U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

2.5.4 STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of properties and stability of soil, and rock supporting foundations

Secondary - None

I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) discusses the site characteristics and parameters that could affect the safe design and siting of the plant. The staff reviews information presented by the applicant for a construction permit (CP), operating license (OL), early site permit (ESP), or combined license (COL) concerning the characteristics and stability of the soil and rock underlying the site that could affect the safe design and siting of the plant. The staff reviews information presented by the applicant for a design certification (DC) to determine if the postulated site parameters for the design, with respect to stability of the soil and rock underlying the site, are correctly identified, are representative of a reasonable number of sites that has been or may be considered for a COL application, and are appropriately justified..

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This SRP section applies to reviews performed for each of these types of applications. The review covers the following specific areas:

1. Geologic features and characteristics of materials (Subsection 2.5.4.1) at the site, specifically:

   A. The potential for surface and subsurface deformation is evaluated in detail in Section 2.5.3 of the applicant's technical submittal. This potential is summarized and cross-referenced in this subsection

   B. Zones of alteration or irregular weathering profiles, and zones of structural weakness.

   C. Unrelieved stresses in bedrock and their potential for creep and rebound effects.

   D. Rocks or soils that might be unstable because of their mineralogy, solubility, consolidation properties, water content, or potentially undesirable response to seismic or other events.

   E. Rock mass containing voids, karsts, and other discontinuities located or oriented such that instabilities or strength reduction in the foundation material may occur.

   F. History of deposition and erosion, including glacial and other preloading influence on soil deposits.

   G. Estimates of soil consolidation, consolidation parameters, such as preconsolidation pressures and coefficient of consolidation and methods used to estimate these values.

2. The static and dynamic engineering properties of soil and rock strata underlying the site (Subsection 2.5.4.2) as supported by representative field and laboratory test data provided by the applicant.

3. The relationship of the foundations of all seismic Category I and other safety-related facilities to the subsurface materials as illustrated on plot plans and profiles (Subsection 2.5.4.3) provided by the applicant.

4. The results of seismic site exploration for example refraction and reflection surveys, suspension logging, down-hole and cross-hole explorations, as presented in the applicant's technical submittal by discussions, plot plans, boring logs, tables, and profiles to support the assumed dynamic soil or rock characteristics (Subsection 2.5.4.4) and stratigraphy.

5. Safety-related excavation and backfill plans and engineered earthwork analysis and criteria (Subsection 2.5.4.5) as illustrated on plot plans and profiles, discussed in the text, and supported by explorations for borrow material, test fills and adequate representative laboratory test records.

6. Groundwater conditions and piezometric pressure in all critical strata (Subsection 2.5.4.6) as they affect the loading and stability, and durability of foundation materials. This part of

the staff review also includes an evaluation of the applicant's plans for dewatering during construction as well as groundwater control throughout the life of the plant.

7. The responses of site soils or rocks to dynamic loading (Subsection 2.5.4.7), including appropriate laboratory and field test records in sufficient number and detail adequate to define mean material properties and their variability needed to support conclusions derived from the analyses.

8. The liquefaction potential (Subsection 2.5.4.8) and consequences of liquefaction of all subsurface soils, including the settlement of foundations. These analyses are based on soil properties obtained by proper and state-of-the-practice laboratory and field tests and involve application of both deterministic and probabilistic procedures.

9. The earthquake design bases (Subsection 2.5.4.9) are evaluated in detail in Section 2.5.2 of the applicant's technical submittal. These are summarized and cross-referenced in this subsection.

10. The results of investigations and analyses conducted to determine foundation stability, deformation and settlement under static and dynamic conditions (Subsection 2.5.4.10). This part of the staff review also includes evaluation of necessary foundation stability monitoring programs, such as long term settlement monitoring program, to verify the design and analysis results and to ensure that static and dynamic stability design requirements are met over the life of the plant.

11. Criteria, references, and design methods (Subsection 2.5.4.11) used in static and seismic analyses of foundation materials, including an explanation of computer programs used in the analyses and soil loads on subsurface facilities.

12. Techniques and specifications to improve subsurface conditions (Subsection 2.5.4.12), which are to be used at the site to provide suitable foundation conditions. Additional information on foundations is covered in SRP Section 3.8.5 and should be cross-referenced to this section.

13. Additional information will be presented dependent on the type of application. For a COL application, the additional information is dependent on whether the application references an ESP, a DC, both or neither. Information requirements are prescribed within the "Contents of Application" sections of the applicable Subparts to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52 .

COL Information Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL information items and requirements and restrictions (e.g., interface requirements and site parameters).

For a COL application referencing a DC, a COL applicant must address COL information items specified in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP sections interface with this section as follows:

1. The reviewer provides findings on the geotechnical parameters and methods employed in the analysis of soil and rock and foundation response to the ground motion environment to the reviewers of the appropriate subsections within SRP Chapter 3, as necessary, to ensure that the static and dynamic loads from soil/rock and corresponding structural deflections, including any reduction in support capability of subsurface materials, can safely be accommodated by structural components.

2. The organization responsible for quality assurance performs reviews of design, construction, and operations phase quality assurance programs under SRP Chapter 17. In addition, while conducting regulatory audits in accordance with Office Instruction NRR-LIC-111 or NRO-REG-108, "Regulatory Audits," the technical staff may identify quality-related issues. If this occurs, the technical staff should contact the organization responsible for quality assurance to determine if an inspection should be conducted.

3. For DC applications and COL applications referencing a DC rule or DC application, review of the site parameters in the Design Control Document (DCD) Tier 1 and Chapter 2 of the DCD Tier 2[1] submitted by the applicant is performed under SRP Section 2.0, "Site Characteristics and Site Parameters." Review of site characteristics and site-related design parameters in ESP applications or in COL applications referencing an ESP is also performed under the same section.

4. The reviewers of SRP Chapter 19 will coordinate the review of the stability of subsurface materials and foundations related to the seismic risk evaluation with the reviewers of this SRP section.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR 50.55a(a)(1) "Codes and standards," requires that structures, systems, and components (SSCs) be designed, fabricated, erected, constructed, tested and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

2. 10 CFR Part 50, Appendix A:

   A. General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of SSCs important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

[1] Additional supporting information of prior DC rule may be found in DCD Tier 2 section 14.3

B. GDC 2, "Design Bases for Protection Against Natural Phenomena," as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

C. GDC 44, "Cooling Water," requires that a system be provided with the safety function of transferring the combined heat load from SSCs important to safety to an ultimate heat sink under normal operating and accidental conditions.

3. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," establishes quality assurance requirements for the design, construction, and operation of those SSCs of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

4. 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes and surface deformation.

5. Applicable to an ESP: 10 CFR 52.17(a)(1), "Contents of Applications; Technical Information." A Site Safety Analysis Report includes (vi) the geological characteristics of the proposed site with consideration of the most severe of the natural phenomena that have been historically reported for the site and (xii) an evaluation of the site against applicable sections of the SRP acceptance criteria.

6. Applicable to a DC: 10 CFR 52.47(a)(1), "Contents of Applications; Technical Information," a DC applicant is required to provide site parameters postulated for the design.

7. Applicable to a COL: 10 CFR 52.79 (a)(iii), "Contents of Applications; Technical Information in Final Safety Analysis Report." A Final Safety Analysis Report (FSAR) is required that includes the geological characteristics of the proposed site with consideration of the most severe of the natural phenomena that have been historically reported for the site and the surrounding area and with sufficient margin for the limited accuracy, and time in which the historical data have been accumulated.

8. 10 CFR Part 100, "Reactor Site Criteria," provides the criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

9. 10 CFR 100.23, "Geologic and Seismic Criteria," provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the U.S. Nuclear Regulatory Commission (NRC) regulations identified above are as follows for the review

described in this SRP section. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

Appropriate sections of the following Regulatory Guides (RGs) are used by the staff for the identified acceptance criteria:

RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," describes a basis acceptable to the staff that may be used to implement GDCs 2 and 44 with regard to the ultimate heat sink, including necessary retaining structures and the canals and conduits connecting the ultimate heat sink with the cooling water system intake structures.

RG 1.28, "Quality Assurance Program Requirements (Design and Construction)," describes a method acceptable to the staff for complying with the Commission's regulations with regard to 10 CFR Part 50, Appendix B, overall quality assurance program requirements during design and construction of nuclear power plants.

RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR Part 100 and 10 CFR 100.23. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, including the spacing and depth of borings and sampling.

RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants," describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics, together with their uncertainties needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR Part 100 and 10 CFR 100.23.

RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,” describes acceptable methods for evaluating the potential for earthquake induced instability of soil resulting from liquefaction and strength degradation in complying with 10 CFR 100.23 and 10 CFR Part 50, Appendix S.

RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” provides guidance regarding the information to be submitted in a COL application for a nuclear power plant.

RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," describes acceptable methods to: (1) conduct geological, seismological, and geophysical, and geotechnical investigations of the site and region around the site, (2) identify and characterize seismic sources, (3) perform probabilistic seismic hazard analysis (PSHA), (4) perform site response analysis, and (5) determine the site-specific ground motion response spectrum (GMRS) for the site.

A thorough evaluation of the geotechnical engineering aspects of the nuclear plant site as described in the following subsections must be presented along with the basic data supporting all conclusions. Sufficient information must be provided to allow the staff and its advisors to conduct independent analyses. The site investigations must be adequate in scope and in technique to provide the necessary data, including best estimate material properties together with their range of potential variability.

2.5.4.1 - Geologic Features. In meeting the requirements of 10 CFR Parts 50 and 100, the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations sufficiently detailed to obtain an unambiguous representation of the geology. The information must be presented in this subsection or cross-referenced to the appropriate subsection in Section 2.5.1 of the applicant's technical submittal.

Geologic features are evaluated by conducting an independent literature search and comparing these results with the information included in the applicant's technical submittal. References used in reviewing this subsection include published or unpublished reports, maps, geophysical data, construction records, etc., by the U.S. Geological Survey (USGS), other Federal agencies, State agencies, and private companies. In conjunction with the literature search, the staff and its advisors review the geological investigations conducted by the applicant. Using the references listed at the end of this section and other sources, the following questions are considered in detail:

A. Are the exploratory techniques used by the site investigator representative of the present state-of-the-art? Do the samples represent the in situ soil conditions?

B. Do the applicant's investigations provide adequate coverage of the site with sufficient detail to define the specific subsurface conditions?

C. Considering the results of the review in SRP Section 2.5.3 for potential surface deformation, have all areas or zones of actual or potential surface or subsurface subsidence, uplift or collapse, or deformation been identified and adequately evaluated?

D. Have all areas or zones of actual or potential surface or subsurface alteration, solution cavities or structural weakness, unrelieved stresses in bedrock, or rocks or soils that might be unstable because of their physical or chemical properties, been identified and adequately evaluated?

2.5.4.2 - Properties of Subsurface Materials. In meeting the requirements of 10 CFR Parts 50 and 100, the description of properties of underlying materials is considered acceptable if state-of-the-art methods are used to determine the static and dynamic engineering properties of all foundation soils and rocks in the site area to sufficient depth that impact behavior during construction and over the life of the facility, including during postulated seismic events. These methods are described, for example, in geotechnical journals published by the American Society of Civil Engineers, applicable standards published by the American Society for Testing and Materials, publications of the Institution of Civil Engineers, and various research reports prepared by universities. The properties of foundation material must be supported by field and laboratory test records.

Normally, a complete field investigation and sampling program must be performed to define the occurrence and properties of underlying materials at a given site. Summary tables must be provided which catalog the important test results; test results should be plotted when appropriate. Also, a detailed discussion of laboratory sample preparation must be given when applicable. For critical laboratory tests, full details must be given, e.g., how saturation of the sample was determined and maintained during testing, transported and how the pore pressures were monitored during the experiment.

The applicant should provide a detailed and quantitative discussion of the criteria used to determine that the samples were properly taken, and tested to define all the critical soil parameters for the site, together with their potential variabilities. A sufficient number of measurements are needed in order to determine the parameters that can adequately represent the field conditions. Factors that should be considered when determining the number of measurements include the spatial variability (both horizontal and vertical); and the reliability and limitations of the method used to obtain the measurements. For most cases, more than one method should be used to determine important parameters (e.g., shear wave velocity). For sites that are underlain by saturated soils and sensitive clays, collapsible and expansive soils, it should be shown that all zones which could become unstable due to liquefaction or strain-softening phenomena have been adequately sampled and tested. The relative density of the soils at the site should be determined. The applicant must also show that the consolidation behavior of the soils as well as their static and dynamic strength has been adequately defined. The discussion should explain how the developed data is used in the safety analyses, how the test data is analyzed to generate appropriate design parameters and present a table indicating the value of the parameters used in the analyses.

Properties of underlying materials are evaluated to determine whether or not the investigations performed (including laboratory and field testing) were sufficient to justify the soil and rock properties used in the foundation analyses.

To determine whether sufficient investigations were performed, the staff carefully reviews the criteria developed and used by the applicant in laying out the boring, sampling and testing program and evaluates the effectiveness of the program in defining the specific foundation conditions at the site to ensure that all critical conditions have been adequately sampled and tested. If suitable criteria have not been developed and used by the applicant, the staff develops appropriate criteria, using RG 1.132 and the data given in the applicant's technical submittal, and determines if sufficient investigation and testing have been carried out. If criteria are given, the staff reviews them to determine if they are appropriate and have been implemented.

For structures with embedment substantially deeper than conventional nuclear power plants, the criteria used to determine the depth of borings, sampling and sampling disturbance evaluation, and laboratory and field test programs are reviewed to ensure that adequate depths and sampling intervals are utilized to establish the soil profile and the general engineering soil properties used in the site response and soil-structure interaction analyses.

If it is the staff's judgment that the applicant's investigations or testing are inappropriate or insufficient, additional investigations likely will be required. The final conclusion is based on professional judgment, considering the complexity of the site subsurface conditions. As part of the review, the staff must ascertain, often with the help of consultants, that

state-of-the-art laboratory and field techniques and equipment are employed in determining the material properties.

2.5.4.3 - Foundation Interfaces. In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of the relationship of foundations and underlying materials is acceptable if it includes (1) a plot plan or plans showing the locations of all site explorations, such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities superimposed thereon; (2) profiles illustrating the detailed relationship of the foundations of all seismic Category I and other safety-related facilities to the subsurface materials; (3) logs of core borings and test pits; and (4) logs and maps of exploratory trenches in the application for an ESP or COL. A supplemental report providing geologic maps and photographs of the excavations for the facilities of the nuclear power plant should be provided when available.

Plot plans and profiles are reviewed by comparing the subsurface materials with the proposed locations (horizontal and vertical) of foundations and walls of all seismic Category I facilities. The profiles and plot plans are cross-checked in detail with the results of all subsurface investigations conducted at the site to ascertain that sufficient exploration has been carried out and to determine whether or not the interpretations made by the investigators are valid and the foundation design assumptions contain adequate margins of safety.

2.5.4.4 - Geophysical Surveys. In meeting the requirements of 10 CFR 100.23, the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical investigations have been performed at the site and the results obtained there from are presented in detail. Completeness of the presentation is judged by whether or not the accuracy and resolution of the exploratory techniques used by the applicant is adequately justified, whether the techniques represent state-of-the-art exploration methods, and whether the applicant's interpretations are supported by adequate field records in the applicant’s technical submittal. Multiple measurements of dynamic properties should be incorporated to capture uncertainty in the primary parameters controlling site response behavior. See also Subsection 2.5.2.3.

Staff evaluation consists of a detailed review of all geophysical explorations conducted at the site, including seismic refraction, reflection, and in-hole surveys and magnetic and gravity surveys. Logs of core borings, trenches, and test pits are reviewed and compared with data from the seismic surveys and other geophysical techniques. Results must be consistent or additional investigations are required. Variability and/or inconsistency in the results must be addressed, and an acceptable basis must be provided to support the selection of characteristic values, and conservative values should be used. The staff will visit the site to examine the walls and floors of excavations at an appropriate time after licensing to confirm conditions as mapped in the open excavations with interpretations and assumptions derived during the investigation program.

2.5.4.5 - Excavation and Backfill. In meeting the requirements of 10 CFR Part 50, the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable if:

A. The sources and quantities of backfill and borrow are identified and are shown to have been adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static); long term solubility properties and dissolution behavior during the life of the facility have been determined; and these data are included, interpreted, and summarized.

B. The extent (horizontally and vertically) of all Category I excavations, fills, and slopes are clearly shown on plot plans and profiles.

C. Compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance over the life of the plant.

D. The impact of compaction methods are incorporated into the structural design of the plant facilities.

E. Quality control methods are discussed and the quality assurance program described and referenced. If backfill is to be placed under safety-related structures, proper inspections, tests, analyses and acceptance criteria (ITAAC) should be specified in the applicant's technical submittal to ensure that the static and dynamic properties of in-place backfill material will be the same as, or better than the design parameters. In case cementitious construction material is to be placed under safety-related structures, proper ITAAC should be specified in the applicant technical submittal to ensure that the cementitious backfill placed underneath any Category I structures to a thickness greater than 5 feet, meets the design, construction and testing of applicable American Concrete Institutes (ACI) standards.

F. Control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced. In addition, the long-term behavior of the backfill subjected to any aggressive groundwater characteristics is evaluated.

G. For sites where deeply embedded structures are involved, deep excavation techniques will likely utilize wall retaining systems rather than a sloped excavation of the soil. A description of the planned excavation technique(s) and design of the wall retention system with sufficient details is provided and it should be able to demonstrate that the excavation technique used will not significantly affect the surrounding soil properties that are relied upon in the analysis and design of the foundation and plant structures.

Excavations, backfill, and earthwork are evaluated by the staff as follows:

A. The investigations for borrow material, including boring and test pit logs, and compaction test data are reviewed and judged as to their adequacy.

B. Laboratory dynamic and static records of tests performed on samples compacted to the design specifications are reviewed to ascertain that state-of-the-art criteria are met. The long term properties of the backfill material should be examined including consideration of the effect of chemical properties of groundwater.

C. Analyses and interpretations are reviewed to ensure that static and dynamic stability requirements are met over the life of the plant.

D. The description of the planned excavation techniques and the design of the wall retention system are reviewed to ensure they address all of the important aspects applicable to deep excavations. These include the type of wall (e.g., soldier pile and lagging walls, diaphragm walls, secant pile walls, soil nail walls), rock excavation methods if applicable (e.g., ripping, drilling, blasting), water control methods (e.g., rain, erosion, groundwater, dewatering), design of the particular wall being used (e.g., wall structure design for the various loads, and external wall stability for soil failure and overall wall stability), and displacement monitoring of the wall/adjacent ground including the use of instrumentation.

E. Excavation and compaction specifications and quality control procedures are reviewed to ascertain conformance to applicable standards.

2.5.4.6 - Ground Water Conditions. In meeting the requirements of 10 CFR Parts 50 and 100, the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections in Section 2.4 of the applicant's technical submittal:

A. Discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant.

B. Plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures. This includes consideration of the potential for substantial head and volume of water due to the deep excavation for the plant structures.

C. Analysis and interpretation of seepage and potential piping conditions during construction.

D. Records of field and laboratory permeability tests as well as dewatering induced settlements.

E. History of groundwater fluctuations as determined by periodic monitoring of an adequate number of local wells and piezometers. Flood conditions should also be considered.

F. Evaluation of chemical properties of the groundwater that may impact long-term behavior of the rock/soil/fill materials as well as structural elements (concrete and steel materials).

Groundwater conditions as they affect foundation stability are evaluated by studying the applicant's records of the historic fluctuations of groundwater at the site as obtained by monitoring local wells and springs and by analysis of piezometer and permeability data from tests conducted at the site. The applicant's dewatering plans during and following construction are also reviewed. Adequacy of these plans is evaluated by comparing with the results of the groundwater investigations and by professional judgment of

groundwater and soil conditions at the site. The impacts of these dewatering plans on temporary and permanent structures are evaluated.

2.5.4.7 - Response of Soil and Rock to Dynamic Loading. In meeting the requirements of 10 CFR Parts 50 and 100, descriptions of the response of soil and rock to dynamic loading are acceptable if:

A. An investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks at the site. Evidence of liquefaction and sand cone formation should be included.

B. Field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P and S wave velocity profiles.

C. Dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus-reduction and hysterietic damping properties of the soils and the results included. If generic soil degradation properties are used in the related preliminary analyses (e.g., site seismic response and soil structure interaction analyses), then reconciliation of the generic properties and laboratory testing results should be performed. The section should be cross-referenced with Subsection 2.5.2.5.

The soil-structure interaction analysis (SSI) should be described in Sections 3.7.1 and 3.7.2 and cross-referenced to this subsection.

Response of soil and rock to dynamic loading and soil-structure interaction is evaluated by a detailed study of the results of the investigations and analyses performed. Specifically, the effects of past earthquakes on site soils or rocks (a requirement in SRP Section 2.5.2) are determined. The data from core borings, from geophysical investigations, and from dynamic laboratory tests such as sonic and resonant column, torsional shear and cyclic triaxial tests on undisturbed samples are evaluated.

The object of the staff review is to ascertain that reasonably conservative dynamic soil and rock characteristic, together with their potential variability, are developed to support plant design and associated analyses and that all potentially significant soil and rock strata have been considered in developing these characteristics. In some cases, independent analyses and interpretations are carried out as outlined in SRP Section 2.5.2, or as required to verify the liquefaction analysis discussed in Subsection 2.5.4.8.

2.5.4.8 - Liquefaction Potential. In meeting the requirements of 10 CFR Parts 50 and 100, if the foundation materials at the site adjacent to and under Category I structures and facilities are saturated soils and the water table is above bedrock, then an analysis of the liquefaction potential at the site is required. The need for a detailed analysis is determined by a study on a case-by-case basis of the site stratigraphy, critical soil parameters, and the location of safety-related foundations. Undisturbed samples obtained at the site and appropriate laboratory tests are required to show if the soils are likely to liquefy.

Liquefaction potential assessments using both deterministic and probabilistic approaches are desirable. When the need for an in-depth analysis is indicated, it may

be based on cyclic triaxial test or other state-of-the-art test data obtained from undisturbed soil samples taken from the critical zones at the site. The seismic force used to determine shear stresses induced in the soil should be consistent with the ground motion determined in a manner that is consistent with SRP Section 2.5.2. The site specific GMRS (adjusted to the depth of liquefiable layer) that meets the requirements of Appendix S, 10 CFR Part 50 with respect to the peak ground acceleration, should be used to evaluate the potential for liquefaction. The criterion that should be used to determine when the soil samples tested "liquefied" should be taken as the onset of liquefaction (defined as the cycle when the pore pressure first equals the confining pressure). Test data showing the rate of pore pressure increase with number of cycles should be presented. If the behavior of the pore pressure is such that peak to peak axial strains greater than a few percent occur before liquefaction, then the applicant must include the effects of these strains in his assessment of the potential hazards that complete or partial liquefaction could have on the stability and settlement of any Category I structures.

Non-seismic liquefaction (such as that induced by erosion, floods, wind loads on structures and wave action) should be analyzed using state-of-the-art and state-of-the-practice methods.

Liquefaction potential is reviewed by a study of the results of geotechnical investigations including boring logs, laboratory classification test data and soil profiles to determine if any of the site soils could be susceptible to liquefaction. The results of in-situ tests such as the standard penetration tests and the density and strength data obtained from undisturbed samples obtained in exploration borings are examined and, when appropriate, related to the liquefaction potential of in situ soils.

If it is determined that there may be liquefaction-susceptible soils beneath the site, the applicant's site exploration methods, laboratory test program, and analyses are reviewed for adequacy and reasonableness. The analysis submitted by the applicant is reviewed in detail and compared to an independent study performed by the staff employing both deterministic and probabilistic methods as appropriate. As a minimum, the staff study consists of:

A. A review of appropriate standard penetration test results, other in-situ test data and groundwater conditions to assess liquefaction potential.

B. A careful review of conventional laboratory and cyclic triaxial test data to ensure that appropriate samples were obtained and tested from critical, liquefiable zones.

C. Confirmation that an adequate number of samples were properly tested and that the test results account for the natural variation in different samples as well as define the cyclic resistance to liquefaction of the soils.

D. An assessment of the liquefaction potential using a conservative envelope of the test data submitted.

E. A calculation of the stress induced by the earthquake that has been arrived at by an envelope of critical conditions calculated for the site based on variations in the properties of the soil strata.

F. Assurance that conservative ranges of relative density of granular soils or relative consistency of fine-grained soils are estimated. Estimates of the "safety factor" obtained from the applicant's analysis are compared to the safety margins estimated by the staff. (The applicant's plan to “eliminate” the liquefaction condition usually by excavation and backfill, vibroflotation or chemical grouting is evaluated as discussed in Subsections 2.5.4.5 and 2.5.4.12.)

G. An assessment of post-earthquake stability and settlements due to partial liquefaction using state-of-the-art techniques.

H. An assessment of nonseismic liquefaction based on state-of-the-art techniques.

2.5.4.9 - Earthquake Design Basis. In meeting the requirements of 10 CFR Part 50, the earthquake design basis analysis is acceptable if a brief summary of the derivation of the site-specific GMRS is presented and references are included to Subsection 2.5.2.6. The staff's evaluation of the amplification characteristics of specific soils and rocks beneath the site as determined by procedures discussed in SRP Subsections 2.5.2.6, 2.5.4.2, 2.5.4.4, and 2.5.4.7 are summarized and cross-referenced herein. The review of SRP Subsection 2.5.4.9 concentrates on determining its consistency or inconsistency with other subsections. Cross-referencing with other sections is expected.

2.5.4.10 - Static and Dynamic Stability. In meeting the requirements of 10 CFR Parts 50 and 100, the discussions of static and dynamic analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static and dynamic stability standpoint including bearing capacity, rebound, settlement, and differential settlements under dead loads of fills and plant facilities, dynamic loads including “live” and seismic loads with consideration of loading sequences and combinations. The bearing capacity estimates must include consideration of settlements associated with the strength estimates. A discussion and evaluation of lateral earth pressures with consideration of surcharges from adjacent structures and construction equipments, and hydrostatic/dynamic ground water loads acting on plant facilities should be included. Field and laboratory test procedures and results must be included to document soil and rock properties used in the analyses. The applicant must show that the methods of analysis used are appropriate for the local soil conditions and the function of the facility.

Static and dynamic analyses of the bearing capacity and settlement of the supporting soils under the loads of fills, embankments, and foundations, as well as the lateral earth pressure on the foundation and structures, are evaluated by state-of-the-art methods. In general, the evaluation procedure includes:

A. Determining whether or not the soil and rock properties used in the analyses represent the actual site conditions beneath the planned locations of plant facilities. The site investigation, sampling, and laboratory test programs must be adequate for this evaluation.

B. Determining whether or not the methods of analysis are appropriate for the planned earthworks, foundations, and soil conditions at the site. Dynamic

properties should be distinguished from static properties, and proper input parameters should be used for static or dynamic stability analysis.

C. Determining whether or not the bearing capacity, settlement, differential settlement, and tilt estimates indicate conservative and tolerable behavior of the planned plant foundations when these values are compared to design criteria and quality assurance specifications.

D. Determining whether or not an adequate settlement monitoring program is described for deep soil sites. The settlement monitoring program should include water pressure and settlement/heave monitoring and clearly specify the instrumentation, the bench marks and interval of date collection. Proper inspections, ITAAC for settlement should be specified in the applicant's technical submittal to ensure that the actual foundation settlements during and after construction not to exceed the design specifications.

E. Evaluation of particularly complex cases on the basis of accepted principles and techniques as supplemented by case histories and confirmatory measurement and analysis programs.

2.5.4.11 - Design Criteria. In meeting the requirements of 10 CFR Part 50, the discussion of criteria and design methods is acceptable if the criteria used for the design, the design methods employed, and the factors of safety obtained in the design analyses are described and a list of references presented. An explanation and verification of the computer analyses used and source references should be included. Site exploration, sampling, testing, and interpretation are judged with respect to completeness, care and technique, meaningful documentation, performance records for similar projects, published guidelines, and state-of-the-art practice. Design safety features, the applicant's proposed confirmatory tests and measurements, and monitoring of performance for planned safety-related foundations and earthworks are reviewed and evaluated on a case-by-case basis.

2.5.4.12 - Techniques to Improve Subsurface Conditions. In meeting the requirements of 10 CFR Part 50, the discussion of techniques to improve subsurface conditions is acceptable if plans, summaries of specifications, and methods of quality control are described for all techniques to be used to improve foundation conditions (such as grouting, vibroflotation, bridging mats, dental work, rock bolting, or anchors). Planned techniques to improve subsurface conditions are evaluated by reviewing the applicant's specifications and techniques for performance and quality control for such activities as grouting, excavation and backfill, vibroflotation, rock bolting, and anchoring.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

Compliance with 10 CFR 50.55a requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected as specified by applicable codes and standards commensurate with the importance of the safety functions to be performed. Standards developed by the American Society for Testing and Materials (ASTM), American Society of Civil

Engineers (ASCE) and other reputable organizations and institutions are used to perform soil analyses and tests for determining the static and dynamic properties of the soils and rock that will underlie the plant's SSCs. To satisfy the geotechnical engineering requirements of 10 CFR Part 100, the applicant's technical submittal must contain a description of subsurface soil and rock characteristics for the proposed site, a description of the excavation techniques and design of soil retaining systems, and include static and dynamic analyses of plant foundations. This information will permit the staff to assess the acceptability of the site and to determine the potential influence of these characteristics on the design of SSCs designated as important to safety. Meeting these requirements provides assurance that plant SSCs important to safety will be designed to withstand appropriately severe static and dynamic loads on the foundations.

Compliance with GDC 1 requires that SSCs be tested in accordance with quality standards commensurate with the importance of their safety functions, that test standards be applicable and sufficient, and that appropriate records maintained. SRP Section 2.5.4 describes staff positions related to static and dynamic test and evaluation programs for soil and rock foundations of structures important to safety. This SRP section describes acceptable programs and laboratory test practices for such subsurface investigations. RGs 1.132 and 1.138 describe acceptable static and dynamic test (and/or evaluation) qualification criteria, including requirements for documentation, for soil and rock foundations at nuclear power plants. Meeting the requirements of GDC 1 provides assurance that the foundation characteristics of the proposed nuclear power plant will be accurately determined and that the design of its earthworks will meet the required quality standards.

Compliance with GDC 2 and Appendix S to 10 CFR Part 50 requires that the SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their intended safety functions. SRP Section 2.5.4 describes staff positions related to site investigations (as well as soil and rock testing and analyses) for determining soil and rock properties and characteristics needed in the analysis and design of earthworks for the proposed nuclear power plant. Analyses are performed to evaluate the responses of soil and rock embankments to seismic and dynamic loading for interaction between soils and structures as well as to determine the liquefaction potential. Stability and deformation characteristics of foundation materials under static and dynamic loadings are also determined. Meeting the requirements of GDC 2 provides assurance that structural foundations and embankments will respond as designed under static and seismic loads, thereby protecting structures and embankments important to safety against loss of integrity.

Compliance with GDC 44 requires that a system be provided to transfer heat under normal operating and accident conditions from SSCs important to safety to an ultimate heat sink. GDC 44 applies to this SRP section because the ultimate heat sink for the cooling water system consists of complex water sources, including necessary retaining structures (e.g., a pond or river with a dam) and the associated canals and conduits connecting sources of water to the nuclear power plant. The earthworks, consisting of the dams and canals, must be constructed in such a way as to ensure that the integrity of the cooling water system will be maintained and that its safety function will be accomplished. Meeting the requirements of GDC 44 provides assurance that engineered safety features will not fail to operate as designed, thereby protecting the plant against loss of core cooling.

Compliance with Appendix B to 10 CFR Part 50 requires that an applicant establish and maintain a quality assurance program. SRP Section 2.5.4 describes staff positions specifically related to the design, testing, and documentation of procedures for the qualification of

subsurface materials and earthworks important to safety. Subsection 2.5.4.5 describes guidance acceptable to the staff for providing data on excavation, backfill, and earthwork analyses. Subsection 2.5.4.12 requires that the applicant discuss techniques to improve subsurface conditions and describe the methods of quality control for all techniques to be used toward that end. Meeting the requirements of Appendix B to 10 CFR Part 50 provides assurance (a) that the static and seismic qualification of subsurface materials and earthworks important to safety will be performed in accordance with established criteria and standards, (b) that the resulting designs, tests, and records will comply with established standards, and (c) that subsurface materials and earthworks will perform as required.

Compliance with Appendix S to 10 CFR Part 50 and GDC 2 requires that nuclear power plant SSCs important to safety be designed to be able to withstand the effects of natural phenomena, such as earthquakes, without loss of capability to perform their safety functions. SRP Section 2.5.4 describes guidance acceptable to the staff for determining soil and rock engineering properties as well as the dynamic stability, including liquefaction, of the subsurface materials. Meeting the requirements of Appendix S to 10 CFR Part 50 provides assurance that the nuclear power plant will be designed to withstand anticipated seismic phenomena and that during normal operations or seismic events, the plant will pose no undue risk to the public as a result of instability, deformation, or failure of structural foundations and earthworks. Compliance with 10 CFR Part 100 requires that the Commission evaluate the suitability of proposed sites for nuclear power and test reactors. Paragraph 100.20(c) requires that physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining each site's acceptability. To satisfy the geotechnical engineering requirements of 10 CFR Part 100, the applicant's technical submittal must contain a description of the proposed site's subsurface materials and foundation characteristics. This information will permit the reviewer to assess the acceptability of the site and to determine the potential influences of these characteristics on the design of plant SSCs. Meeting this requirement provides assurance (a) that the nuclear power plant will be designed to withstand anticipated geologic, geotechnical, and seismic phenomena and (b) that, during normal operations or seismic events, the plant will pose no undue risk to the public as a result of instability, deformation, or failure of structural foundations and earthworks.

Compliance with 10 CFR 100.23 requires that the geologic and seismic conditions at the proposed site be considered during the siting and design of a nuclear power plant. It describes the investigations required to the obtain geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. 10 CFR 100.23(d)(4) requires a determination of static and dynamic engineering properties of materials that underlie the site, thereby affecting (a) behavior during earthquakes and (b) transmission of earthquake-induced motions to the foundations of the plant. Guidance on geologic investigations that provide data on subsurface characteristics and materials properties is provided in RG 1.132. Guidance on laboratory testing of soil and rock properties is provided in RG 1.138. Guidance on procedures and criteria for assessing seismic soil liquefaction is provided in RG 1.198. Meeting these requirements provides assurance that plant SSCs will withstand the effects of seismic events, thereby minimizing the probability that a failure would initiate an accident or exacerbate the consequences of an accident.

III. REVIEW PROCEDURES

The procedures outlined below are used to review CP applications, ESP applications, DC applications and COL applications that do not reference an ESP to determine whether data and

analyses for the proposed site meet the acceptance criteria given in Subsection II of this SRP section. For reviews of OL applications, these procedures are used to verify that the data and analyses remain valid and that the facility's design specifications are consistent with these data. As applicable, reviews of OLs and COLs include a determination on whether the content of technical specifications related to the stability of subsurface materials and foundations is acceptable and whether the technical specifications reflect consideration of any identified unique conditions. DC applications do not contain site specific characteristics; however, site parameters postulated for the design need to be reviewed using the procedures described below.

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

General Review Procedures

The review process is conducted in a similar manner and concurrent with that described in SRP Section 2.5.1. The services of consultants are used on selected sites to aid the staff in evaluating the geotechnical engineering aspects of particular sites.

The results of site investigations (such as borings, geologic maps, logs of trenches and pits, permeability test records, results of seismic investigations, laboratory test results, profiles, and plot plans) are evaluated and cross-checked in detail to determine whether or not the assumptions used in the applicant's evaluation are conservative. The design criteria are reviewed to ascertain that they reflect state-of-the-art and state-of-the-practice. For those facilities that have complex subsurface conditions, where marginal safety has been achieved, or where the applicant proposes to construct a seismic Category I earth or rockfill dam, an independent analysis of the design is performed by the staff or its advisors.

To ensure that the safety implications of any new geologic information are reviewed, as described in SRP Sections 2.5.1 and 2.5.3, the staff proposes a geologic mapping license condition in the SER for each COL site where plant excavation and geologic mapping have not been completed prior to a license being granted.

Review Procedures Specific to 10 CFR Part 52 Application Type

1. Early Site Permit Reviews

   Subpart A to 10 CFR Part 52 specifies the requirements and procedures applicable to the Commission's review of an ESP application for approval of a proposed site. Information required in an ESP application includes a description of the site characteristics and design parameters of the proposed site. However, the specific locations of major structures are generally not known at the ESP stage and, therefore, some subsections within SRP Chapter Section 2.5.4 may not be complete. The subsections within SRP Section 2.5.4 that are not complete in the ESP application will be reviewed in detail as part of the COL or CP review.

   In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design

parameters, or terms and conditions on the ESP at the COL stage. Accordingly, the reviewer should ensure that all physical attributes of the site that could affect the design basis of SSCs important to safety are reflected in the site characteristics, design parameters, or terms and conditions of the ESP.

2. Standard Design Certification Reviews

DC applications do not contain general descriptions of site characteristics because this information is site-specific and will be addressed by the COL applicant. However, pursuant to 10 CFR 52.47(a)(1), a DC applicant must provide site parameters postulated for the design. The reviewer verifies that:

A. The postulated site parameters are representative of a reasonable number of sites that have been or may be considered for a COL application;

B. The appropriate site parameters are included as Tier 1 information. This convention has been used by previous DC applicants. Additional guidance on site parameters is provided in SRP Section 2.0;

C. Pertinent parameters are stated in a site parameters summary table; and

D. The applicant has provided a basis for each of the site parameters.

3. Combined License Reviews

For a COL application referencing a certified standard design, NRC staff reviews that application to ensure sufficient information was presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. Should the actual site characteristics not fall within the certified standard design site parameters, the COL applicant will need to demonstrate by some other means that the proposed facility is acceptable at the proposed site. This might be done by re-analyzing or redesigning the proposed facility.

For a COL application referencing an ESP, NRC staff reviews the application to ensure the applicant provided sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP as applicable to this SRP section. In accordance with 10 CFR 52.79(b)(2), should the design of the facility not fall within the site characteristics and design parameters, the application shall include a request for a variance from the ESP that complies with the requirements of 10 CFR 52.39 and 10 CFR 52.93.

In addition, long-term environmental changes and changes to the region resulting from human or natural causes may have introduced changes to the site characteristics that could be relevant to the design basis. In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Consequently, a COL application referencing an ESP need not include a reinvestigation of the site characteristics that have previously been accepted in the referenced ESP. However, in accordance with 10 CFR 52.6, “Completeness and Accuracy of Information,” the applicant or licensee is responsible for identifying changes

of which it is aware, that would satisfy the criteria specified in 10 CFR 52.39. Information provided by the applicant in accordance with 10 CFR 52.6(b) will be addressed by the staff during the review of a COL application referencing an ESP or a DC.

For a COL application referencing either an ESP or DC or both, the staff should review the corresponding sections of the ESP and DC Final Safety Evaluation Report (FSER) to ensure that any ESP conditions, restrictions to the DC, or COL action items identified in the FSERs, in addition to the COL information items specified in the referenced DC, are appropriately handled in the COL application.

For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the FSAR meets the acceptance criteria. DCs have referred to the FSAR as the DCD. The reviewer should also consider the appropriateness of specified COL information items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added as COL information items to the DC FSAR.

IV. EVALUATION FINDINGS

The review should document the staff's evaluation of site characteristics with respect to the relevant regulatory criteria. The evaluation should support the staff's conclusions as to whether the regulations are met. The reviewer should state what was done to evaluate the applicant's technical submittal. The staff's evaluation includes verification that the applicant followed applicable regulatory guidance, performance of independent calculations, and/or confirmation of appropriate assumptions. The reviewer may state that certain information provided by the applicant was not considered essential to the staff's review and was not reviewed by the staff. While the reviewer might summarize or quote the information offered by the applicant in support of its application, the reviewer should clearly articulate the bases for the staff's conclusions. The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. Early Site Permit Reviews

The following statements should be preceded by a summary of the site characteristics and design parameters to be included in any ESP that might be issued for the ESP site: As set forth above, the applicant has presented and substantiated information to establish the engineering properties as well as the static and dynamic stability of the subsurface soil and rock. In addition, the applicant has used the latest field and laboratory methods in accordance with RGs 1.132, 1.138, and 1.198, to determine these properties. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has established site characteristics and design parameters acceptable to meet the applicable requirements of 10 CFR 52.17, 10 CFR 100.23, and Appendix S of 10 CFR Part 50. In Subsections 2.5.4.3, 2.5.4.5, 2.5.4.6, 2.5.4.7, 2.5.4.9, 2.5.4.10, 2.5.4.11, and 2.5.4.12 the applicant did not provide sufficient information for the staff to complete its review. Each of these subsections deals with information related to building location and design, which is not available at the ESP stage, and will need to be completed as part of any COL or CP application.

1. Design Certification Reviews

The following statement should be preceded by a list of the applicable site parameters used for the plant:

The applicant has provided the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information), and the staff agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. The stability of subsurface materials and foundations is site-specific and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the values of the actual site characteristics specified in a COL or CP application.

2. Construction Permit, Operating License, and Combined License Reviews

The following statements should be preceded by a summary of the site characteristics and parameters used for the plant:

As set forth above, the applicant has presented and substantiated information to establish the geotechnical engineering aspects of the plant site. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has performed sufficient investigations at the site to justify the soil and rock characteristics used in the design, and that the design analyses contain adequate margins of safety for construction and operation of the nuclear power plant and meets the requirements of 10 CFR Part 50, Appendix A (GDCs 1, 2 and 44); Appendices B and S of 10 CFR Part 50; and 10 CFR 100.23.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL information items relevant to this SRP section.

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations. If the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the applicant must demonstrate the acceptability of its alternate method.

VI. REFERENCES

1. 10 CFR 50.55a, "Codes and Standards."

2. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

3. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

4. 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."

5. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

6. 10 CFR Part 52.

7. 10 CFR Part 100, "Reactor Site Criteria."

8. ASCE, “Bearing Capacity of Soils,” Technical Engineering and Design Guide, American Society of Civil Engineers, 1994.

9. ASCE, “Settlement Analysis,” Technical Engineering and Design Guide, American Society of Civil Engineers, 1994.

10. ASTM Standards, American Society for Testing and Materials.

11. Engineering Manual EM 1110-1-1906, "Engineering and Design Soil Sampling," U.S. Army Corps of Engineers, September 1996.

12. Engineering Manual EM 1110-2-1908, "Engineering and Design Instrumentation of Embankment Dams and Levees” U.S. Army Corps of Engineers, June 1995.

13. Engineering Manual EM 1110-2-1906, "Laboratory Soils Testing," U.S. Army Corps of Engineers, August 1986

14. Geotechnique, The Institution of Civil Engineers, London

15. Journal of the Geotechnical and Geoenvironmental Engineering Division, Proceedings of the American Society of Civil Engineers.

16. R.E. Hunt, “Geotechnical Engineering Investigation Handbook,” CRC Press, Taylor and Francis Group, Boca Raton FL, 2005.

17. RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

18. RG 1.28, "Quality Assurance Program Requirements (Design and Construction)," U.S. Nuclear Regulatory Commission, Washington, DC.

19. RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

20. RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

21. RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," U.S. Nuclear Regulatory Commission, Washington, DC.

22. RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” U.S. Nuclear Regulatory Commission, Washington, DC.

23. RG 1.208, “A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion,” U.S. Nuclear Regulatory Commission, Washington, DC.

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, and were approved by the Office of Management and Budget, approval numbers 3150-0011, 3150-0151, and 3150-0093.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

SRP Section 2.5.4
Description of Changes

Section 2.5.4 "Stability of Subsurface Materials and Foundations"

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 4, dated May 2010 of this SRP. See ADAMS Accession No. ML100610449. Changes include considerations in areas related to geotechnical engineering and foundation stability analysis based on lessons learned from past Section 2.5.4 reviews and newer reactor design.

The following changes were made throughout the sections:

1. Updated text and references to include Regulatory Guide 1.208.

2. Updated text with editorial and clarifying statements.

I. AREAS OF REVIEW

1. Updated text to include the evaluation of foundation stability monitoring programs.

2. Updated text to include the review interface between organization responsible for quality assurance and the technical staff.

3. Updated text to include the review interface between SRP Chapter 19 and SRP Section 2.5.4 for seismic risk evaluation.

II ACCEPTANCE CRITERIA

1. Updated text to include Regulatory Guide 1.208 as an acceptance criterion.

2. Updated text to provide clarification on number of measurements to determine parameters that represent the field conditions.

2. Updated text to include guidance on deeply embedded foundations and excavation.

3. Updated text to include the specification of an ITAAC when backfill is to be placed under safety related structures.

4. Updated text to include the long- term behavior of the backfill subjected to aggressive groundwater.

3. Updated text to include settlement monitoring program and settlement ITAAC for deep soil sites.

4. Updated text to provide clarification on the site specific GMRS to be used in the potential for liquefaction evaluation.

8. Updated text to provide clarification on static and dynamic stability.

III REVIEW PROCEDURES

Updated text with editorial and clarifying statements.

IV. REFERENCES

Added Regulatory Guide 1.208, “A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion.”