schedule for the remainder of the review. In this transmittal, the staff should note any additional information needed to make the reclamation plan or environmental report complete. Detailed technical questions, although not required, can be included, if they are identified during the acceptance review. If the contents of the reclamation plan or environmental report do not clearly demonstrate compliance with applicable regulatory criteria, then the staff may decline to docket the reclamation plan and will return it to the licensee for revisions.

Detailed Review

Following completion of the acceptance review, the staff will conduct a detailed technical review of the reclamation plan. During the detailed review, if there is a need for additional information, the staff will send to the licensee a request for additional information identifying the issue or concern, basis for the concern, and the kind of information needed to resolve the concern. After the staff receives a satisfactory response to the request for additional information, the detailed review will be concluded. NRC documents the results of this review and the basis for acceptance or denial of the requested licensing action in a technical evaluation report, and in an environmental assessment (10 CFR 51.21) if there is a finding of no significant impact, or in an environmental impact statement (10 CFR 51.20) if the reclamation plan is part of an application for a new mill or if one of the other requirements for an environmental impact statement have been met (10 CFR 51.20). The detailed review should evaluate the environmental, economic, and technical evidence presented by the applicant to support the ability of the proposed facility to meet applicable regulatory requirements. In the case of amendments to an existing license as a result of changes to a previously approved reclamation plan, the need for an environmental assessment will be determined on a case-by-case basis.

In determining the acceptability of any aspect of tailings reclamation, the staff will evaluate the use of alternatives to meeting the specific requirements in 10 CFR Part 40, Appendix A. In evaluating the use of alternatives, the staff will determine if the proposed reclamation design satisfactorily demonstrates the requisite requirements of economic benefit and equivalent protection. In this standard review plan, we identify alternatives that have been found to be acceptable by the staff in previous reviews. Alternatives developed by licensees need not be limited to those discussed here. Other alternatives can be proposed, as long as the economic benefit and equivalent protection can be demonstrated.

The Standard Review Plan

The standard review plan is written to cover a variety of site conditions and reclamation designs. Each section presents the complete procedure and acceptance criteria for all the areas of review pertinent to that section. For any given application, the staff reviewer may select and emphasize particular aspects of each standard review plan section as appropriate for the reclamation plan. Because of this, the staff may not carry out, in detail, all of the review steps listed in each standard review plan section, in the review of every reclamation plan.

I. Areas of Review

This subsection describes the scope of the review (i.e., what is being reviewed). It contains a brief description of the specific technical information and analyses in the reclamation plan that need to be reviewed by each technical reviewer.

II. Review Procedures

This subsection discusses the appropriate review technique. It is generally a step-by-step procedure that the reviewer uses to determine whether the acceptance criteria have been met.

III. Acceptance Criteria

This subsection delineates criteria that the reviewer can apply to determine the acceptability of the applicant's compliance demonstration. The technical bases for these criteria have been derived from 10 CFR Parts 20, 40, and 51, NRC regulatory guides, general design criteria, codes and standards, NRC branch technical positions, standard testing methods (e.g., American Society for Testing and Materials standards), technical papers, and other similar sources. These sources typically contain solutions and approaches previously determined by the staff to be acceptable for making compliance determinations for the specific area of review. These acceptance criteria have been defined so that staff reviewers can use consistent and well-documented approaches for review of all reclamation plans. In the absence of well-defined acceptance criteria, the staff will rely on "professional judgment" and what is normally practiced in the profession. Licensees may take approaches to demonstrating compliance that are different from those in this standard review plan. However, they should recognize that, as is the case for regulatory guides, substantial staff time and effort have gone into the development of these procedures and criteria, and a corresponding amount of time and effort may be required to review and accept new or different solutions and approaches. Thus, licensee-proposed solutions and approaches to safety problems or safety-related design areas other than those described in this standard review plan may require longer review times and NRC requests for more extensive supporting information. The staff is willing to consider proposals for other solutions and approaches on a generic basis, apart from a specific review, to avoid the impact of the additional review time for individual cases.

IV. Evaluation Findings

This subsection presents the staff's general conclusions and findings that result from review of each area of the reclamation plan, as well as an identification of the applicable regulatory requirements. Conclusions and findings for a specific site and review area are dependent on the site characteristics and type of licensing action being considered. For each standard review plan section, a conclusion is included in the technical evaluation report/safety evaluation report or in the environmental assessment/environmental impact statement, in which results of the review are published. These documents contain a description of the review; the basis for the staff findings, including aspects of the review selected or emphasized; where the reclamation design or the licensee's plans deviate from the criteria stated in the standard review plan; and the evaluation findings.

Standard Review Plan Updates

The standard review plan will be revised and updated periodically as the need arises to clarify the content or correct errors and to incorporate modifications approved by NRC management.

REFERENCE

NRC. NUREG–1748, "Environmental Review guidance for Licensing Actions associated with NMSS Programs." Washington, DC: NRC, Office of Nuclear Material Safety and Safeguards. 2001.

1.0 GEOLOGY AND SEISMOLOGY

The reclamation plan and its supporting documents must contain sufficient regional and site-specific geologic and seismologic information related to the proposed disposal site and reclamation design, including regional and site-specific stratigraphy, structure, geomorphology, and seismology. This standard review plan establishes the requirements for staff of the U.S. Nuclear Regulatory Commission (NRC) to conduct and document the review of new reclamation plans for mill tailings impoundments, or amendments to previously approved reclamation plans in the areas of geology and seismology.

1.1 Stratigraphic Features

1.1.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific stratigraphy. The reclamation plans should describe surface and subsurface strata and the interpretation of their orientation, occurrence, thickness, composition, age, and relationship. The reviewer should coordinate the stratigraphic information with the evaluation of the site's geotechnical stability, surface water and erosion protection, and ground-water resources protection information as described in standard review plan Chapters 2.0, 3.0, and 4.0, respectively. The purpose of this review is to determine if there has been an acceptable characterization of site and regional stratigraphy so that sufficient information has been presented for use in the reclamation plan and design of the tailings cell.

1.1.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific features to determine if a thorough evaluation of the regional and site stratigraphy has been presented.

The following specific descriptive information should be reviewed to determine its adequacy for characterizing the regional and site-specific stratigraphic features:

(1) Description of regional stratigraphic units by rock classification and type

(2) Distribution of regional stratigraphic units

(3) Age relationships of regional and site-specific stratigraphic units

(4) Detailed site stratigraphy based on outcrop and well borings conducted to determine rock types and their texture, composition, distribution, and thickness

The staff determination of compliance should be based in part on professional judgment, considering the complexity of the subsurface conditions at the site.

1.1.3 Acceptance Criteria

The characterization of regional and site stratigraphy will be acceptable if the information presented conforms to the following criteria:

(1) The regional and site-specific stratigraphy are described in sufficient detail to produce an adequate understanding of the site-specific subsurface characteristics, including descriptions of major stratigraphic units and their orientations, age relationships, thicknesses, distributions and any stratigraphic features (e.g., facies changes) likely to affect site stability or ground-water resource protection.

(2) Stratigraphic units are described in sufficient detail to provide input to a geotechnical stability analysis.

(3) Descriptions of regional and site-specific stratigraphic units contain sufficient information for input to an analysis of ground water resources and the protection thereof.

(4) Regional stratigraphic information is discussed in sufficient detail to support site-specific information.

(5) Descriptions of the regional and site stratigraphy are based on published literature and site data and conform to standard geological classifications.

(6) Discussions of regional stratigraphy are adequately referenced and supported by published reports, maps, logs, and cross sections.

(7) Site descriptions are based on field investigations and adequate sampling to define physical and chemical properties of surface and subsurface materials such as soils and underlying geologic formations at the site.

(8) Maps are at a scale sufficient to show the locations of all site explorations such as borings, geophysical surveys, trenches, and sample locations.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site conditions.

1.1.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.1, results in the acceptance of the characterization of regional and site stratigraphy, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of the regional and site stratigraphy during reclamation and decommissioning at the_______________ uranium mill facility. This review included an evaluation using the review procedures in Section 1.1.2 and the acceptance criteria outlined in Section 1.1.3 of the Title II standard review plan.

The licensee has provided an acceptable description of the stratigraphic features by presenting a description of the site and regional stratigraphy using published information and information collected for the specific purpose of supporting determinations of geotechnical stability and ground water analyses at the site. Data gathering, investigations, and analyses have used acceptable standards and practices. Data and interpretations are presented to allow effective incorporation into geotechnical and ground-water analyses.

On the basis of the information and analysis presented in the review plan on the stratigraphic features at the _______________ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), which requires that tailings impoundments not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand is likely to occur, or an acceptable alternative method of determination of seismic hazard has been used, have been met. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and post-operational periods. The description of the physical and chemical properties of the underlying soils and geologic formations of the site is sufficient to meet the requirements of 10 CFR Part 40, Appendix A, Criterion 5G(2) with regard to the extent to which they will control transport of contaminants and solutions. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.1.5 References

None.

1.2 Structural and Tectonic Features

1.2.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific structural and tectonic setting. The reclamation plan should contain a definition of surface and subsurface structural and tectonic features and an interpretation of their origin, occurrence, age, and potential impacts, if any, on the stability of the site. Review of the structural and tectonic information should be coordinated with the evaluation of the site's geotechnical stability, surface water and erosion protection, and ground-water resources protection information as described in standard review plan Chapters 2.0,3.0,and 4.0, respectively. The reviewer will determine whether the information presented is sufficient to support an analysis of geologic features as they affect the facility.

1.2.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific information to determine if a thorough evaluation of structural and tectonic features has been presented. This may include analyses of photogrammetric data, results of field reconnaissance and detailed mapping, review of pertinent literature, and geophysical data and studies. Features that should be considered in the review include structural features such as faults and fractures, crustal deformation, and volcanic features that may affect the site stability or ground-water conditions.

The following specific descriptive information should be reviewed to determine its adequacy for characterizing the regional and site-specific structural features necessary to support the evaluations of reclamation system performance:

(1) Description and location of regional structural features based on published information and field reconnaissance

(2) Description and location of site subsurface structural features from sources such as available borings, drill logs, geophysical logs and data, and existing literature

(3) Description of any volcanic features such as flows, cones, plugs, or dikes located in the site region

(4) Age relationships of regional and site-specific structural and tectonic features

(5) Discussion of published literature containing interpretations of any of the information in Items 1, 2, 3, and 4, above

(6) A description of known mineral resources and recovery operations

Staff determination of compliance should be based in part on professional judgment, considering the complexity of the subsurface conditions at the site.

1.2.3 Acceptance Criteria

The characterization of regional and site structural features will be acceptable if the information presented in the reclamation plan conforms to the following criteria:

(1) Descriptions of regional and site-specific structural and tectonic features are based on published literature and gathered data.

(2) Regional structural and tectonic features, particularly faults, are defined in sufficient detail to present an adequate understanding of the structural geologic conditions that may have a likelihood of affecting the site stability or ground-water regime.

(3) Site-specific structural and tectonic features, particularly faults, are described in sufficient detail to present adequate information for an analysis of the site stability.

Information presented adequately addresses the uncertainties and variability within the site area and the potential impacts on the disposal facility.

(4) The structural and tectonic province or provinces that influence the site seismicity are identified and described.

(5) The tectonic history of the pertinent province(s) is discussed in sufficient detail to support an analysis of the potential for disruption of the site by tectonic activity.

(6) Discussions of structural, tectonic, and volcanic features are adequately referenced and are supported by maps, logs, and cross sections showing locations of all site explorations and surveys, and depicting surface and subsurface structural and tectonic features.

(7) Descriptions contain discussions of age relationships of structural and tectonic features.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site conditions.

1.2.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.2, results in the acceptance of the characterization of the structural and tectonic features of the region and site, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of structural and tectonic features at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 1.2.2 and the acceptance criteria outlined in Section 1.2.3 of the Title II standard review plan.

The licensee has acceptably described the regional and site-specific structural and tectonic features by presenting discussions and interpretations of pertinent data and reportsthat may have an impact on the site or tailings disposal system. Information presented includes descriptions of any faults capable of disrupting the site and any other information necessary to support an analysis of the geotechnical stability or ground-water conditions at the site. In addition, the staff concludes that the licensee has used acceptable methods of investigation and analysis to support its conclusions.

On the basis of the information and analysis presented in the review plan on the structural and tectonic features at the _______________ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), which requires that tailings impoundments not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand is likely to occur, or an acceptable alternative method of determination of seismic hazard has been used, have been met. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and postoperational periods. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.2.5 References

None.

1.3 Geomorphic Features

1.3.1 Areas of Review

The staff should review the information presented in the reclamation plan on the regional and site-specific geomorphic features. The reclamation plan should analyze regional and local landforms to determine evidence for geomorphic processes that may impact the long-term stability of the site, including information to support an evaluation of the potential for any destructive geomorphic processes, such as mass wasting, extreme erosion, and stream encroachment. The reviewer should coordinate the geomorphic information with the evaluation of the site's geotechnical stability and surface water and erosion protection information as described in standard review plan Chapters 2.0 and 5.0, respectively. The results of this review will be used to determine the acceptability of the design during operation and long-term stabilization.

1.3.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific geomorphic information to determine if a thorough evaluation has been presented. Information should be detailed enough for the reviewer to make a determination regarding the geomorphic stability of the site.

The following specific descriptive information should be reviewed to determine the acceptability of the assessment of the regional and site-specific geomorphology as it relates to geomorphic stability of the site:

(1) Description of the physiographic (geomorphic) province(s) in which the site is located, including a discussion of the distinguishing characteristics such as elevation and relief

(2) Discussion of the active processes, such as erosion, mass wasting, and stream encroachment, within the site region and the nature and extent of those processes

(3) Topographic maps depicting geomorphic surfaces, physiographic provinces, landforms, drainage networks, rivers, surficial geologic units, areas of subsidence, and geomorphic hazards

(4) Aerial photographs of the site area

(5) Discussion of the age, occurrence, and origin of geomorphic features, in particular those that may adversely affect site stability

1.3.3 Acceptance Criteria

The characterization of regional and site geomorphic features and geomorphic stability will be acceptable if the information presented conforms to the following criteria:

(1) Descriptions of the regional and site-specific geomorphology and geomorphic processes include information sufficient to allow the reviewer to assess the nature and extent of major active processes that may modify the present-day topography of the geomorphic province(s) and the site area.

(2) The geomorphic features, particularly potential geomorphic hazards, are clearly delineated on topographic base maps of adequate scale to enable the reviewer to assess their occurrence and distribution.

(3) Descriptions are adequately referenced and are supported by published reports and maps or site data.

(4) The regional and site-specific geomorphology and geomorphic processes are described in sufficient detail to support an analysis of the geomorphic and geotechnical stability of the site.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site conditions.

1.3.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.3, results in the acceptance of the characterization of the geomorphic features of the region and site and provides information sufficient to support an assessment of the geomorphic stability, the following conclusions may be presented in the technical evaluation report.

The NRC has completed its review of the information concerning the characterization of geomorphic features at the ______________ uranium mill facility. This review included an evaluation using the review procedures in Section 1.3.2 and the acceptance criteria outlined in the Title II standard review plan.

Geology and Seismology

The licensee has acceptably described the geomorphic features by presenting an adequate description of regional and site geomorphology using published information and information collected for the specific purpose of supporting determinations of the stability of site. Data gathering, investigations, and analyses have used acceptable standards and practices. Data and interpretations are presented to allow effective incorporation into other site analyses.

On the basis of the information and analysis presented in the review plan on the geomorphic features at the _______________ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), which requires that tailings impoundments not be located near a capable fault that would cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand is likely to occur, or an acceptable alternative method of determination of seismic hazard has been used, have been met. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and postoperational periods. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.3.5 References

None.

1.4 Seismicity and Ground Motion Estimates

1.4.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific seismicity and the basis for determining the vibratory ground motion (peak horizontal acceleration) at the site from seismic events. The purpose of this review is to determine the potential for seismic events to affect the site. The reviewer will determine whether the information presented is sufficient to support an analysis of the design for the operational and closure periods.

1.4.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific information to determine if a thorough evaluation of the potential for seismic activity has been presented. The information should be sufficient to enable the reviewer to determine the vibratory ground motion (peak horizontal acceleration) at the site from seismic events.

The following specific descriptive information should be reviewed to determine the acceptability of the characterization of the seismicity and the assessment of the stability of the site and geotechnical design:

(1) A listing of all recorded earthquakes in the tectonic province in which the site is located and in other tectonic provinces within 200 km [124 mi] of the site. This listing should contain the date of occurrence of the earthquake, its magnitude, and the location of the epicenter. Since earthquakes have at times been reported in terms of intensity at a given location, or effect on ground, structures, and people at a specific location, some of this information may have to be estimated by use of appropriate empirical relationships.

(2) Data obtained by standard photogeologic analysis and field reconnaissance of the study area and from review of the pertinent literature. Information in the form of maps, papers, or other data, specific to the area or region, generated by state and federal agencies or published in the literature.

(3) An association of epicenters or locations of highest intensity of historic earthquakes with tectonic structures, where possible. Epicenters or locations of highest intensity that cannot be reasonably identified with tectonic structures should be identified with tectonic provinces.

(4) Maps on which the locations of epicenters of historic earthquakes, associated tectonic structures, and tectonic provinces have been depicted.

(5) The applicant proposed maximum earthquakes associated with each tectonic province or capable fault or structure.

(6) Deterministic and/or probabilistic seismic hazard analyses.

For a deterministic analysis, the potential ground motion at the site from capable faults within the site region should be assessed. The term "capable fault" as used in 10 CFR Part 40, Appendix A, Criterion 4(e) has the same meaning as defined in Section III(g) of Appendix A to 10 CFR Part 100. Alternatively, the licensee may choose to use the term "capable tectonic source" as defined in Appendix A to Regulatory Guide 1.165 (NRC, 1997) to conduct its analysis.

A probabilistic seismic hazard analysis yields a curve of exceedence probability versus peak horizontal acceleration. The 10^{-4} value represents a 1 in 10 chance of the site exceeding the peak horizontal acceleration in a 1,000-year period, which is appropriate for a 1,000-year design life. The seismic hazard analysis of uranium recovery mill sites by Bernreuter, et al. (1994) contains probabilistic analyses for Title II mill sites. The study by Bernreuter, et al. (1994) is intended as a screening study; the probabilistic seismic hazard estimates are not site specific and are only calculated for random earthquakes.

(7) Seismic design ground motion (peak horizontal acceleration).

Geology and Seismology

Staff determination of compliance should be based in part on professional judgment, considering the complexity of the regional and site-specific seismicity. The reviewer will focus on evaluating the maximum credible earthquake, as required by 10 CFR Part 40, Appendix A, Criterion 4(e), unless an alternate method of determining ground motion is presented as allowed in the Introduction to Appendix A. One such alternative to the maximum credible earthquake is a probabilistic seismic hazard analysis, which is presented in Section 1.4.3, below.

1.4.3 Acceptance Criteria

The regional and site-specific seismicity and ground motion estimates will be acceptable if the following criteria are met:

(1) The information presented on the regional and site-specific seismicity contains sufficient detail to allow the staff to determine the vibratory ground motion (peak horizontal acceleration) at the site caused by seismic events and to further use that determination to assess the geotechnical stability of the site. The geotechnical stability of the site is sufficient to control radiological hazards for 1,000 years to the extent reasonably achievable, and, in any case, for at least 200 years.

(2) In conducting this review, the staff will consider a deterministic and/or a probabilistic seismic hazard analysis as an acceptable method for selecting the peak horizontal acceleration for a site. An analysis of the geotechnical stability of the design proposed in the reclamation plan will be based on the resultant peak horizontal acceleration (Chapter 2.0, "Geotechnical Stability," of this standard review plan).

  (a) <u>Deterministic Analysis</u>: The use of a deterministic seismic hazard analysis is acceptable if:

    (i) Capability is determined by suitable methods, such as those outlined by Slemmons (1977).

    (ii) Fault length versus magnitude relationships for determining the maximum magnitude earthquake that may be produced by each capable fault or capable tectonic source are developed using acceptable approaches such as those of Slemmons, et al. (1982); Bonilla, et al. (1984); or Wells and Coppersmith (1994).

    (iii) For each maximum magnitude earthquake, the peak horizontal acceleration at the site is determined using the applicable attenuation relationship between earthquake magnitude and distance for the site. Campbell (1997); Campbell and Bozorgnia (1994); and Boore, et al. (1993, 1997) offer examples of acceptable attenuation relationships. In applying the relationship, the site-to-source distance should be the distance between the site and the closest approach of the fault.

(iv) The peak horizontal acceleration value adopted for each capable fault or tectonic source is not less than the median value provided by the attenuation relationship. Possible soil amplification effects are considered.

(v) To assess potential ground motion at the site from earthquakes not associated with known tectonic structures (i.e., random or floating earthquakes), the largest floating earthquakes reasonably expected within the tectonic province are identified. In addition, the largest floating earthquakes characteristic of any adjacent tectonic provinces are identified, if such earthquakes cause appreciable ground motion at the site. For each of these earthquakes, the peak horizontal acceleration at the site is calculated as stated previously, with 15 km [9 mi] used as the site-to-source distance for floating earthquakes within the host tectonic province. For floating earthquakes in other tectonic provinces, the distance between the site and the closest approach of the province boundary is used as the site-to-source distance.

(vi) The peak horizontal acceleration for the site is the maximum value of the peak horizontal accelerations determined for earthquakes from all capable faults, tectonic sources, and tectonic provinces.

(b) Probabilistic Analysis: The use of a probabilistic seismic hazard analysis as an alternative to the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), is acceptable, as is stated in the Introduction to Appendix A, if:

(i) It is shown that the design proposed by the licensee will achieve a level of stabilization and containment, and a level of protection for public health and safety and the environment, which is equivalent to, to the extent practicable, or more stringent than that achieved by the requirements of 10 CFR Part 40, Appendix A.

(ii) The licensee takes into account local conditions when estimating the seismic design of the facility because peak horizontal acceleration values are often calculated for hypothetical rock foundations. The effects of local site conditions on the peak ground acceleration are reviewed in Chapter 2.0 in the standard review plan.

(3) The presentation on seismotectonic stability is acceptable if sufficient information is presented to support interpretations and conclusions. If the staff should conclude that the information presented is insufficient, it will request additional information or investigations. Staff determination of compliance should be based, in part, on professional judgment, considering the complexity of site and seismic conditions.

1.4.4 Evaluation Findings

If the staff review as described in standard review plan Section 1.4 results in the acceptance of the characterization of the seismicity of the region and site and the seismic design ground motion, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of the seismicity at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 1.4.2 and the acceptance criteria outlined in Section 1.4.3 of the Title II standard review plan.

The licensee has presented information and investigations that support its conclusions about the seismic characterization of the site and the seismic design value. Information presented includes descriptions of historical earthquakes, locations of their epicenters, an analysis of the seismic hazard at the site, and the design peak horizontal acceleration. The staff concludes that the information presented is sufficient to support an analysis of the geotechnical stability. In addition, the staff concludes that the licensee has used acceptable methods of investigation and analysis to support its conclusions.

On the basis of the information and analysis presented in the review plan on the seismicity and ground motion estimates at the _______________ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), which requires that tailings impoundments not be located near a capable fault that would cause a maximum credible earthquake large than that which the impoundment could reasonably be expected to withstand is likely to occur, or an acceptable alternative method of determination of seismic hazard has been used, have been met. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and postoperational periods. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.4.5 References

Bernreuter, D., E. McDermott, and J. Wagoner. "Seismic Hazard Analysis of Title II Reclamation Plans." Livermore, California: Lawrence Livermore National Laboratory. 1994.

Bonilla, M.G., R. K. Mark, and J.J. Lienkaemper. "Statistical Relations Among Earthquake Magnitude, Surface Rupture Length, and Surface Fault Displacement." *Bulletin of the Seismological Society of America.* Vol. 74. pp. 2,379–2,411. 1984.

Boore, D.M., W.B. Joyner, and T.E. Fumal. "Estimation of Response Spectra and Peak Acceleration From Western North American Earthquakes: An Interim Report." Open-File Report 93-509. U.S. Geological Survey. 1993.

———. "Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work." *Seismological Research Letters*. Vol. 68. pp. 128,153. 1997.

Campbell, K. "Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Velocity, and Pseudo-Absolute Acceleration Response Spectra." *Seismological Research Letters*. Vol. 68. pp. 154–179. 1997.

Campbell, K.W. and Y. Bozorgnia. "Near Source Attenuation of Peak Horizontal Acceleration From Worldwide Accelerograms Recorded From 1975 to 1993." Fifth U.S. National Conference on Earthquake Engineering, Chicago, Illinois, July 10–14. 1994.

NRC. Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion." Washington, DC: NRC, Office of Standard Development. March 1997.

Slemmons, D.B. "State-of-the-Art for Assessing Earthquake Hazards in the United States: Report 6, Faults and Earthquake Magnitudes." Miscellaneous Paper S-73-1. Vicksburg, Mississippi: U.S. Corps of Engineers, U.S. Army Engineer Waterways Experiment Station. 1977.

Slemmons, D.B., P. O'Malley, R.A. Whitney, D.H. Chung, and D.L. Bernreuter. "Assessment of Active Faults for Maximum Credible Earthquakes of the Southern California-Northern Baja Region." Publication No. UCID 19125 University of California. Livermore, California: Lawrence Livermore National Laboratory. 1982.

Wells, D.L. and K.J. Coppersmith. "New Empirical Relationships Among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement." *Bulletin of the Seismological Society of America*. Vol. 84. pp. 974–1,002. 1994.

2.0 GEOTECHNICAL STABILITY

The reclamation plan and its supporting documents must contain geotechnical information, design details, and construction considerations related to the proposed disposal site and to all materials associated with the reclamation design, including soil and rock cover, foundation materials, contaminated materials, and other materials, for any zones (liners, filters, or capillary breaks). Standard review plan Chapter 2.0 establishes the procedures for NRC staff to conduct and document the review of geotechnical stability aspects of reclamation plans for mill tailings impoundments, amendments to the approved reclamation plans, or license termination.

2.1 Site and Uranium Mill Tailings Characteristics

2.1.1 Areas of Review

The staff should review information presented in the reclamation plan on the geotechnical aspects of the regional and site stratigraphy, the geotechnical characteristics of the uranium mill tailings and other materials designated for stabilization, and borrow area stratigraphy and material characteristics. "Other materials" are contaminated soil from site cleanup operations, tailings from other sites accepted for disposal at this site, and any contaminated materials from mill decommissioning activities to be disposed of at this site. This review should cover exploration data, sampling and laboratory techniques, test results, descriptions of physical properties, and static and dynamic geotechnical engineering parameters of the materials, as well as discussions of ground-water conditions (e.g., perched, confined, or unconfined) for all critical subsurface strata at the site, including information on the fluctuations of the hydraulic head. Review of the ground-water information should be coordinated with the review of information on ground-water resources protection, as described in standard review plan Chapter 4.0. Review of stratigraphic and seismologic information should be coordinated with the review of the geology and seismology information as described in standard review plan Chapter 1.0. Borrow area restoration plans should be evaluated.

2.1.2 Review Procedures

The information to be reviewed depends on whether the proposed tailings disposal is below grade, either in mines or specially excavated pits, or in above ground impoundments. The reviewer should focus on the appropriateness of the site characterization for the proposed tailings disposal scheme. The reviewer should examine the site stratigraphy and evaluation of engineering properties of the underlying materials at the site, uranium mill tailings, other materials, and borrow materials to determine if appropriate methods were properly used in characterizing the materials.

The reviewer should examine the following specific descriptive information to determine its adequacy for characterizing the site and for supporting the evaluations of reclamation system performance:

(1) Site stratigraphy, based on borings and other investigations conducted to determine the type, location, and thickness of underlying materials

(2) Regional and site-specific seismologic information to determine the potential for impact on the geotechnical stability of the site and site structures

(3) Stratigraphy specifying type, location, and thickness of borrow material and other materials designated for stabilization in the tailings disposal cell

(4) *In situ* testing programs and procedures conducted to determine the engineering properties of underlying materials at the site, borrow area material, other materials, and tailings

(5) Sampling programs conducted to obtain laboratory samples for determination of engineering properties of borrow materials, underlying materials at the site, other materials, and tailings

(6) Laboratory testing used to determine the engineering properties of borrow materials, underlying materials at the site, other materials, and tailings

(7) Physical and engineering properties of borrow materials, underlying materials at the site, other materials, and tailings

(8) Records of historical ground-water-level fluctuations at the site

The reviewer should evaluate methods used to characterize the site to ensure that they comply with generally accepted standards, such as those of the American Society for Testing and Materials (1977) and are commonly used in the geotechnical engineering profession. Areas to be examined in this respect include the *in situ* and laboratory testing programs, sampling techniques, and analyses for determining the physical and engineering properties of materials at the site. Field investigations and laboratory testing procedures not commonly used in the geotechnical engineering profession will be reviewed in detail.

Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site subsurface conditions.

2.1.3 Acceptance Criteria

The site characterization information constitutes part of the input data needed for analysis and design of the tailings impoundment facility. The site characterization will be acceptable if it provides the needed input for the design and analysis of the disposal facility and meets the following criteria:

(1) The site stratigraphy is described in sufficient detail to provide an understanding of the site-specific subsurface features, including structural features and other characteristics of underlying soil and rock.

(2) Information on regional and local faults and seismicity, as obtained from field data, published literature, and historical records is presented in sufficient detail to effectively

incorporate that information into a geotechnical stability analyses. (Note: This aspect of the review should be coordinated with the geology and seismology review performed in accordance with standard review plan Chapter 1.)

(3) Sampling scope and techniques are appropriate and sufficient to ensure that samples collected are representative of the range of *in situ* soil conditions, taking into consideration variability and uncertainties in such conditions within the site.

(4) For all soils that might be unstable because of their physical or chemical properties, locations and dimensions are identified and the properties have been documented.

(5) Investigations (including laboratory and field testing) are conducted using appropriate standards published by the American Society for Testing and Materials or the International Society for Rock Mechanics and are sufficient to establish the static and dynamic engineering parameters of borrow materials, other materials, tailings, and underlying soil and rock materials at the site (NRC, 1978, 1979).

(6) A detailed discussion of laboratory sample preparation techniques is presented, when standard procedures are not used.

For critical laboratory tests, details such as how saturation of the sample was determined and maintained during testing, or how the pore pressures changed are provided. A detailed and quantitative discussion of the criteria used to verify that the samples were properly taken and tested in sufficient number to define the critical soil parameters for the site is presented. In the case of tailings material (e.g., license amendment reviews), the evaluations of its strength and settlement characteristics are presented in detail.

(7) Parameter values are presented to enable evaluation of properties of mill tailings, borrow materials, other materials, and underlying soil and rock, including the following:

(a) Compressibility and rate of consolidation

(b) Shear strength, including, for sensitive soils, possible loss of shear strength resulting from strain-softening

(c) Liquefaction potential

(d) Permeability

(e) Dispersion characteristics

(f) Swelling and shrinkage

(g) Long-term moisture content for radon barrier material

(h) Cover cracking

(8) Soil stratigraphy and relevant parameters that are used in the geotechnical evaluations (settlement, stability, liquefaction potential, etc.) are discussed in detail.

(9) Records of historical ground-water-level fluctuations at the site as obtained from monitoring local wells and springs and/or by analysis of piezometer and permeability data from tests conducted at the site are presented in sufficient detail to effectively incorporate the information into geotechnical stability analyses. (Note: This aspect of the review should be coordinated with the hydrogeologic characterization review performed according to standard review plan Chapter 4.0.)

The information should be sufficient to provide the required input for the design of the facility and to enable the reviewer to assess compliance with the regulatory requirements, such as site features contributing to waste isolation; facility location with respect to an active fault; and reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years.

2.1.4 Evaluation Findings

If the staff review as described in standard review plan Section 2.1 results in the acceptance of the characterization of the site and uranium mill tailings sufficient to support a conclusion regarding the geotechnical stability of the site, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the site stratigraphy and uranium mill tailings at the ________________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.1.2 and the acceptance criteria outlined in Section 2.1.3 of the Title II standard review plan.

The licensee has acceptably described the geotechnical characteristics of the site and uranium mill tailings based on sampling techniques that are acceptable, and will ensure that a representative range of *in situ* soil conditions will be examined. Unstable soils have been identified. Investigations and analyses have used acceptable standards and practices. Laboratory sample preparation and testing techniques are appropriately described and include: (1) compressibility and rate of consolidation, (2) shear strength, (3) liquefaction potential, (4) permeability, (5) dispersion characteristics, (6) swelling and shrinkage, and (7) physical properties. Records of historic ground-water-level fluctuations are presented to allow effective incorporation into geotechnical stability analyses.

On the basis of the information presented in the application and the detailed review conducted of the characteristics of the site and uranium mill tailings at the _______________ uranium mill facility, the NRC staff concludes that the characterization of the site and uranium mill tailings and associated conceptual and numerical models provide an acceptable input, which along with other information such as results of design analysis, will enable the staff to make a finding on the demonstration of compliance with the following criteria in Appendix A to 10 CFR Part 40: (1) Criterion 1, which relates to the site features that contribute to the permanent waste isolation characteristics of the site; (2) Criterion 3, which states the primary option for disposal of tailings below grade is mines or excavated pits (if applicable for the site); (3) Criterion 4(e), which requires that the impoundment not be located near a capable fault on which a maximum credible earthquake, larger than one that the impoundment could reasonably be expected to withstand, might occur; (4) Criterion 5(G)(2), relating to the permeability characteristics of the site; and (5) Criterion 6(1), which requires reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

2.1.5 References

American Society for Testing and Materials Standards:

D 420, "Guide for Investigating and Sampling Soil and Rock."

D 421, "Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants."

D 422, "Method for Particle-Size Analysis of Soils."

D 653, "Terminology Relating to Soil, Rock, and Contained Fluids."

D 854, "Test Method for Specific Gravity of Soils."

D 1140, "Test Method for Amount of Material in Soils Finer Than the No. 200 Sieve."

D 1452, "Practice for Soil Investigation and Sampling by Auger Borings."

D 1586, "Method for Penetration Test and Split-Barrel Sampling of Soils."

D 1587, "Practice for Thin-Walled Tube Sampling of Soils."

D 2113, "Practice for Diamond Core Drilling for Site Investigation."

D 2166, "Test Method for Unconfined Compressive Strength of Cohesive Soil."

D 2216, "Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock and Soil-Aggregate Mixtures."

D 2217, "Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants."

D 2487, "Test Method for Classification of Soils for Engineering Purposes."

D 2488, "Practice for Description and Identification of Soils (Visual-Manual Procedure)."

D 2573, "Test Method for Field Vane Shear Test in Cohesive Soils."

D 3441, "Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil."

D 3550, "Practice for Ring-Lined Barrel Sampling of Soils."

D 4221, "Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer."

D 4318, "Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."

D 4647, "Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test."

D 4750, "Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)."

NRC. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Revision 1. Washington, DC: NRC, Office of Standards Development. March 1979.

———. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." Washington, DC: NRC, Office of Standards Development. April 1978.

2.2 Slope Stability

2.2.1 Areas of Review

The staff should examine exploration data, test results, slope characterization data, design details, and static and dynamic analyses related to the stability of all natural and manmade earth and rock slopes whose failure, under any of the conditions to which they could be exposed throughout the period of regulatory interest, could adversely affect the integrity of the reclamation actions. This review should also include examination of static and dynamic materials properties, test and design methods, pore pressures within and beneath the embankment, and the design seismic coefficient. Information on the design seismic event should be obtained from results of the review completed using standard review plan Chapter 1.0. The review will focus on (i) the design of the impoundment during operation when a large volume of tailings liquor would be present and (ii) its stability over the long term.

2.2.2 Review Procedures

The reviewer should examine data gathered from site investigations, such as borings: maps; laboratory and field tests; soil profiles; site plans; results of seismic investigations; permeability tests; and static, dynamic, or pseudostatic stability analyses to determine whether the assumptions and analyses used in the reclamation plan are conservative. The degree of conservatism required depends on the type of analysis used, the variability and uncertainty in the values of the parameters considered in the slope stability analysis, the number of borings, the sampling program, the extent of the laboratory testing program, and the resultant safety factor. For instances in which safety factors are low, the reviewer should ensure that reasonable ranges of soil properties have been considered. Other factors, such as flood conditions, pore pressure effects, possible erosion of soils, and seismic amplification effects, should be conservatively assessed. The design criteria and analyses should be reviewed to ascertain whether the techniques employed are appropriate and represent commonly accepted methods [e.g., U.S. Army Corps of Engineers (1970b)].

The reviewer should examine the spatial variability of the measured properties to ensure that it has been adequately defined. The reviewer should also examine slope characterization data to ensure that nearby slopes, the failure of which could adversely affect the stability of the reclamation action, have been properly characterized.

The reviewer should determine whether the static and dynamic stability analyses demonstrate that there is an adequate factor of safety against failure.

The reviewer should examine the slope stability analysis to determine that an appropriately conservative approach has been used and that adverse conditions to which the slope might be subjected have been considered. The reviewer should confirm that the static analyses include calculations using appropriate assumptions and methods to assess the following:

(1) Uncertainties and variations in the shape of the slope, the boundaries and parameters of the several types of soils within the slope, the forces acting on the slope, and the pore pressures acting within and beneath the slope

(2) The failure surface corresponding to the lowest factor of safety

(3) The effect of the assumptions inherent in the method of analysis used

The reviewer should ensure that the analysis is conservative and that possible failure modes have been considered, including evaluation of the effect of the maximum credible earthquake, or the appropriate design criteria found acceptable in standard review plan Section 1.4. The reviewer will also verify that the impoundment will not be located near a capable fault on which a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand might occur.

The reviewer should be aware that no single method of analysis is applicable for all stability assessments. Therefore, no single method of analysis is recommended. If the staff review indicates that questionable assumptions have been made or that non-standard or inappropriate methods of analysis have been used, the staff may model the slope in a manner consistent with the data and perform an independent analysis.

The reviewer should verify that disposal cell slopes will be relatively flat after final stabilization to minimize the potential for erosion and to provide a conservative factor of safety. In evaluating the slope, the reviewer will focus on determining if the slopes are 5h:1v as required by 10 CFR Part 40, Appendix A, Criterion 4(c). If slopes steeper than 5h:1v are proposed, the reviewer must evaluate these steeper slopes as an alternative to the requirements of

Criterion 4(c). In conducting a review of steeper slopes, the reviewer must evaluate the acceptability of the steeper slope using the applicable criteria in this standard review plan and determine if there is an acceptable economic basis and an equivalent level of protection available to justify an alternative to 10 CFR Part 40, Appendix A, Criterion 4(c). The reviewer should evaluate whether a full self-sustaining vegetative cover can be placed over the tailings pile, primarily to reduce the wind and water erosion to negligible levels. If a vegetative cover is not suitable for the site conditions, the reviewer should verify that an appropriate rock cover has been provided. This verification should be coordinated with the review using standard review plan Chapter 3.0.

Because dams at operating facilities, or dams that continue to hold water after the cessation of operations, are also subject to the National Dam Safety Program Act of 1996, the reviewer should determine if the dam is classified as a structure with low hazard potential or high hazard potential. If the dam is classified as high hazard, the reviewer should evaluate the emergency action plan for the facility.

2.2.3 Acceptance Criteria

The analysis of slope stability will be acceptable if it meets the following criteria:

(1) Slope characteristics are properly evaluated.

(a) Cross sections and profiles of natural and cut slopes whose instability would directly or indirectly affect the control of residual radioactive materials are presented in sufficient number and detail to enable the reviewer to select the cross sections for detailed stability evaluation.

(b) Slope steepness is a minimum of five horizontal units (5h) to one vertical unit (1v) or less. The use of slopes steeper than 5h:1v is considered an alternative to the requirements in 10 CFR Part 40, Appendix A, Criterion 4(c). When slopes steeper than 5h:1v are proposed, a technical justification should be offered as to why a 5h:1v or flatter slope cannot be constructed. Appropriate compensating factors and conditions are incorporated in the slope design for assuring long-term stability. In addition, the application must contain an evaluation showing the economic benefit of slopes steeper than 5h:1v as well as a demonstration of equivalent protection.

(c) Locations selected for slope stability analysis are determined considering the location of maximum slope angle, slope height, weak foundation, piezometric level(s), the extent of rock mass fracturing (for an excavated slope in rock), and the potential for local erosion.

(2) An appropriate design static analysis is presented.

(a) The analysis includes calculations with appropriate assumptions and methods of analysis (NRC, 1977). The effect of the assumptions and limitations of the methods used is discussed and accounted for in the analysis. Acceptable methods for slope stability analysis include various limit equilibrium analysis or numerical modeling methods.

(b) The uncertainties and variability in the shape of the slope, the boundaries and parameters of the several types of soils and rocks within and beneath the slope, the material properties of soil and rock within and beneath the slope, the forces acting on the slope, and the pore pressures acting within and beneath the slope are considered.

(c) Appropriate failure modes during and after construction and the failure surface corresponding to the lowest factor of safety are determined. The analysis takes into account the failure surfaces within the slopes, including through the foundation, if any.

(d) Adverse conditions such as high water levels from severe rain and the probable maximum flood are evaluated.

(e) The effects of toe erosion, incision at the base of the slope, and other deleterious effects of surface runoff are assessed.

(f) The resulting safety factors for slopes analyzed are comparable to the minimum acceptable values of safety factors for slope stability analysis given in NRC Regulatory Guide 3.11 (NRC, 1977).

(3) Appropriate analyses considering the effect of seismic ground motions on slope stability are presented.

(a) Evaluation of overall seismic stability, using pseudostatic analysis or dynamic analysis, as appropriate (U.S. Army Corps of Engineers, 1977; NRC, 1977). Alternatively, a dynamic analysis following Newmark (1965) can be carried out to establish that the permanent deformation of the disposal cell from the design seismic event will not be detrimental to the disposal cell. The reviewer should verify that the yield acceleration or pseudostatic horizontal yield coefficient necessary to reduce the factor of safety against slippage of a potential sliding mass to 1.0 in a "Newmark-type" analysis has been adequately estimated (Seed and Bonaparte, 1992).

(b) An appropriate analytical method has been used. A number of different methods of analysis are available (e.g., slip circle method, method of slices, and wedge analysis) with several variants of each (Lambe and Whitman, 1979; U.S. Army Corps of Engineers, 1970b; NRC, 1977; Bromhead, 1992). Limit-equilibrium analysis methods do not provide information regarding the variation of strain within the slope and along the slip surface. Consequently, there is no assurance that the peak strength values used in the analysis can be mobilized simultaneously along the entire slip surface unless the material shows ductile behavior (Duncan, 1992). Residual strength values should be evaluated if mobilized shear strength at some points is less than the peak strength. The reviewer should ensure that appropriate conservatism has been incorporated in the analysis using the limit equilibrium methods. The limit equilibrium analysis methodologies may be replaced by other techniques, such as finite element or finite difference methods. If any important interaction effects cannot be included in an analysis, the reviewer must determine that such effects have been treated in an approximate but conservative fashion. The engineering judgment of the reviewer should be used in assessing the adequacy of the resulting safety factors (NRC, 1983a,b).

(c) For dynamic loads, the dynamic analysis includes calculations with appropriate assumptions and methods (NRC, 1977; Seed, 1967; Lowe, 1967; Department of the Navy, 1982a,b,c; U.S. Army Corps of Engineers, 1970a,b, 1971, 1972; Bureau of Reclamation, 1968). The effect of the assumptions and limitations of the methods used is discussed and accounted for in the analysis.

(d) For dynamic loads, a pseudostatic analysis is acceptable in lieu of dynamic analysis if the strength parameters used in the analysis are conservative, the materials are not subject to significant loss of strength and development of high pore pressures under dynamic loads, the design seismic coefficient is 0.20 or less, and the resulting minimum factor of safety suggests an adequate margin, as provided in NRC Regulatory Guide 3.11 (NRC, 1977).

(e) For pseudostatic analysis of slopes subjected to earthquake loads, an assumption is made that the earthquake imparts an additional horizontal force acting in the direction of the potential failure (U.S. Army Corps of Engineers, 1970b, 1977; Goodman, 1989). The critical failure surface obtained in the static analysis is used in this analysis with the added driving force. Minimum acceptable values for safety factors of slope stability analysis are given in Regulatory Guide 3.11 (NRC, 1977).

(f) The assessment of the dynamic stability considers an appropriate design level seismic event and/or strong ground motion acceleration, consistent with that identified in Chapter 1 of this review plan. Influence of local site conditions on the ground motions associated with the design level event is evaluated. The design seismic coefficient to be used in the pseudostatic analysis is either 67 percent of the peak ground acceleration at the foundation level of the tailings piles for the site or 0.1g, whichever is greater.

(g) If the design seismic coefficient is greater than 0.20g, then the dynamic stability investigation (Newmark, 1965) should be augmented by other appropriate methods (i.e., finite element method), depending on specific site conditions.

(h) In assessing the effects of seismic loads on slope stability, the effect of dynamic stresses of the design earthquake on soil strength parameters is accounted for. As in a static analysis, the parameters such as geometry, soil strength, and hydrodynamic and pore pressure forces are varied in the analysis to show that there is an adequate margin of safety.

(i) Seismically induced displacement is calculated and documented. There is no universally accepted magnitude of seismically induced displacement for determining acceptable performance of the disposal cell (Seed and Bonaparte, 1992; Goodman and Seed, 1966). Surveys of five major geotechnical consulting firms by Seed and Bonaparte (1992) indicate that the acceptable displacement is from 15 to 30 cm [6 to 12 in.] for tailings piles. The reviewer should ensure that this criterion is also augmented by provisions for periodic maintenance of the slope(s).

(j) Where there is potential for liquefaction, changes in pore pressure from cyclic loading are considered in the analysis to assess the effect of pore pressure increase on the stress-strain characteristics of the soil and the post-earthquake stability of the slopes. Liquefaction potential is reviewed using Section 2.4 of this review plan. Evaluations of dynamic properties and shear strengths for the tailings, underlying foundation material, radon barrier cover, and base liner system are based on representative materials properties obtained through appropriate field and laboratory tests (NRC, 1978, 1979).

(k) The applicant has demonstrated that impoundments will not be located near a capable fault on which a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand might occur.

(4) Provision is made to establish a vegetative cover, or other erosion prevention, to include the following considerations:

(a) The vegetative cover and its primary functions are described in detail.

This determination should be made with respect to any effect the vegetative cover may have on reducing slope erosion and should be coordinated with the reviewer of standard review plan Chapter 3.

If strength enhancement from the vegetative cover is taken into account, the methodology should be appropriate (Wu, 1984).

(b) In arid and semi-arid regions, where a vegetative cover is deemed not self-sustaining, a rock cover is employed on slopes of the mill tailings. If credit is taken for strength enhancement from rock cover, the reviewer should confirm that appropriate methodology has been presented.

The design of a rock cover, where a self-sustaining vegetative cover is not practical, is based on standard engineering practice. Standard review plan Chapter 3 discusses this item in detail.

(5) Any dams meet the requirements of the dam safety program if the application demonstrates the following:

(a) The dam is correctly categorized as a low hazard potential or a high hazard potential structure using the definition of the U.S. Federal Emergency Management Agency.

(b) If the dam is ranked as a high hazard potential, an acceptable emergency action plan consistent with the Federal Emergency Management Agency guide (U.S. Federal Emergency Management Agency, 1998) has been developed.

(6) The use of steeper slopes as an alternative to the requirements in 10 CFR, Part 40, Appendix A, will be found acceptable if the following are met:

(a) An equivalent level of stabilization and containment and protection of public health, safety, and the environment is achieved.

(b) A site-specific need for the alternate slopes and an appropriate economic benefit are demonstrated.

2.2.4 Evaluation Findings

If the staff review as described in standard review plan Section 2.2 results in the acceptance of the slope stability, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the slope stability at the ______________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.2.2 and the acceptance criteria outlined in Section 2.2.3 of the Title II standard review plan.

The licensee has acceptably described the slope stability evaluation by (1) providing cross sections and profiles of natural and cut slopes in sufficient detail and number to represent significant slope and foundation conditions; (2) placing tailings below grade or in demonstrably safe above-grade disposal facilities; (3) ensuring that slope steepnesses are five horizontal (5h) to one vertical (1v) or less or by providing technical justification for a different slope ratio; (4) providing measurements of static and dynamic properties of soil and rock using standards such as those established by the American Society for Testing and Materials, International Society of Rock Mechanics, NRC, or the U.S. Army Corps of Engineers; (5) selecting locations for slope stability analyses while considering the location of maximum slope angle, slope height, weak foundation, the extent of rock mass fracturing, and the potential for local erosion; and (6) describing vegetative cover and its primary functions in detail. Where the licensee has proposed use of steeper slopes as an alternative to the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c), the staff has evaluated the licensee's demonstration that steeper slopes would result in economic savings and also ensure the long-term stabilization of the tailings with a level of protection equivalent to that required in 10 CFR Part 40, Appendix A, Criterion 4(c). Therefore, the use of steeper slopes complies with the alternatives requirement in 10 CFR Part 40, Appendix A.

The static loads analysis is acceptable and includes (1) appropriate uncertainties and variabilities in important rock/soils parameters; (2) consideration of appropriate failure modes; (3) a discussion of the effect of the assumptions inherent in the method of analysis used; (4) consideration of adverse conditions, including flooding, with appropriate safety factors; and (5) the effects of toe erosion, incision of the base of the slope, and other deleterious effects of surface runoff.

The dynamic and pseudostatic analyses are acceptable and include (1) calculations with appropriate assumptions and methods; (2) treatment of important interaction effects in a conservative fashion; (3) an accounting of the dynamic stresses of the maximum credible earthquake on soil strength parameters; (4) for pseudostatic analyses of slopes subjected to earthquake loads, consideration of the added driving horizontal force acting in the direction of a potential failure; (5) determination that possible permanent deformation sustained in the slope from a maximum credible earthquake will not damage the effectiveness of the disposal cell; (6) determination that the magnitude of seismically induced displacement does not exceed 15 to 30 cm [6 to 12 in.]; (7) a selection of appropriate design-level seismic events or strong ground motion accelerations; (8) evaluations of local site conditions; (9) evaluations of the potential for liquefaction and the effect of pore pressure increase on the stress-strain characteristics of the soil and post-earthquake stability of the slopes; (10) evaluations of the dynamic properties and shear strength of the tailings, underlying foundation, radon barrier cover, and base liner system; and (11) design of a self-sustaining vegetative or rock cover that is consistent with commonly accepted engineering practice.

On the basis of the information presented in the application and the detailed review conducted of the slope stability at the _____________ uranium mill facility, the NRC staff concludes that the slope stability and associated conceptual and numerical models pertaining to design in the reclamation plan provide an acceptable input to demonstration of compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 4(c), which provides requirements for the long-term stability of the embankment and cover slopes for tailings; Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or employment of a rock cover to reduce wind and water erosion to negligible levels, that individual rock fragments are suited for the job, and that the impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient; Criterion 4(e), which requires that the impoundment not be located near a capable fault on which a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand might occur; Criterion 5(A)(5), which requires the structural integrity of slopes (dikes) to prevent massive failure of the dikes; and Criterion 6(1), relating to providing reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

2.2.5 References

American Society for Testing and Materials Standards:

D 2850, "Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression."

D 3080, "Method for Direct Shear Test of Soils Under Consolidated Drained Conditions."

D 4767, "Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils."

Bromhead, E.N. *The Stability of Slopes.* London, England: Blackie Academic & Professional. 1992.

Bureau of Reclamation. *Earth Manual.* First Edition. Washington, DC: U.S. Department of the Interior. 1968.

Department of the Navy. "Soil Mechanics." NAVFAC DM 7.1. May 1982a.

———. "Foundations and Earth Structures." NAVFAC DM 7.2. May 1982b.

———. "Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction." NAVFAC DM 7.3. May 1982c.

Duncan, J.M. "State-of-the-Art: Static Stability and Deformation Analysis. Stability and Performance of Slopes and Embankments-II, Volume 1." Proceedings of a Specialty Conference. R.B. Seed and R.W. Boulanger, eds. Geotechnical Special Publication No. 31. New York, New York: American Society of Civil Engineers. 1992.

Goodman, R.E. *Introduction to Rock Mechanics.* 2nd edition. New York, New York: John Wiley and Sons. 1989.

Goodman, R.E. and H.B. Seed. "Earthquake-Induced Displacements in Sand Embankments." *ASCE Journal of the Soil Mechanics and Foundations Division* Volume 92, No. SM2. March 1966.

Lambe, T.W. and R.V. Whitman. *Soil Mechanics, SI Version.* New York, New York: John Wiley and Sons. 1979.

Lowe, J., III. "Stability Analysis of Embankments." *ASCE Journal of the Soil Mechanics and Foundations Division.* Vol. 93, No. SM4. 1967.

Newmark, N.M. "Effects of Earthquakes on Dams and Embankments." *Geotechnique.* June 1965.

NRC. NUREG/CR–3199, "Guidance for Disposal of Uranium Mill Tailings: Long-Term Stabilization of Earthen Cover Materials." Washington, DC: NRC. 1983a.

———. NUREG/CR–3397, "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments." Washington, DC: NRC. 1983b.

———. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Revision 1. Washington, DC: NRC, Office of Standards Development. March 1979.

———. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." Washington, DC: NRC, Office of Standards Development. April 1978.

———. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills." Revision 2. Washington, DC: NRC, Office of Standards Development. December 1977.

Seed, H.B. "Slope Stability During Earthquakes." *ASCE Journal of the Soil Mechanics and Foundations Division.* Vol. 93, No. SM4. 1967.

Seed R.B. and R. Bonaparte. "Seismic Analysis and Design of Lined Waste Fills: Current Practice. Stability and Performance of Slopes and Embankments--II, Volume 1." Proceedings of a Specialty Conference. R.B. Seed and R.W. Boulanger, eds. Geotechnical Special Publication No. 31. New York, New York: American Society of Civil Engineers. 1992.

U.S. Army Corps of Engineers. "Earthquake Design and Analysis for Corps of Engineer Dams." ER1110-2-1806. U.S. Department of the Army, Office of the Chief of Engineers. April 1977.

———. "Soil Sampling." Engineering Manual EM1110-2-1907. Department of the Army, Office of the Chief of Engineers. March 1972.

———. "Instrumentation of Earth and Rockfill Dams." Engineering Manual EM1110-2-1908, Part 1 and 2. Department of the Army, Office of the Chief of Engineers. August and November 1971.

———. "Laboratory Soil Testing." Engineering Manual EM1110-2-1906. Department of the Army, Office of Chief Engineers. November 1970a.

———. "Engineering and Design Stability of Earth and Rock Fill Dams." Engineering Manual EM1110-2-1902. Department of the Army, Office of the Chief of Engineers. 1970b.

U.S. Federal Emergency Management Agency. "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners." Washington, DC: U.S. Federal Emergency Management Agency. 1998.

Wu, T.H. "Effect of Vegetation on Slope Stability, "Soil Reinforcement and Moisture Effects on Slope Stability." Transportation Research Record 965. National Research Council, Transportation Research Board. 1984.

2.3 Settlement

2.3.1 Areas of Review

The staff should review the methods and results of testing and analyses conducted to estimate deformation of subsurface materials and uranium mill tailings. This should include examination of material properties and thicknesses of compressible materials, factors used in stress calculations, calculated pore pressures within and beneath the embankment, resulting total and differential settlement of the tailings surface under both static and seismic conditions, and the effects of such settlements on the radon barrier layer of the cover of the disposal cell and erosion protection layer. Liquefaction and associated settlement are addressed in standard review plan Section 2.4. One of the purposes of this review is to determine if the licensee has an acceptable method for determining if tailings consolidation is sufficient to allow the placement of a radon barrier.

2.3.2 Review Procedure

The reviewer should examine the assessments of the magnitudes and distributions of settlement of the disposal cell and the analyses of the potential for cracking of the radon barrier from tensile strains in order to determine the adequacy of the design.

The reviewer should confirm that clay layers and slime in the tailings pile and foundations have been considered in the assessment of both immediate and long-term settlement.

In reviewing the assessment of settlements, the reviewer should give particular attention to the identification and thicknesses of compressible soil layers within the tailings and in the foundation. Settlement should be calculated at several locations within the disposal cell to enable a determination of the overall settlement pattern of the disposal cell cover. The locations for settlement calculations should be selected considering the presence of sand/slime tailings and foundation materials. The tailings are expected to be a hydraulically placed material comprised of interspersed sand and slime tailings. The following specific items should be reviewed to determine the acceptability of the assessment of the magnitudes and distribution of settlement:

(1) The analysis of immediate settlement of tailings surfaces, considering rebound from excavation and settlement from instantaneous compression of underlying materials and the tailings pile. The computation of incremental tailings loading and the width of the loaded area, as well as the determination of the undrained modulus and Poisson's ratio should be examined. Calculations of the settlement of hydraulically placed tailings should be examined.

(2) The analysis of consolidation settlement from delayed compression (caused by pore-pressure dissipation) of underlying materials and the tailings pile.

The calculation of settlement should be reviewed to ensure that each compressible soil layer within or underneath the tailings pile is considered and is assigned proper thickness and that the appropriate level of stress change is applied at the mid-depth of the soil layer.

(3) The estimate of the time at which the primary consolidation settlement of the tailings will be essentially complete. Generally, the radon barrier and disposal cell cover may be placed only after the settlement of tailings is essentially complete.

(4) The analysis of secondary settlement from long-term creep.

(5) The distribution of settlement magnitudes for assessment of differential settlement.

(6) Evaluation of the potential for cracking of the radon barrier layer as result of long-term settlement of the cover.

2.3.3 Acceptance Criteria

The analysis of tailings settlement will be acceptable if it meets the following criteria:

(1) Computation of immediate settlement follows the procedure recommended in NAVFAC DM–7.1 (Department of the Navy, 1982). If a different procedure is used, the basis for the procedure is adequately explained.

The procedure recommended in NAVFAC DM–7.1 (Department of the Navy, 1982) for calculation of immediate settlement is adequate if applied incrementally to account for different stages of tailings emplacement. If this method is used, the reviewer should verify that the computation of incremental tailings loading and the width of the loaded area, as well as the determination of the undrained modulus and Poisson's ratio, have been computed and documented.

Settlement of tailings arises from compression of soil layers within the disposal cell and in the underlying materials. Because compression of sands occurs rapidly, compression of sand layers in the disposal cell and foundations must be considered in the assessment of immediate settlement. However, the contribution of immediate settlement to consolidation settlement cannot be ignored. Clay layers and slime undergo instantaneous elastic compression controlled by their undrained stiffness as well as long-term inelastic compression controlled by the processes of consolidation and creep (NRC, 1983a).

(2) Each of the following is appropriately considered in calculating stress increments for assessment of consolidation settlement:

(a) Decrease in overburden pressure from excavation

(b) Increase in overburden pressure from tailings emplacement

(c) Excess pore-pressure generated within the disposal cell

(d) Changes in ground-water levels from dewatering of the tailings

(e) Any change in ground-water levels from the reclamation action

(3) Material properties and thicknesses of compressible soil layers used in stress change and volume change calculations for assessment of consolidation settlement are representative of *in situ* conditions at the site.

(4) Material properties and thicknesses of embankment zones used in stress change and volume change calculations are consistent with as-built conditions of the disposal cell.

(5) Values of pore pressure within and beneath the disposal cell used in settlement analyses are consistent with initial and post-construction hydrologic conditions at the site.

(6) Methods used for settlement analyses are appropriate for the disposal cell and soil conditions at the site. Contributions to settlement by drainage of mill tailings and by consolidation/compression of slimes and sands are considered. Both instantaneous and time-dependent components of total and differential settlements are appropriately considered in the analyses (NRC, 1983a,b,c).

The procedure recommended in NAVFAC DM–7.1 (Department of the Navy, 1982) for calculation of secondary compression is adequate.

(7) The disposal cell is divided into appropriate zones, depending on the field conditions, for assessment of differential settlement, and appropriate settlement magnitudes are calculated and assigned to each zone.

(8) Results of settlement analyses are properly documented and are related to assessment of overall behavior of the reclaimed pile.

(9) An adequate analysis of the potential for development of cracks in the radon/infiltration barrier as a result of differential settlements is provided (Lee and Shen, 1969).

2.3.4 Evaluation Findings

If the staff review, as described in standard review plan Section 2.3, shows that the settlement has no impact on the integrity and functionality of the radon barrier and disposal cell cover, then the following conclusions can be presented in the technical evaluation report. If the settlement impacts the cell cover integrity, then the licensee will be required to revise the design to ensure the functionality of the cell cover before a technical evaluation report can be prepared.

The staff has competed its review of the settlement at the ______________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.3.2 and the acceptance criteria outlined in Section 2.3.3 of the Title II standard review plan.

The licensee has acceptably described settlement by presenting computations following the procedure recommended in NAVFAC DM–7.1 (Department of the Navy, 1982) or by explaining the technical merit for an alternative procedure. Material properties, thickness, and load increments used to calculate settlement are representative of site conditions. The applicant has acceptably considered each of the following: (1) decrease in overburden pressure from excavation, (2) increase in overburden pressure from emplaced tailings, (3) excess pore-pressure generated within the tailings disposal cell, (4) changes in ground-water levels from dewatering of the tailings, and (5) changes in ground-water levels from reclamation actions. Pore pressures within and beneath the disposal cell/embankment are consistent with initial and as-built hydrologic site conditions. Methods used to determine settlement are appropriate for the tailings embankment and soil conditions at the site. The results of the settlement analyses are properly documented. The tailings embankment has been subdivided acceptably into assessment zones with appropriately assigned settlement magnitudes. The settlement data provide information to assess the possibility of surface ponding or sudden change of gradient caused by settlement. An acceptable analysis for the development of cracks in the radon/infiltration barrier is provided.

On the basis of information presented in the application and the detailed review conducted of the characteristics of the settlement at the ______________ mill facility, the NRC staff concludes that the settlement and associated conceptual and numerical models present information needed to demonstrate compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or employment of a rock cover to reduce wind and water erosion to negligible levels, that individual rock fragments are suited for the job, and that the impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient; and Criterion 6(1), relating to providing reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

2.3.5 References

American Society for Testing and Materials Standards:

D 2435, "Test Method for One-Dimensional Consolidation Properties of Soil."

D 4719, "Test Method for Pressuremeter Testing in Soils."

Department of the Navy. 1982. *Soil Mechanics.* NAVFAC DM–7.1. May 1982.

Lee, K.L. and C.K. Shen. "Horizontal Movements Related to Subsidence." ASCE Journal of Soil Mechanics and Foundations Division. Vol. 95, No. SM1. 1969.

NRC. 1983a. NUREG/CR–3204, "Consolidation of Tailings." Washington, DC: NRC. 1983a.

———. NUREG/CR–3199, "Guidance for Disposal of Uranium Mill Tailings: Long-Term Stabilization of Earthen Cover Materials." Washington, DC: NRC. 1983b.

———. NUREG/CR–3397, "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments." Washington, DC: NRC. 1983c.

2.4 Liquefaction Potential

2.4.1 Areas of Review

The staff should review the analysis of the liquefaction potential of subsurface, pile, and embankment materials, and the associated test and data interpretations. Consequences of the liquefaction of subsurface soils and/or uranium mill tailings affecting the settlements within and stability of the disposal cell and the erosion protection layer should also be reviewed. Design features or mitigation actions that address liquefaction potential should be examined. The effect of settlements not induced by liquefaction is considered in standard review plan Section 2.3 and is also considered in standard review plan Section 2.4.3.

2.4.2 Review Procedures

The reviewer should examine the analysis of liquefaction potential by studying the results of geotechnical investigations and *in situ* tests such as standard penetration, cone penetration, piezocone, density, and strength tests as well as boring logs, laboratory classification test data, water table measurements, perched water zones, and soil profiles, to determine if any of the site soils or the tailings pile material could be susceptible to liquefaction.

If it is determined that there may be soils susceptible to liquefaction beneath the site or in the tailings pile, the reviewer should examine the adequacy of site exploration programs, the laboratory test program, and the analyses. Where global liquefaction potential exists, the reviewer should determine that it has been mitigated or eliminated. Minor or local liquefaction potential should have been accounted for in settlement analyses.

The reviewer should compare the liquefaction potential analysis in the reclamation plan to an independent study performed by the staff, if necessary.

2.4.3 Acceptance Criteria

The analysis of the liquefaction potential will be acceptable if the following criteria are met:

(1) Applicable laboratory and/or field tests are properly conducted (NRC, 1978, 1979; U.S. Army Corps of Engineers, 1970, 1972).

(2) Data for all relevant parameters for assessing liquefaction potential are adequately collected and the variability has been quantified.

(3) Methods used for interpretation of test data and assessment of liquefaction potential are consistent with current practice in the geotechnical engineering profession (Seed and Idriss, 1971, 1982; National Center for Earthquake Engineering Research, 1997). An assessment of the potential adverse effects that complete or partial liquefaction could have on the stability of the embankment may be based on cyclic triaxial test data obtained from undisturbed soil samples taken from the critical zones in the site area (Seed and Harder, 1990; Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates, 1972).

(4) If procedures based on laboratory tests combined with ground response analyses are used, laboratory test results are corrected to account for the difference between laboratory and field conditions (NRC, 1978; Naval Facility Engineering Command, 1983).

(5) The time history of earthquake ground motions used in the analysis is consistent with the design seismic event.

(6) If the potential for complete or partial liquefaction exists, the effects such liquefaction could have on the stability of slopes and settlement of tailings are adequately quantified.

(7) If a potential for global liquefaction is identified, mitigation measures consistent with current engineering practice or redesign of tailings ponds/embankments are proposed and the proposed measures provide reasonable assurance that the liquefaction potential has been eliminated or mitigated.

(8) If minor liquefaction potential is identified and is evaluated to have only a localized effect that may not directly alter the stability of embankments, the effect of liquefaction is adequately accounted for in analyses of both differential and total settlement and is shown not to compromise the intended performance of the radon barrier. Additionally, the disposal cell is shown to be capable of withstanding the liquefaction potential associated with the expected maximum ground acceleration from earthquakes. The licensee may use post-earthquake stability methods (e.g., Ishihara and Yoshimine, 1990) based on residual strengths and deformation analysis to examine the effects of liquefaction potential. Furthermore, the effect of potential localized lateral displacement from liquefaction, if any, is adequately analyzed with respect to slope stability and disposal cell integrity.

2.4.4 Evaluation Findings

If the staff review, as described in standard review plan Section 2.4, results in the acceptance of the licensee liquefaction potential analysis and conclusions on the impact on the performance of the disposal cell, the following conclusions may be presented in the technical evaluation report:

Geotechnical Stability

The staff has completed its review of the liquefaction potential at the _____________ uranium mill facility. This review included an evaluation using the review procedures in standard review plan Section 2.4.2 and acceptance criteria outlined in standard review plan Section 2.4.3.

The licensee has acceptably evaluated liquefaction potential based on results from properly conducted laboratory and/or field tests. The methods used for interpretation of test data are consistent with current practice. Where global liquefaction is identified, mitigation measures or redesign of tailings ponds/embankments are proposed and the new design provides reasonable assurance that the liquefaction potential has been eliminated or mitigated. In the case of minor/local liquefaction potential, its effect is accounted for in the analysis of both differential and total settlement and is shown not to compromise the intended performance of the radon barrier and erosion protection.

On the basis of the information presented in the application and the detailed review conducted of the liquefication potential at the _______________ uranium mill facility, the NRC staff concludes that the results of evaluation of liquefaction potential and associated conceptual and numerical models present input to a demonstration of compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 4(c), which provides long-term stability requirements for the slopes of the tailings embankment and cover; and Criterion 6(1), which requires a reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

2.4.5 References

American Society for Testing and Materials Standards:

D 3999, "Test Method for the Determination of the Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus."

D 4015, "Test Method for Modulus and Damping of Soils by the Resonant-Column Method."

Ishihara, K. and M. Yoshimine. "Evaluation of Settlements in Sand Deposits Following Liquefaction During Earthquake." *Soil Foundations*. Vol. 32, No. 1. Japanese Society of Soil Mechanics and Foundation Engineering. 1990.

National Center for Earthquake Engineering Research. "Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils." T.L. Youd and I.M. Idriss, eds. Technical Report No. NCEER 97-002. Buffalo, New York: State University of New York.

Naval Facility Engineering Command. "Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction. NAVFAC DM–7.3. Alexandria, Virginia: Department of the Navy.

NRC. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Revision 1. Washington, DC: NRC, Office of Standards Development. March 1979.

———. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." Washington, DC: NRC, Office of Standards Development. April 1978.

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Seed, H.B. and I.M. Idriss. "A Simplified Procedure for Evaluating Soil Liquefaction Potential." *Journal of Soil Mechanics and Foundation Division.* Vol. 97, No. SM 9. pp. 1,249–1,274. 1971.

Seed, R.B. and L.F. Harder. "SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength." Proceedings of the H. Bolton Seed Memorial Symposium. Berkeley, California: University of California, May 10–11. pp. 351–376. 1990.

Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates. "Soil Behavior Under Earthquake Loading Conditions: State-of-the-Art Evaluation of Characteristics for Seismic Responses Analyses." Washington, DC: U.S. Atomic Energy Commission. 1972.

U.S. Army Corps of Engineers. "Soil Sampling." Manual EM 1110-2-1907. March 1972.

———. "Laboratory Soil Testing, Engineering." Manual EM1110-2-1906. November 1970.

2.5 Design of Disposal Cell Cover Engineering Design

2.5.1 Areas of Review

The staff should review information presented on disposal cell cover engineering design. including field exploration data, laboratory test results, design details, and construction and installation considerations pertinent to the geotechnical aspects of design and any associated geomembranes (i.e., disposal cell configuration and thickness, compaction requirements, gradations, permeability, and dispersivity).

2.5.2 Review Procedures

The reviewer should examine the disposal cell design and engineering parameters to assess the geotechnical aspects of the disposal cell cover. Specific aspects of the review should consider the following items:

(1) Determination that an adequate quantity of the specified borrow material has been identified at the borrow source.

(2) Confirmation that placement density, specific gravity, moisture content, dispersivity, and shrinkage properties used in the disposal cell design have been determined by suitable laboratory testing so that long-term stability standards will be met. (Note that permeability issues are discussed separately in standard review plan Section 2.7.)

(3) Confirmation that appropriate measures for controlling the effects of erosion, surface water flows, and vegetative root penetrations have been taken.

(4) Verification that the particle size gradation of the disposal cell cover material, bedding layers, other layers in the cover, and the rock layer are compatible to ensure stability against particle migration during the period of regulatory interest.

(5) Determination that the disposal cell has been designed to accommodate the effects of anticipated freeze-thaw cycles.

(6) Assessment, if bentonite amendment to the radon barrier material of the disposal cell cover is proposed, of whether supporting discussions define appropriate laboratory testing and field procedures associated with evaluating amended materials.

(7) Determination if the cracking potential of the disposal cell has been adequately addressed [Cracking from both settlement and shrinkage should be evaluated (this is evaluated using standard review plan Section 2.3).]

(8) Assessment of the acceptability of plans for installation and use of any geomembranes.

(9) Confirmation that the information used in the disposal cell cover design appropriately reflects the staff findings on the information reviewed using standard review plan Chapters 1.0, 2.0, 3.0, and 4.0.

Note that hydraulic conductivity aspects of the disposal cell cover design are assessed using standard review plan Section 2.7 and that review of the disposal cell design features is addressed in standard review plan Sections 2.2, 2.3, and 2.4. Review of the radon attenuation aspects of the disposal cell design is addressed in standard review plan Chapter 5.0.

2.5.3 Acceptance Criteria

The assessment of the disposal cell cover design and engineering parameters will be acceptable if it meets the following criteria:

(1) Detailed descriptions of the disposal cell material types [e.g., Unified Soil Classification System (Holtz and Kovacs, 1981)] and/or soil mixtures (e.g., bentonite additive) and the basis for their selection are presented.

An analysis is included demonstrating that an adequate quantity of the specified borrow material has been identified at the borrow source. The information on borrow material includes boring and test pit logs and compaction test data.

The soils that are considered suitable include the Unified Classification System Classes CL, CH, SC, and CL-ML, with desirable characteristics and limitations as listed in Table 3-1 of the "Construction Methods and Guidance for Sealing Penetrations in Soil Covers" (Bennett and Homz, 1991; Bennett and Kimbrell, 1991). The preferred material for the low-permeability layers is inorganic clay soil. This soil should be compacted to a low saturated hydraulic conductivity of at least 1×10^{-7} cm/sec. For drainage layers, cobble types GW, GP, SP, and SW are recommended, with GW and GP being the preferred types (Bennett, 1991).

Measures for resisting cracking, heaving, and settlement, and providing protection from burrowing animals, root penetration, and erosion over a long period of time are described.

(2) A sufficiently detailed description of the applicable field and laboratory investigations and testing that were completed, and the material properties (e.g., permeability, moisture-density relationships, gradation, shrinkage and dispersive characteristics, resistance to freeze-thaw degradation, cracking potential, and chemical compatibility, including any amendment materials) are identified (U.S. Army Corps of Engineers, 1970, 1972; Fermulk and Haug, 1990; NRC, 1978, 1979; Lee and Shen, 1969; Spangler and Handy, 1982).

(3) Details are presented (including sketches) of the disposal cell cover termination at boundaries, with any considerations for safely accommodating subsurface water flows.

(4) A schematic diagram displaying various disposal cell layers and thicknesses is provided.

The particle size gradation of the disposal cell bedding layer and the rock layer are established to ensure stability against particle migration during the period of regulatory interest (NRC, 1982).

(5) The effect of possible freeze-and-thaw cycles on soil strength and radon barrier effectiveness is adequately considered (e.g., Aitken and Berg, 1968).

If the region experiences prolonged freezing, the disposal cell cover may be affected by the freeze-thaw cycle. During freezing, ice crystals and lenses can form in the soil, causing heaving. On the other hand, during melting and thawing, the soil may lose its bearing capacity because of development of supersaturated conditions (Spangler and Handy, 1982). Major factors affecting growth of ice in soil are the temperature below the freezing point, the capillary characteristics of the soil, and the presence of water. The reviewer should check whether the soil is susceptible to frost heave, considering that uniformly graded soils containing more than 10 percent of particles smaller than 0.02 mm and well-graded soils with more than 3 percent of particles smaller than 0.02 mm are susceptible (Holtz and Kovacs, 1981; Spangler and Handy, 1982). After many freeze-thaw cycles, the soil may become a loose collection of aggregates with significantly reduced overall strength.

(6) A description is given (with sketches) of any penetrations (e.g., monitoring wells) through the disposal cell system, including details of penetration sealing and disposal cell cover integrity. Bennett and Kimbrell (1991) suggest methods for seal design that are acceptable.

(7) An adequate analysis is presented of the potential for development of cracks in the disposal cell cover as a result of differential settlement and shrinkage. Note that cracking issues associated with settlement are discussed in standard review plan Section 2.3.3.

(8) An adequate description of the geomembranes and their major properties (e.g., physical, mechanical, and chemical) is provided if low permeability geomembranes are proposed as a part of the disposal cell cover. Methods for installation of the membranes in accordance with the manufacturer's recommendations are discussed. The shear strength of the interface between compacted clay and geomembranes used in the stability analyses under both static and dynamic loads is noted. The expected service life of the geomembrane is analyzed.

(9) Information on site characterization, slope stability, settlement, and liquefaction used in the disposal cell cover design appropriately reflects the staff evaluation, and therefore, constitutes inputs that would contribute to the demonstration of disposal cell design compliance with the regulations.

2.5.4 Evaluation Findings

If the staff review as described in standard review plan Section 2.5 results in the acceptance of the disposal cell cover design, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the disposal cell cover design at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.5.2 and acceptance criteria outlined in Section 2.5.3 of the Title II standard review plan

The licensee has acceptably defined the disposal cell cover design by presenting detailed descriptions of the disposal cell material types and/or soil mixtures, including the basis for their selection. The applicant has identified an adequate quantity of the specified borrow material at the borrow source. An acceptable schematic diagram displaying various disposal cell layers and thicknesses is provided. A description of the applicable field and laboratory investigations and testing is provided, including identification of material properties. The properties of the cover materials have been measured properly using standards such as American Society for Testing and Materials, NRC, or U.S. Army Corps of Engineers. Details (including sketches) have been provided of (1) disposal cell termination boundaries; (2) penetrations, including sealing and disposal cell integrity; and (3) geomembranes and their physical, mechanical, and chemical properties. Methods of installation for the membranes have been discussed and the expected service life has been justified. The analysis of the potential for development of cracks in the disposal cell cover is acceptable.

On the basis of the information presented in the application and the detailed review conducted of the disposal cell cover design at the _______________ uranium mill facility, the NRC staff concludes that the disposal cell engineering parameters and associated conceptual and numerical models are acceptable and provide input to demonstration of compliance with the following criteria in 10 CFR, Part 40, Appendix A: Criterion 4(c), which provides requirements for the embankment and cover slopes for tailings; and Criterion 6(1), which requires a reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years.

2.5.5 References

American Society for Testing and Materials Standards:

D 75, "Practice for Sampling Aggregates."

D 4992, "Practice for the Evaluation of Rock To Be Used for Erosion Control."

Aitken, G.W. and R.L. Berg. "Digital Solution of Modified Berggren Equation to Calculate Depths of Freeze or Thaw in Multi-layered Systems." Special Report 122. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory. 1968.

Bennett, R.D. NUREG/CR–5432, "Recommendations to the NRC for Soil Cover Systems Over Uranium Mill Tailings and Low-Level Radioactive Wastes: Identification and Ranking of Soils for Disposal Facility Covers." Volume 1. Washington, DC: NRC. 1991.

Bennett, R.D. and R.C. Homz. NUREG/CR–5432, "Recommendations to the NRC for Soil Cover Systems Over Uranium Mill Tailings and Low-Level Radioactive Wastes: Laboratory and Field Tests for Soil Covers." Volume 2. Washington, DC: NRC. 1991.

Bennett, R.D. and A.F. Kimbrell. NUREG/CR–5432, "Recommendations to the NRC for Soil Cover Systems Over Uranium Mill Tailings and Low-Level Radioactive Wastes: Construction Methods for Sealing Penetrations in Soil Covers." Vol. 3. Washington, DC: NRC. 1991.

Fermulk, N. and M. Haug. "Evaluation of *In Situ* Permeability Testing Methods." *ASCE Journal of Geotechnical Engineering.* Vol. 116, No. 2. pp. 297–311. 1990.

Holtz, R.D. and W.D. Kovacs. *An Introduction to Geotechnical Engineering.* Englewood Cliffs, New Jersey: Prentice-Hall. 1981.

Lee, K.L. and C.K. Shen. 1969. "Horizontal Movements Related to Subsidence." *Journal of Soil Mechanics and Foundation Division.* Vol. 95, No. SM–1. New York, New York: American Society of Civil Engineers. 1969.

NRC. NUREG/CR–2684, "Rock Riprap Design Methods and Their Applicability to Long-Term Protection of Uranium Mill Tailings Impoundments." Washington, DC: NRC. 1982.

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———. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." April 1978. Washington, DC: NRC, Office of Standards Development. April 1978.

Spangler, M.G. and R.L. Handy. *Soil Engineering.* New York, New York: Harper and Row. 1982.

U.S. Army Corps of Engineers. "Soil Sampling." Engineering Manual EM1110-2-1907. March 1972.

———. "Laboratory Soil Testing." Engineering Manual EM1110–2–1906. November 1970.

2.6 Construction Considerations

2.6.1 Areas of Review

The staff should review information on the geotechnical aspects of reclamation construction. These aspects should include details such as the sequence and schedule for construction activities, material specifications and placement procedures, and quality control aspects of the construction procedures. The geotechnical aspects of the planned construction operations should be reviewed to identify any deviations from standard engineering practice for earthworks, including measures to protect against erosion and provisions for a vegetative cover.

2.6.2 Review Procedures

The reviewer should determine if all the tailings and contaminated materials at the site can be placed within the configuration of the proposed stabilized pile. The construction sequence should be reviewed to verify the feasibility of achieving the intended final configuration of the tailings, particularly when tailings are to be relocated to new areas of the remediated pile, and to determine whether the schedule for completion is reasonable. The reviewer should also confirm that the construction schedule will allow the radon barrier to be completed as expeditiously as practical after ceasing operations.

The reviewer should examine material placement, placement moisture content (drying, if needed), placement density, and desired permeability to ensure that design specifications will be met. If mixing of the fine tailings (slimes) with sand tailings is proposed, the specifications to control the mixture and the determination of the engineering properties of this mixture should be examined for adequacy.

The reviewer should examine the proposed construction quality control program to verify that adequate provisions have been included to ensure that the construction will be in accordance with the NRC-approved reclamation plan. In particular, details of the proposed testing and inspection program, including the type and frequency of tests proposed, should be reviewed and compared with NRC guidance on testing and inspection.

Methods and schedules for emplacing the vegetative cover should be reviewed to determine that they are reasonable, and that seeds for the planned vegetation are compatible with the local climate.

2.6.3 Acceptance Criteria

The analysis of construction considerations will be acceptable if the following criteria are met:

(1) Engineering drawings are complete and clearly show the design features (e.g., embankments, riprap, and channels).

(2) Sources and quantities of borrow material are identified, are shown to have been adequately characterized and quantified through field and laboratory tests, and are demonstrated to be adequate for meeting the geotechnical design requirements for the disposal cell (NRC, 1978, 1979). The background levels of contamination in the borrow materials, if any, are properly established.

(3) Methods, procedures, and requirements for excavating, hauling, stockpiling, and placing of contaminated and non-contaminated materials and other disposal cell materials are provided and are shown to be consistent with commonly accepted engineering practice for earthen works (Department of the Navy, 1982a,b; Denson, et al., 1987).

Material placement and compaction procedures are adequate to achieve the desired moisture content (drying, if needed) placement density and permeability. Recommendations made in NUREG/CR–5041 (Denson, et al., 1987) for gradation, placement, and compaction necessary to achieve design drainage rates and volumes, prevent internal erosion or piping, and allow for collection and removal of liquids are acceptable. Compaction specifications include restrictions on work related to adverse weather conditions (e.g., rainfall, freezing conditions).

Specifications for controlling the mixture of fine tailings (slime) with sand tailings are consistent with commonly accepted engineering practice and testing programs for determination of engineering properties of this mixture.

(4) A plan for embankment construction is presented, that demonstrates embankments can be constructed in accordance with the design.

(5) Plans, specifications, and requirements for disposal cell compaction are supported by field and laboratory tests and analyses to assure stability and reliable performance.

(6) Testing and surveying programs to determine the extent of cleanup required are adequate. The contamination cleanup plan includes the method for determining the extent of the contaminated area and a confirmation program to demonstrate that the contaminated material has been removed. Details of the site cleanup (radiological aspects) are addressed in standard review plan Chapter 5.0.

(7) A plan for settlement measurement is provided that is satisfactory for producing representative settlement data throughout the area of the disposal cell. Settlement measurement stations are of sufficient coverage and are strategically placed to yield adequate information for determination of total, differential, and residual settlements. Monitoring monuments are designed to be durable. The reviewer should also determine the reasonableness of the proposed monitoring frequency in accordance with NUREG/CR–3356 (NRC, 1983). In the past, the staff has determined that the final radon barrier may be emplaced once 90 percent of expected settlement has occurred.

(8) All tailings and contaminated materials at the site can be placed within the planned configuration of the stabilized pile.

(9) Procedures, specifications, and requirements for riprap, rock mulch, and filter production and placement are provided and are shown to be consistent with commonly accepted engineering practice and the design specifications (NRC, 1977, 1982).

(10) The construction sequence is described and demonstrated to be adequate to achieve the intended configuration for the tailings, particularly when tailings are to be relocated to new areas of the reclaimed pile. The proposed time to completion has been shown to be reasonably achievable, and the construction schedule provides for completing the radon barrier as expeditiously as practical after ceasing operations in accordance with an approved reclamation plan.

(11) The vegetation program or rock cover design is described and demonstrated to be adequate (Wu, 1984; NRC, 1982).

(12) Appropriate quality control provisions are provided to ensure that the construction will be in accordance with the reclamation plan. The descriptions of the methods, procedures, and frequencies by which the construction materials and activities are to be tested and inspected are reasonable and appropriate records will be maintained (NRC, 1983).

(13) Tailings are placed below grade, or the licensee has demonstrated that the above-grade disposal design provides reasonably equivalent isolation of the tailings from natural erosional forces. Tailings pile topographic features take into account wind protection and vegetation cover.

2.6.4 Evaluation Findings

If the staff review as described in this section results in the acceptance of the licensee proposed construction considerations, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the construction consideration at the ______________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.6.2 and the acceptance criteria outlined in Section 2.6.3 of the Title II standard review plan.

The licensee has acceptably described the construction considerations by (1) providing complete engineering drawings showing all design features; (2) describing sources and quantities of borrow material, including acceptable field and laboratory testing; and (3) identifying methods, procedures, and requirements for excavations, haulage, stockpiling, and placement of materials and demonstrating that all are consistent with accepted engineering practices for earthen works. An acceptable plan for embankment construction is provided. Disposal cell compaction plans are supported by field and laboratory tests that assure stability and performance. The licensee has an acceptable program to determine the extent of cleanup using appropriate testing and surveying programs. An acceptable plan for settlement measurement is provided, including (1) proper coverage and placement of settlement measurement stations, (2) durable monitoring monuments, and (3) reasonable monitoring frequencies. All tailings and contaminated materials have been demonstrated to fit within the planned configuration of the stabilized pile. Procedures, specifications, and requirements for riprap, rock mulch, and filters are provided and are shown to be consistent with commonly accepted engineering practices and design specifications. An acceptable construction sequence, including a reasonable time to completion, has been described. An acceptable vegetation program or rock cover design is proposed. Appropriate quality control provisions are in place to ensure that construction will be in accordance with the reclamation plan and that appropriate records will be maintained.

On the basis of the information presented in the application and the detailed review conducted of the construction considerations at the ______________ uranium mill facility, the NRC staff concludes that the construction considerations and associated conceptual and numerical models provide input to a demonstration of compliance with the following criteria in 10 CFR, Part 40, Appendix A: Criterion 4(c), which provides requirements for the embankment and cover slopes for tailings; Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or employment of a rock cover to reduce wind and water erosion to negligible levels, that individual rock fragments are suited for the job, and that the impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient; Criterion 6(1), relating to providing reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years; and Criterion 6A(1), which requires that the radon barrier be completed as expeditiously as practical after ceasing operations in accordance with a Commission-approved reclamation plan.

2.6.5 References

American Society for Testing and Materials Standards:

D 698, "Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort."

D 1556, "Test Method for Density and Unit Weight of Soil In Place by the Sand Cone Method."

D 1557, "Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort."

D 2167, "Test Method for Density and Unit Weight of Soil In Place by the Rubber Balloon Method."

D 2922, "Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shouldow Depth)."

D 2937, "Test Method for Density of Soil in Place by the Drive Cylinder Method."

D 3017, "Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shouldow Depth)."

D 3740, "Practice for the Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction."

D 4253, "Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table."

D 4254, "Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density."

D 4643, "Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method"

D 4718, "Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles."

D 4914, "Test Methods for Density of Soil and Rock In Place by the Sand Replacement Method in a Test Pit."

D 5030, "Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit."

Denson, R.H., et al. NUREG/CR–5041, "Recommendations to the NRC for Review Criteria for Alternative Methods of Low-Level Radioactive Waste Disposal." Washington, DC: NRC. 1987.

Department of the Navy. "Foundations and Earth Structures." NAVFAC DM–7.2. May 1982a.

———. "Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction." NAVFAC DM–7.3. May 1982b.

NRC. NUREG/CR–3356, "Geotechnical Quality Control: Low-Level Radioactive Waste and Uranium Mill Tailings Disposal Facilities." Washington, DC: NRC. 1983.

———. NUREG/CR-2684, "Rock Riprap Design Methods and Their Applicability to Long-Term Protection of Uranium Mill Tailings Impoundments." Washington, DC: NRC. 1982.

———. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Revision 1. Washington, DC: NRC, Office of Standards Development. March 1979.

———. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." Washington, DC: NRC, Office of Standards Development. April 1978.

———. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills." Revision 2. Washington, DC: NRC, Office of Standards Development. 1977.

Wu, T.H. "Effect of Vegetation on Slope Stability: Soil Reinforcement and Moisture Effects on Slope Stability." Transportation Research Record 965. National Research Council, Transportation Research Board. 1984.

2.7 Disposal Cell Hydraulic Conductivity

2.7.1 Areas of Review

The staff should review test results, calculations, the technical bases for disposal cell design hydraulic conductivity values, the field testing program, and the quality control program.

2.7.2 Review Procedures

The reviewer should examine the geotechnical design aspects of the disposal cell to ensure that the disposal cell cover component has a minimal hydraulic conductivity, to limit radon emissions from, and water infiltration into, stabilized mill tailings. The geotechnical reviewer should coordinate with the water resources protection reviewer (see standard review plan Chapter 4.0) to ensure that regulatory requirements for ground-water protection can be met by the proposed radon barrier.

The reviewer should verify that an adequate technical basis has been presented for the design hydraulic conductivity (K) value for the disposal cell cover. For any situation in which a $K<10^{-7}$ cm/sec is proposed by the licensee, the staff should verify that either a test fill program will be undertaken to verify the constructability to achieve the desired K value, or the reclamation plan narrative and accompanying analyses have adequately demonstrated the acceptability of the design K value, considering technical papers on this subject (e.g., Rogowski, 1990; Panno, et al., 1991; Benson and Daniel, 1990). If the reclamation plan acceptably demonstrates that field testing is not required, the reviewer should document the technical basis in the technical evaluation report. If field testing is required, the staff should ensure that the test fill specifications require that the hydraulic conductivity value be verified by in-place testing with double-ring infiltrometers or other approved methods.

The test reviewer should examine the test fill construction plan and verification program for adequacy, including such aspects as (1) use of proper procedures and equipment for placement and compaction operations; (2) verification of the material and thickness for the barrier test zone; (3) comparison of gradation, bentonite amendment, and moisture/density testing with specifications; (4) review of the quality control plan; and (5) review of the proposed construction schedule.

2.7.3 Acceptance Criteria

The analysis of disposal cell hydraulic conductivity will be acceptable if it meets the following criteria:

(1) A sufficient technical basis is provided for the design hydraulic conductivity (K) value for the disposal cell.

The hydraulic conductivity is minimized by compacting fine-grained soil for a sufficient depth above the stabilized tailings. Natural borrow soils having insufficient silt and clay content to effectively reduce the hydraulic conductivity of the barrier can be amended with bentonite for improved effectiveness. (Note that construction issues are discussed separately using standard review plan Section 2.6.)

(2) A field testing program adequate to verify the constructability of the disposal cell with a design hydraulic conductivity $K<10^{-7}$ cm/sec is provided unless the reclamation plan demonstrates that field testing is not required (Benson and Daniel, 1990; NRC, 1979).

To meet to the U.S. Environmental Protection Agency (EPA) ground-water standards, designers of disposal cells for mill tailings sites are proposing increasingly smaller design hydraulic conductivity (K) values. It is not unusual for laboratory permeability test values to yield results of 10^{-8} to 10^{-10} cm/sec. Such tests are performed on compacted soil samples considered by the design engineer to represent the soil to be used for the disposal cell. However, several technical papers (Rogowski, 1990; Panno et al., 1991; Benson and Daniel, 1990) have raised serious questions concerning the exclusive use of laboratory testing for demonstrating hydraulic conductivity values in those cases in which a radon barrier K-value less than 10^{-7} cm/sec is specified. On the basis of these technical papers, field testing is necessary to confirm the radon barrier hydraulic conductivity, since construction operations and soil material variability can create preferred pathways, joints, seams, holes, and flaws that effectively increase the value of this parameter. Test results should take into consideration the variability and uncertainty in site conditions and material properties. The test results should be properly documented and available for inspection.

(3) An appropriate quality control program is followed for the field testing to determine hydraulic conductivity (NRC, 1983).

For all cases in which $K<10^{-7}$ cm/sec and the test fill program requirement has been defined, specifications and related documents (Remedial Action Inspection Plan, etc.)

will require an adequate quality control program. An acceptable quality control program should contain mechanisms to ensure that as-built construction duplicates the test fill construction techniques on the cell barrier (NRC, 1983). The objective of the quality control program will be to provide assurance that uniform and high-quality construction of the cell barrier has been achieved. Records for implementation of the quality control program during the construction of the cell barrier should be properly maintained and available for inspection.

(4) A reasonable construction schedule is proposed. The proposed construction schedule should promote completion of the radon barrier as expeditiously as practical after ceasing operations in accordance with a written, Commission-approved reclamation plan.

2.7.4 Evaluation Findings

If the staff review as described in standard review plan Section 2.7 results in the acceptance of the disposal cell hydraulic conductivity, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the disposal cell hydraulic conductivity at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 2.7.2 and the acceptance criteria outlined in Section 2.7.3 of the Title II standard review plan.

The licensee has acceptably evaluated the disposal cell cover materials hydraulic conductivity by providing a sufficient technical basis for the design K-value for the disposal cell. A field testing program adequate to verify the constructability of the disposal cell with a hydraulic design conductivity of $K<10^{-7}$ cm/sec is presented. The applicant followed an acceptable quality control program for the field testing to determine the hydraulic conductivity.

On the basis of the information presented in the application and the detailed review conducted of the disposal cell hydraulic conductivity at the _______________ uranium mill facility, the NRC staff concludes that the disposal cell hydraulic conductivity and associated conceptual and numerical models provide an acceptable input to the demonstration of compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 4(c), which provides requirements for the embankment and cover slopes for tailings Criterion 6(1), relating to providing reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years; Criterion 6(4), relating to verification of radon barrier effectiveness and records maintenance.

2.7.5 References

American Society for Testing and Materials Standards:

D 2434. "Test Method for Permeability of Granular Soils (Constant Head)."

Geotechnical Stability

D 3385. "Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers."

D 5093. "Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer With a Sealed Inner Ring."

Benson, C.H. and D.E. Daniel. "Influence of Clods on Hydraulic Conductivity of Compacted Clay." *ASCE Journal of Geotechnical Engineering.* Vol. 116, No. 8. pp. 1,231–1,248. 1990.

NRC. NUREG/CR–3356, "Geotechnical Quality Control: Low-Level Radioactive Waste and Uranium Mill Tailings Disposal Facilities." Washington, DC: NRC. 1983.

———. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Revision 1. Washington, DC: NRC, Office of Standards Development. March 1979.

Panno, S.V., et al. "Field-Scale Investigation of Infiltration Into a Compacted Soil Liner. *Ground Water.* Vol. 29, No. 6. pp. 914–921. 1991.

Rogowski, A.S. "Relationship of Laboratory- and Field-Determined Hydraulic Conductivity in Compacted Clay Layer." EPA/600/S2–90/025. Cincinnati, Ohio: Risk Reduction Engineering Laboratory. 1990.

3.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

3.1 Hydrologic Description of Site

Criterion 1 of 10 CFR Part 40, Appendix A, addresses the general goals of siting and designing facilities to provide for permanent isolation of tailings, and minimizing the potential for dispersion by natural forces, without the need for active maintenance. Information presented in Section 3.1 will be used in later sections of this standard review plan to assess the ability of the site and the site design to meet this and other requirements of 10 CFR Part 40.

It is important to note that the siting criteria presented in 10 CFR Part 40, Appendix A are intended to apply to uranium mills that have not yet been constructed. For many, if not most, uranium mills, reclamation plans are developed for sites that have existed for several decades. In fact, many mills were producing uranium before the siting criteria were developed. Therefore, the staff concludes that Criterion 1 is more relevant to new facilities (or modifications to old facilities) than to facilities that existed before regulations were developed.

3.1.1 Areas of Review

The staff should review hydrologic site characterization information, including (1) identification of the relationships of the site to surface-water features in the site area and (2) identification of mechanisms, such as floods and dam failures, that may require special design features to be implemented. This review requires identification of the hydrologic characteristics of streams, lakes (e.g., location, size, shape, drainage area), and existing or proposed water control structures that may adversely affect the long-term stability of the site design features.

3.1.2 Review Procedures

The staff should evaluate the completeness of the information and data, by sequential comparison with information available from references. On the basis of the description of the hydrosphere (e.g., geographic location and regional hydrologic features), potential site flood mechanisms are identified. The information normally presented is not amenable to independent verification, except through cross-checks with available publications related to hydrologic characteristics of the site region and through observation during site visits.

The staff should also analyze geomorphic considerations, as described in Section 1 of this standard review plan. On the basis of these analyses, the staff should estimate the potential for geomorphic instability to occur and to have a significant effect on the ability of the site and its protective features to prevent flood intrusion and erosion over a long period of time. If geomorphic problems are identified, the staff should give particular attention to several areas of the design, depending on site conditions and potential for geomorphic changes to occur. These areas include the (1) apron and toe of the disposal cell, (2) intersection of natural gullies with erosion protection features, and (3) diversion channel outlets. A detailed discussion of the erosion protection design for these and other features is given in Section 3.4.2 of this standard review plan.

3.1.3 Acceptance Criteria

The hydrologic description of the site will be considered acceptable if:

(1) The description of structures, facilities, and erosion protection designs is sufficiently complete to allow independent evaluation of the impact of flooding and intense rainfall.

(2) Site topographic maps are of good quality and of sufficient scale to allow independent analysis of pre- and post-construction drainage patterns.

(3) The reclamation plan contains sufficient information for the staff to independently evaluate the hydraulic designs presented. In general, detailed information is needed for each method that is used to determine the hydraulic designs and erosion protection provided to meet NRC regulations. NUREG–1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and thus conform to NRC requirements. NUREG–1623 (NRC, 1998) also provides discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement, without the use of active maintenance. Specific design methods are provided and form the primary basis for staff review of erosion protection designs.

3.1.4 Evaluation Findings

If the staff evaluation of hydrologic and hydraulic engineering aspects of the reclamation plan confirms that the information acceptably characterizes the site and the site design features, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the flooding potential at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 3.1.2 and acceptance criteria outlined in Section 3.1.3 of the Title II standard review plan.

On the basis of the information presented in the application and the detailed review conducted of the flooding potential for the _______________ uranium mill facility the NRC staff concludes that (1) the flood analyses and investigations adequately characterize the flood potential at the site, (2) the analyses of hydraulic designs are appropriately documented, and (3) the general reclamation plan with respect to surface-water hydrology and erosion considerations represents a feasible plan for complying with the requirements of 10 CFR Part 40, Appendix A. The characterization of flood potential and the documentation of the site design conform to the requirements of Criterion 1 of 10 CFR Part 40, Appendix A, related to presenting a design that provides for permanent isolation of tailings and minimizes disturbance and dispersion by natural forces.

3.1.5 Reference

NRC. NUREG–1623, "Design of Erosion Protection for Long-Term Stabilization." Draft Report for Comment. Washington, DC: NRC. February 1999.

3.2 Flooding Determinations

3.2.1 Areas of Review

The staff should assess the flooding potential for the site, and should determine precipitation potential, precipitation losses, runoff response characteristics, and peak flow estimates for the probable maximum flood or project design flood (if a flood less than the probable maximum flood is used). The staff should review the following design analyses: (1) the analyses and justification for the use of a flood less than the probable maximum flood, if applicable; (2) the probable maximum precipitation potential and resulting runoff for site drainage and for drainage areas adjacent to the site; and (3) the modeling of physical rainfall and runoff processes to estimate flood conditions at the site.

The assessment of flooding also should include a review of possible geomorphic changes that could affect the erosion protection design for the site. As applicable, the staff should review the following: (1) identification of types of geomorphic instability; (2) changes to, and impacts associated with, flooding and flood velocities, from geomorphic changes; and (3) mitigative measures to reduce or control geomorphic instability. This information must be reviewed to determine the acceptability of hydraulic engineering designs to mitigate the geomorphic conditions and to avoid the need for ongoing active maintenance.

The assessment of flooding should also include a review of potential dam failures, if upstream reservoirs exist. Peak water levels, flood routing procedures, and velocities should be reviewed in the determination of potential hazards because of failure of upstream water control structures from either seismic or hydrologic causes. If an existing analysis concludes that seismic or hydrologic events will not cause failures of upstream dams and produce the governing flood at the site, the analysis should be reviewed to verify that information that supports such a conclusion (e.g., record of contact with dam designers) is included. If an analysis is provided that concludes that a dam failure flood from a probable maximum flood or a seismically induced flood is the design-basis flood, the computations should be reviewed to verify that appropriate and/or conservative model input parameters have been used.

3.2.2 Review Procedures

The evaluation of flooding is, for review purposes, separated into two parts: (1) flooding on large adjacent streams, as applicable and (2) localized flooding on drainage channels and protective features. The acceptability of using the probable maximum flood as the design flood event is presented in Section 2.2.1 of NUREG–1623 (NRC, 1998). The review procedure for evaluating a probable maximum precipitation/probable maximum flood event is outlined in Appendix D of NUREG–1623 (NRC, 1998). For large drainage areas, probable maximum flood estimates approved by the U.S. Army Corps of Engineers and found in published or unpublished reports of that agency, or generalized estimates, may be used instead of independent staff-developed estimates. The staff should also assess flood history in the site area by examining historic regional flood data. For many areas, historic flood peaks could be a small percentage of the probable maximum flood. If the historic maximum floods exceed or closely approximate the proposed probable maximum flood estimates, the staff should perform a detailed evaluation to determine the basis for the estimates. The staff should compare basin lag times, rainfall distributions, soil types, and infiltration loss rates to determine if there is a logical basis for the probable maximum flood values being less than historic floods. Without such estimates, the staff should generally use U.S. Army Corps of Engineers models to independently estimate probable maximum flood discharge and water levels at the site. If detailed computer models are used, the staff should review the adequacy of the various input parameters to the model, including, but not limited to, the following: drainage area, lag times and times of concentration, design rainfall, incremental rainfall amounts, temporal distribution of incremental rainfall, and runoff/infiltration relationships.

The staff should review the dam failure analyses presented in the reclamation plan or should independently estimate the peak flows at the site. Often, it may be much easier to perform simplified flood analyses assuming a dam failure, rather than detailed analyses of the seismic resistance of a dam. In such cases, the staff should review those simplified flood analyses using the procedures outlined in standard review plan Section 3.3.4.

The staff should evaluate the information presented in the reclamation plan using procedures found in Appendix C of NUREG–1623 (NRC, 1998) in those cases in which it is documented that it is impractical to design erosion protection features for an occurrence of the probable maximum flood. These documents contain detailed information regarding justification of a stability period of less than 1,000 years. To assure that minimum NRC requirements are met, the staff should independently check and evaluate the ability of the design to resist such flood events.

In the detailed review of flooding, the staff should carefully consider the following factors that are important in determining a local probable maximum precipitation/probable maximum flood event:

- Determination of Design Rainfall Event. The staff should consult appropriate hydrometeorological reports and determine that correct values of the 1- and 6-hour probable maximum precipitation events, as applicable, have been given.

- Infiltration Losses. The staff should check calculations to verify that appropriate values of infiltration have been selected.

- Times of Concentration. The staff should verify that appropriate methods (depending on the slope, configuration, etc.) have been selected. The staff should independently verify that the methods selected compare reasonably well with various velocity-based methods.

- Rainfall Distributions. The staff should verify that the rainfall distributions (particularly the 2½-, 5-, and 15-minute distributions) compare well with the distributions suggested in Appendix D to NUREG–1623 (NRC, 1998).

For dam failures, the staff should review estimates of flood potential and water levels. Depending on the potential for flooding, the staff should verify that the dam failure analyses are either realistic or conservative by determining locations and sizes of upstream dams, assuming an instantaneous failure (complete removal) of the dam embankment, and computing the peak outflow rate.

If this simplified analysis indicates a potential flooding problem, the analysis may be repeated using more refined techniques, and the staff may request additional information and data. Detailed failure models, such as those of the Army Corps of Engineers and National Weather Service, will be used to identify the outflows, failure modes, and resultant water levels at the site.

Assessments of flooding will be used to determine the acceptability of hydraulic engineering design to avoid the need for ongoing active maintenance at the site.

If a flood less than a probable maximum flood can cause dam failure and is proposed as the design-basis flood, the staff should employ the review procedures outlined above to determine the impracticality of designing for a probable maximum flood and to determine the acceptability of the flood used.

3.2.3 Acceptance Criteria

The flooding determinations for the site will be considered acceptable if:

The designs conform to the suggested criteria in Appendix D to NUREG–1623 (NRC, 1998). NUREG–1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to meet NRC requirements. It also presents discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Acceptable design methods are presented and form the primary basis for staff review of erosion protection designs. These methods were derived from regulatory requirements, other regulatory guidance, staff experience, and various technical studies.

Information pertinent to computation of the design flood is submitted in sufficient detail to enable the staff to perform an independent flood estimate, specifically:

- Model input parameters are adequate.

- Staff and the reclamation plan estimates of flood levels and peak discharges are in agreement.

- Computational methods for design flood estimates are adequate.

"Worst conditions" postulated in the analysis of upstream dam failures are (1) an approximate 25-year flood on a normal operating reservoir pool level coincident with the dam-site equivalent of the earthquake for which the remedial action project is designed, (2) a flood of about one-half the severity of a probable maximum flood on a normal reservoir pool level coincident with the dam-site equivalent of one-half of the earthquake for which the remedial action project is designed; and (3) a probable maximum flood (or design flood) on a normal reservoir pool. Conditions 1 and 2 are applied when the dam is not designed with adequate seismic resistance; Condition 3 is applied when the dam is not designed to safely store or pass the design flood.

If the proposed design is based on less than a probable maximum flood event, the licensee offers reasonable assurance of conforming to the stability requirement of 200 years.

Dam failure analyses are either realistic or conservative, and include locations and sizes of upstream dams, instantaneous failure (complete removal) of the dam embankment, and compute the peak outflow rate.

3.2.4 Evaluation Findings

If the staff evaluation of hydrologic and hydraulic engineering aspects of the reclamation plan confirms that the assessments of flooding are acceptable, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the flooding potential at the ______________ uranium mill facility. This review included an evaluation using the review procedures in Section 3.2.2 and the acceptance criteria outlined in Section 3.2.3 of the Title II standard review plan.

On the basis of information presented in the application and the detailed review conducted of the flooding potential for the _______________ uranium mill facility, the NRC staff concludes that the flood analyses and investigations adequately characterize the flood potential at the site and that the surface water hydrology and flooding considerations represent a feasible plan for meeting the requirements of 10 CFR Part 40, Appendix A.

The mill tailings at the ________________ uranium mill facility will be protected from flooding and erosion by an engineered rock riprap layer that has been designed in accordance with the guidance suggested by the staff. Flood analyses presented by the licensee demonstrate that this erosion protection is adequate, based on (1) selection of proper rainfall and flooding events; (2) selection of appropriate parameters for determining flood discharges; and (3) computation of flood discharges, using appropriate and/or conservative methods.

The licensee presented analyses to show that the site is located in an area rarely flooded by off-site floods and that it is protected from direct on-site precipitation and flooding. The erosion protection is large enough to resist flooding from the shallow depths and minimal forces of floods occurring from a probable maximum flood in the upstream drainage area. The staff therefore concludes that the erosion potential at the proposed site has been acceptably minimized, since any flooding at the site is mitigated by the erosion protection, and the forces associated with off-site floods are minimal. The staff also concludes that because the rainfall and flooding events have very low probabilities of occurrence over a 1,000-year period, no damage to erosion protection is expected from these, or more frequent, events. Therefore, maintenance or repair of damage will not be necessary.

On the basis of the information presented in the application and the detailed review conducted of the flooding potential for the _______________ uranium mill facility, the NRC staff concludes that the flood analyses contribute to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 1, requiring that erosion, disturbance, and dispersion by natural forces over the long term are minimized and that the tailings are disposed of in a manner that does not require active maintenance to preserve conditions of the site; Criterion 4(a), requiring that upstream rainfall catchment areas are minimized to decrease erosion potential and to resist floods that could erode or wash out sections of the tailings disposal area; Criterion 6(1), requiring that the design be effective for a period of 200–1,000 years; and Criterion 12, requiring that active maintenance is not necessary to preserve isolation.

3.2.5 Reference

NRC. NUREG–1623, "Design of Erosion Protection for Long-Term Stabilization." Washington, DC: NRC. 1998.

3.3 Water Surface Profiles, Channel Velocities, And Shear Stresses

3.3.1 Areas of Review

Depending on the type of computational models used, the staff should review the model, including the determination of flooding depths, channel velocities, and/or shear stresses used to determine riprap sizes needed for erosion protection. The staff should review the various detailed computations for each model and should review the acceptability of the input parameters to the model. The staff should estimate the flood levels, velocities, shear stresses, and magnitudes, as described below. The review should be oriented toward verifying that the site will not require ongoing active maintenance.

3.3.2 Review Procedures

Using the guidance presented in Appendix D to NUREG–1623 (NRC, 1998) the staff should verify that localized flood depths, velocities, and shear stresses used in models for rock size determination or soil cover slope analysis are acceptable. For off-site flooding effects, the staff should verify that computational models have been correctly and appropriately used and that the data from the model have been correctly interpreted. The staff should verify that acceptable models and input parameters have been used in all the various portions of the flood analyses and that the resulting flood forces have been adequately accommodated.

Staff estimates may be made independently from basic data, by detailed review and checking of the reclamation plan analyses, or by comparison with other estimates that have been previously reviewed in detail. The evaluation of the adequacy of the estimates is a matter of engineering judgment, and is based on the confidence in the estimate, the degree of conservatism in each parameter used in the estimate, and the relative sensitivity of each parameter as it affects the flood level, flood velocity, or design of the erosion protection.

The staff review should evaluate whether ongoing active maintenance will be required at the site.

3.3.3 Acceptance Criteria

The water surface profiles, channel velocities, and shear stresses calculated for the site will be considered acceptable if:

The proposed designs conform to the suggested criteria in Appendix D to NUREG–1623 (NRC, 1998). NUREG–1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to comply with NRC requirements. This document also contains discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific design methods are presented, and reasonable similarity to these methods forms the primary basis for staff acceptance of erosion protection designs. Specifically:

- Localized flood depths, velocities, and shear stresses used in models for rock size determination or soil cover slope analysis conform to the guidance presented in Appendix D to NUREG–1623 (NRC, 1998).

- For off-site flooding effects, computational models have been correctly and appropriately used and that the data from the model have been correctly interpreted.

- Acceptable models and input parameters have been used in all the various portions of the flood analyses and that the resulting flood forces have been adequately accommodated.

3.3.4 Evaluation Findings

If the staff evaluation of hydrologic and hydraulic engineering aspects of the reclamation plan confirms that the assessments of flooding are acceptable, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the flooding models at the ____________ uranium mill facility. This review included an evaluation using the review procedures in Section 3.3.2 and the acceptance criteria outlined in Section 3.3.3 of the Title II standard review plan. On the basis of the information presented in the application and the detailed review conducted of the flooding models for the ____________ uranium mill facility, the NRC staff concludes that flood velocities and forces associated with flooding at the site have been acceptably computed.

The mill tailings will be protected from flooding and erosion by an engineered rock riprap layer that has been designed in accordance with the guidance suggested by the staff. Flood analyses presented by the licensee demonstrate that adequate protection is provided by (1) selection of proper models to assess rainfall and flooding events, (2) selection of appropriate parameters for models for determining flood forces, and (3) computation of flood forces using appropriate and/or conservative methods.

The staff considers that the riprap layers proposed will not require active maintenance over the 1,000-year design life, because the licensee adopted models that conservatively compute flood forces used to design the erosion protection. Thus, the use of conservative design parameters will result in no damage to the erosion protection designed using those methods. The staff further concludes that the hydraulic design features are sufficient to protect the tailings from flood forces that are very large and have very low probabilities of occurrence over a 1,000-year period. Therefore, maintenance of the rock layers will not be necessary.

The staff concludes that the analyses and models used at the _____________ uranium mill facility contribute to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 1, requiring that erosion, disturbance, and dispersion by natural forces over the long term are minimized and that the tailings are disposed of in a manner that does not require active maintenance to preserve conditions of the site; Criterion 6(1), requiring the design to be effective for a period of 1,000 years; and Criterion 12, requiring that active ongoing maintenance is not necessary o preserve isolation of the tailings.

3.3.5 Reference

NRC. NUREG–1623, "Design of Erosion Protection for Long-Term Stabilization." Washington, DC: NRC. 1998.

3.4 Design of Erosion Protection

3.4.1 Areas of Review

Design details and analyses pertinent to the following aspects of erosion protection will be reviewed, as applicable:

(1) Erosion protection for slopes and channel banks to protect against flooding from nearby large streams

(2) Erosion protection for the top and side slopes of the pile

(3) Erosion protection for the apron/toe area of the side slope

(4) Erosion protection for drainage and diversion channels, including channel outlets

(5) Durability of the erosion protection

(6) Construction considerations, including specifications, quality assurance programs, quality control programs, and inspection programs

In Section 3.4.2.4 (below), sedimentation in diversion channels is also addressed. Criterion 4(f) of 10 CFR Part 40, Appendix A, suggests that deposition of sediment in impoundment areas should be considered for enhancing the cover thickness. The staff considers it important to differentiate between beneficial and detrimental sediment accumulations. For example, if sediment could be conveniently routed to the middle of an impoundment, without long-term erosion or ponding of runoff that could affect ground-water conditions, such deposition may enhance long-term cover thickness. However, this is difficult to actually achieve. The major problem with sediment is that it tends to accumulate in diversion channels that are constructed on relatively flat slopes. High-velocity runoff from steep slopes carries sediment into low-velocity diversion channels, and that sediment can eventually accumulate and completely block the channel. Thus, it can be seen that some sediment buildup is good and some is bad. The review should evaluate the need for ongoing active maintenance of the site.

3.4.2 Review Procedures

The staff should check the analyses in the reclamation plan or perform independent review analyses of floods, flood velocities, and rock durability according to the guidelines in Appendix D to NUREG–1623 (NRC, 1999).

(1) Banks of Natural Channels

The staff should review designs for riprap to be placed on the side slopes of a reclaimed pile or on natural channel banks to protect against erosive velocities from floods on large rivers. Guidance is presented in Appendix D to NUREG–1623 (NRC, 1999) for assessing floods, determining input parameters to models, and determining riprap requirements.

(2) Top Slope and Side Slopes

The staff should review input parameters to calculations and models according to the recommendations given in Appendix D to NUREG–1623 (NRC, 1998) and referenced technical procedures. The staff should assess the design flow rate, the depth of flow, angle of repose, specific gravity, and other parameters. For both the top and side slopes, the rock sizes should be checked using the recently developed, simplified procedures discussed in NUREG–1623 (NRC, 1998).

(3) Apron/Toe

The design of the apron and toe is reviewed by verifying that several design features in this area have been properly designed, in accordance with the recommendations in NUREG–1623 (NRC, 1998).

For the lower end of the side slope where it meets the toe, the staff should verify that proper consideration has been given to the potential occurrence of increased shear forces resulting from turbulence and energy dissipation produced by hydraulic jumps, when the flow transitions from supercritical to subcritical. The staff should verify that appropriate design criteria have been used to increase the rock size to account for the increased velocities or shear forces.

For the main area of the toe, the staff should assure that appropriate methods have been used to design the riprap, depending on the magnitude of the slope of the toe.

For the downstream end of the toe, the staff should verify that acceptable assumptions have been made regarding the assumed collapse of the rock into scoured areas to prevent gully intrusion. Flow concentrations, collapsed slopes, and computational models should be evaluated.

For the natural ground area at the downstream end of the toe, the staff should verify that appropriate methods have been used to compute scour depths and that natural erosion will not adversely affect long-term stability.

(4) Diversion Channels

Using the criteria and guidance presented in Appendix D to NUREG–1623 (NRC, 1998), the staff should evaluate the design of diversion channels in several critical areas.

For the main channel area, the staff should verify that appropriate models and input parameters have been used to design the erosion protection. The staff should assure that flow rates, flow depths, and shear stresses have been correctly computed.

For the channel side slopes, the staff should verify that the side slopes are capable of resisting flow velocities and shear stresses from flows that occur directly down the side slope. This occurs often when diversion channels are constructed perpendicular to natural gullies (which discharge into the diversion channel). The shear forces in these locations often greatly exceed the forces produced by flows in the channel, particularly when the slope of the natural ground in the area is greater than the slope of the diversion channel.

For the outlet of the diversion channel, the staff should evaluate the design of erosion protection to assure that erosion in the discharge area (normally a natural gully, swale, or channel) has been adequately addressed. Designs similar to apron/toe designs should be evaluated to determine their resistance to erosion. Appendix D to NUREG–1623 (NRC, 1998) discusses acceptable methods for designing channel outlets.

For the entire length of the diversion channel, the staff should evaluate the effects of sediment accumulations on flow velocities, channel capacity, and need for increased rock size. Particular attention should be given to designs in which steep natural streams discharge into relatively flat diversion channels, greatly increasing the potential for blockage of the channel. Appendix E to NUREG–1623 (NRC, 1998) discusses acceptable methods for assessing sedimentation in diversion channels.

(5) Rock Durability

The staff should review the results of durability testing of proposed rock sources to assure that durable rock will be used. Appendix D to NUREG–1623 (NRC, 1998) presents a detailed method for evaluating rock quality for various locations and applications.

(6) Construction Considerations

The staff should review the plans, specifications, inspection programs, and quality assurance/quality control programs to assure that adequate measures are being taken to construct the design features according to accepted engineering practices. The staff should compare the information presented with typical programs used in the construction industry. Appendix F to NUREG–1623 (NRC, 1998) contains examples of acceptable specifications and testing programs that were approved by the staff and actually applied at several sites.

(7) The review shall specifically evaluate whether the erosion protection design is sufficient to avoid the need for ongoing active maintenance at the site.

3.4.3 Acceptance Criteria

The design of erosion protection for the site will be considered acceptable if:

The proposed designs conform to the suggested criteria in NUREG–1623 (NRC, 1998) . NUREG–1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to comply with NRC requirements. This document also contains discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific design methods are presented, and reasonable similarity to these methods forms the primary basis for staff acceptance of erosion protection designs. NUREG–1623 (NRC, 1998) updates and expands the final staff technical position (NRC, 1990).

If active maintenance is proposed as an alternative to the designs suggested above, such an approach will be found acceptable if the following criteria are met:

(1) The maintenance approach must achieve an equivalent level of stabilization and containment and protection of public health, safety, and the environment.

(2) The licensee must demonstrate a site-specific need for the use of active maintenance and an economic benefit.

(3) The licensee must provide funding for the maintenance by increasing the amount of the required surety. The staff should determine if the licensee's estimate of funding required for active maintenance is adequate. The licensee should also work with the

long-term custodian to assess any additional funding requirements related to long-term surveillance and monitoring.

3.4.4 Evaluation Findings

If the staff evaluation of hydrologic and hydraulic engineering aspects of the reclamation plan confirms that the erosion protection designs are acceptable, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the design of erosion protection at the _______________ uranium mill facility. This review included an e evaluation using the review procedures in Section 3.4.2 and the acceptance criteria outlined in Section 3.4.3 of the Title II standard review plan. On the basis of the information presented in the application and the detailed review conducted of the erosion protection designs are acceptable.

The mill tailings will be protected from flooding and erosion by an engineered rock riprap layer. The riprap has been designed in accordance with the guidance suggested by the NRC staff. The staff considers that erosion protection that meets that guidance will provide adequate protection against erosion and dispersion by natural forces over the long term. In addition to the adequacy of the flood analyses discussed in standard review plan Sections 3.2 and 3.3, the staff concludes that adequate erosion protection designs are provided by (1) use of appropriate methods for determining erosion protection needed to resist the forces produced by the design discharge, and (2) selection of a rock type for the riprap layer that will be durable and capable of providing the necessary erosion protection for a long period of time. Further, the staff considers that the riprap layers proposed will be durable over the 1,000-year design life, for the following reasons: (1) the rock proposed for the riprap layers was evaluated using rock quality procedures suggested by the staff and is not expected to deteriorate significantly over the 1,000-year design life; (2) the rock fragments are dense, resistant to abrasion, and free from cracks, seams, and other defects; and (3) during construction, the rock layers will be placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion, and segregation of the rock.

The riprap for the relatively flat top and side slopes is designed to be sufficiently large to minimize erosion potential. The rock will be capable of resisting flooding and erosion, depending on the slope selected. Thus, the staff concludes that the relatively steep slopes, with their corresponding rock designs, are acceptable.

On the basis of its review of the designs for the _______________ uranium mill facility, the staff concludes that the hydraulic designs contribute to meeting the requirements of 10 CFR Part 40, Appendix A: (1) Criterion 1, requiring that erosion, disturbance, and dispersion by natural forces over the long term are minimized and that the tailings are disposed of in a manner that does not require active maintenance to preserve conditions of the site; (2) Criterion 4(c), requiring embankments and cover slopes to be relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety that ensure long-term stability; (3) Criterion 4(d), requiring that the rock cover reduces wind and water erosion to negligible levels, including consideration of such factors as the shape, size, composition, and gradation of the rock particles; (4) Criterion 4(f), requiring the design to promote deposition, where feasible; (5) Criterion 6(1), requiring the design to be effective for 200–1,000 years; and (5) Criterion 12, requiring that active on-going maintenance is not necessary to preserve isolation.

3.4.5 References

NRC. NUREG–1623, "Design of Erosion Protection for Long-Term Stabilization." Draft Report for Comment. Washington, DC: NRC. 1999.

———. "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites." Washington, DC: NRC. 1990.

3.5 Design of Unprotected Soil Covers And Vegetative Soil Covers

3.5.1 Areas of Review

If an unprotected soil cover or a vegetative soil cover is proposed, the following design details, calculations, and analyses will be reviewed:

(1) Determination of allowable shear stresses and permissible velocities for the cover

(2) Determination of allowable shear stresses and permissible velocities for the cover in a degraded state, including the effects of fires, droughts, vegetation succession, and other impacts to the ability of the cover to function without maintenance

(3) Information on types of vegetation proposed and their abilities to survive natural phenomena

(4) Information, analyses, and calculations of all input parameters to models used

The review will consider whether the design of covers is sufficient to avoid the need for ongoing active maintenance at the site.

3.5.2 Review Procedures

If a soil cover is proposed, the staff should evaluate the design using the general criteria outlined in Appendix A to NUREG–1623 (NRC, 1998). Particular attention should be given to the input parameters to various models.

(1) The staff should verify that the design flow rate includes an appropriate flow concentration factor that reflects consideration of settlement, soil removal by sheet flow and wind, degradation of the vegetation cover, intrusion of trees, blockage of flows by fallen trees, etc.

(2) The staff should verify that estimates of Manning's "n" value correspond to the vegetation cover proposed and are proper for estimating allowable shear stresses and permissible velocities.

(3) The staff should verify that appropriate values of allowable shear stresses and permissible velocities have been used and conservatively reflect potential changes that could occur to the cover over a long period of time as a result of fires, droughts, diseases, vegetation succession, or general cover degradation.

(4) The staff should check analyses and/or independently calculate allowable slopes using several different methods and ranges of input parameters. Using a range of flow concentration factors, shear stresses, permissible velocities, "n" values, and models, the staff should check the sensitivity of the analyses and should verify that reasonable and appropriate values of input parameters have been selected.

If a sacrificial soil cover is proposed to meet the minimum 200-year stability requirement, the staff should check the calculations using Appendix B to NUREG–1623 (NRC, 1998) and the justification for reduction of the stability period using Appendix C to NUREG–1623 (NRC, 1998).

(5) The reviewer shall determine whether the design is adequate to avoid the need for ongoing active maintenance at the site.

3.5.3 Acceptance Criteria

The design of unprotected soil covers and vegetative soil covers for the site will be considered acceptable if:

The designs conform to the suggested criteria in NUREG–1623 (NRC, 1998). NUREG–1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and thus meet NRC requirements. This document also provides discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific acceptance criteria for many of the review areas are presented and form the primary basis for staff review of erosion protection designs. These criteria were derived from regulatory requirements, other regulatory guidance, staff experience, and various technical references.

If active maintenance is proposed as an alternative to the designs suggested above, such an approach will be found acceptable if the following criteria are met:

(1) The maintenance approach must achieve an equivalent level of stabilization and containment and protection of public health, safety, and the environment.

(2) The licensee must demonstrate a site-specific need for the use of active maintenance and an economic benefit.

(3) The licensee must provide funding for the maintenance by increasing the amount of the required surety. The licensee should also work with the long-term custodian to assess any additional funding requirements related to long-term surveillance and monitoring.

3.5.4 Evaluation Findings

If the staff's evaluation of hydrologic and hydraulic engineering aspects of the reclamation plan confirms that the cover designs are acceptable, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the design of erosion protection covers at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 3.5.2 and the acceptance criteria outlined in Section 3.5.3 of the Title II standard review plan. On the basis of its review, the staff concludes that the designs are acceptable and meet the requirements of 10 CFR Part 40, Appendix A.

The mill tailings will be protected from flooding and erosion by an engineered soil cover. The cover has been designed in accordance with the guidance suggested by the staff. The staff considers that a soil cover that meets that guidance will provide adequate protection against erosion and dispersion by natural forces over the long term. In addition to the adequacy of the flood analyses discussed in standard review plan Sections 3.2 and 3.3, the staff concludes that adequate cover designs are provided by:

(1) Use of appropriate methods for determining cover slopes needed to resist the forces produced by the design discharge

(2) Selection of a cover that will be capable of providing the necessary erosion protection for a long period of time

The relatively flat top and side slopes of the cover are designed to provide long-term stability. The erosion potential of the cover is minimized by designing slopes that are sufficiently flat to minimize velocities and to resist flooding and erosion. Thus, the staff concludes that the cover slopes are acceptable.

On the basis of the information presented in the application and the detailed review conducted of the erosion protection covers for the _______________ uranium mill facility, the NRC staff concludes that the cover designs contribute to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 1, requiring that erosion, disturbance, and dispersion by natural forces over the long term are minimized and that the tailings are disposed of in a manner that does not require active maintenance to preserve conditions of the site; Criterion 4(b), requiring siting and design such that topographic features provide good wind protection; Criterion 4(c), requiring that embankments and cover slopes are relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety; Criterion 6(1), requiring the design to be effective for 200 to 1,000 years; and Criterion 12, requiring that active ongoing maintenance is not necessary to preserve isolation.

3.5.5 Reference

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