U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

2.5.3 SURFACE DEFORMATION

REVIEW RESPONSIBILITIES

Primary- Organization responsible for the review of basic geologic and seismic information

Secondary- None

I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) addresses the review of site characteristics that could affect the siting and safe design of the plant. U.S. Nuclear Regulatory Commission (NRC) staff reviews information presented by the applicant for an early site permit (ESP), a combined license (COL), an operating license (OL) or construction permit (CP) concerning the potential for tectonic and non-tectonic surface deformation. The SRP Section 2.5.3 applies to the reviews performed for each of these types of applications.

Requirements in the *Code of Federal Regulations* and guidance in NRC Regulatory Guides (RGs) specify the importance of geologic data in siting nuclear power facilities. During site characterization investigations for this section of the Final Safety Analysis Report (FSAR), the applicant collects information related to surface deformation or subsidence due to faulting,

dissolution of carbonate rock or salt, and diapirism. The primary purpose for conducting these investigations is to determine site suitability in regard to whether there is a potential for future surface deformation that may affect the design and operation of the proposed nuclear power plant. This SRP section provides criteria for the review and acceptance of the basic data-gathering process and findings and to support the staff's assessment of the completeness of this information and the final safety decision to clearly establish whether there is a potential for surface deformation.

NRC staff reviews the geologic, seismic, geophysical, and geotechnical information submitted by an applicant with respect to surface deformation (tectonic and non-tectonic) potential. The technical information derives from various investigations: work that the applicant initiates and completes for the preparation of the application and information from the published findings in peer reviewed scientific literature; information acquired from interviews with knowledgeable experts. The applicant reports this information in its application in each of three areas defined by radii of 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) around the site. The three areas correspond to, respectively, the site vicinity, site area, and site location. However, applicants need to report any significant neotectonic features found beyond these distance ranges, which have a potential to impact the site safety.

As part of the process for review of potential surface deformation issues, staff evaluates the technical information provided by the applicant, with a focus on the Quaternary Period. The Quaternary Period is defined as the geologic period that began approximately 2.6 million years ago (Ma) and continues to the present. Emphasis is placed on Quaternary-age features because evidence of surface deformation during the last approximately 2.6 million years generally indicates a potential for future surface deformation to occur.

The applicant provides geologic, seismic, geophysical, and geotechnical information in Safety Analysis Report (SAR) Section 2.5.3 addressing the following specific topics that are the basis for the assessment of the potential for tectonic and non-tectonic surface deformation at the site:

1. Geologic, Seismic, and Geophysical Investigations. The reviewer assesses information provided by an applicant related to Quaternary tectonics, structural geology, stratigraphy, paleoseismology, geochronological methods used for age dating, and the geologic history of the site vicinity, area, and location. Staff reviews to ensure that the information is complete; acceptably considers other studies carried out in the same areas; and is supported by detailed investigations conducted by the applicant. For coastal and inland sites near large bodies of water, similar detailed investigations are to be conducted by the applicant for onshore and offshore geology and seismology. The applicant shall determine if surface deformation features are located beneath bodies of water and need to be considered in the assessment.

2. Geologic Evidence for Surface Deformation. The reviewer assesses information provided by an applicant for the site vicinity, area, and location to confirm presence or absence of surface tectonic (i.e., faults) and non-tectonic (e.g., growth faults; subsidence and collapse due to dissolution of limestone, salt or gypsum deposits, or salt diapirism) deformation.

3. Timing of Deformation. If deformation features are present in the site vicinity, area, or location, the reviewer evaluates the information used to constrain the age of the most recent deformation event, and, if applicable, the ages of preceding events. The reviewer

determines whether the timing of deformation has been acceptably demonstrated, or estimated, by the applicant's information. Further, the reviewer assesses the sensitivity and resolution of the investigative methods applied by the applicant for acquiring the information.

4. Correlation of Earthquakes with Tectonic Features. The reviewer evaluates information on all historically-reported earthquakes within the site vicinity in regard to hypocenter location accuracy and origin of source. The reviewer evaluates the proposed correlations between earthquake hypocenter locations and tectonic features in the site vicinity, to determine if these features have evidence of historical activity.

5. Relationship of Geologic features in the Site Vicinity to Regional Geologic Features. The reviewer examines information presented by an applicant on relationships between faults or other deformation features in the site vicinity to the regional framework to determine that interrelationships are adequately described in regard to potential for inducing future surface deformation at the site.

6. Potential for Surface Deformation at the Site. The reviewer evaluates the assessment provided by the applicant for potential future surface deformation at the site. The reviewer determines that sufficient geological, seismological, and geophysical information has been provided to clearly establish whether there is a potential for future surface deformation at the site. If the potential for future surface deformation exists, the reviewer evaluates the information in the application that demonstrates the potential effects of surface deformation are within the design basis of the facility.

The reviewer confirms that information provided by the applicant is documented through appropriate references to relevant published and unpublished materials. Illustrative materials provided to document site characteristics should include, but are not necessarily limited to, structural, tectonic, physiographic, topographic, geologic, gravity, and magnetic maps; geologic cross-sections showing soil horizons, stratigraphy, lithology, and structure; geologic maps of trenches and test pits; seismic reflection or refraction and other geophysical survey profiles; soil and core boring logs; geophysical borehole logs; aerial photographs; Light Detection And Ranging (LiDAR) and satellite imagery. Some sites might require maps illustrating areas of subsidence, karst or other dissolution features, mechanically weak zones of soil and rock, paleoliquefaction features, irregular weathering conditions and weathering depths, landslide potential, locations of oil and gas wells, faults, and joints. Maps should include superimposed plot plans of site facilities, site boundaries, and the relationship of all Seismic Category I facilities to subsurface geologic features. Locations of all site structures, borings, trenches, test pits, seismic reflection and refraction and other geophysical data collection profiles, and geologic cross-sections should also be included on plot plans. The geologic terminology used should conform to that found in standard references.

Applying information derived from the application, other published and unpublished scientific literature, and the reviewer's technical knowledge and professional judgment, the reviewer assesses the adequacy of geologic, seismic, geophysical, and geotechnical information cited in support of the applicant's conclusions concerning suitability of the proposed site. Depending on completeness of the application, staff also might need to conduct a literature review at an appropriate level of detail. However, the application and its supporting information should enable staff to logically progress from data and assumptions to conclusions drawn without the need for an extensive independent literature review. Staff should evaluate that an applicant has

provided all pertinent data, including information that may support alternative interpretations to data or conclusions formed by the applicant.

Review Interfaces

Other SRP sections interface with this section as follows:

1. SRP Section 2.0, “Site Characteristics and Site Parameters.” For COL applications referencing a DC rule, 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 Section 2.0.

2. SRP Section 2.5.1, “Geologic Characterization Information.” Review and acceptance of the applicant's basic data-gathering processes and findings that are presented in support of the geologic and seismic assessments, and completeness of this information, is performed under SRP Section 2.5.1 on “Geologic Characterization Information.” Information in SRP Section 2.5.3 on the potential for surface deformation, including characteristics of Quaternary-aged faults, should be consistent with information reviewed in SRP Section 2.5.1.

3. SRP Section 2.5.2, “Vibratory Ground Motion.” Review of historical earthquake data to determine the ground motion response spectra (GMRS) and probabilistic seismic hazard assessment (PSHA) is performed under SRP Section 2.5.2 on “Vibratory Ground Motion.” Information in SRP Section 2.5.3 on the potential for surface deformation, including characteristics of Quaternary-aged faults, should be consistent with information used in SRP Section 2.5.2. Particular attention should be given to new information that has the potential to affect seismic source-zones that were developed in prior investigations.

4. SRP Section 2.5.4, “Stability of Subsurface Materials and Foundations.” Review of information concerning properties and stability of all soils and rock that may affect plant facilities under both static and dynamic loading conditions, including vibratory ground motions associated with the GMRS, is performed under SRP Section 2.5.4 on “Stability of Subsurface Materials and Foundations.”

II. ACCEPTANCE CRITERIA

Requirements

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

1. Applicable to a COL, CP: Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion (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

1 Additional supporting information of prior DC rules may be found in DCD Tier 2 Section 14.3.

sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated.

2. Applicable to an ESP: 10 CFR 52.17(a)(1), "Contents of Application; 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.

3. Applicable to a COL: 10 CFR 52.79 (a)(iii). 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.

4. Applicable to COL, ESP, CP, OL: 10 CFR 100.23, "Geologic and Seismic Siting Criteria." Subpart (c) of 10 CFR 100.23, requires that the geologic and seismic characteristics of the site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site; provide sufficient information to support estimates of the safe-shutdown earthquake ground motion; and permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. 10 CFR 100.23(c) further specifies that all geologic and seismic factors that may affect design and operation of the proposed nuclear power plant must be investigated, irrespective of whether such factors are explicitly included in 10 CFR 100.23(c)(e.g., volcanic activity). Most importantly, 10 CFR 100.23(d)(2) requires that the geologic and seismic siting factors considered for design include a determination of the potential for surface tectonic and non-tectonic deformations. Sufficient geological, seismological and geophysical data must be provided to clearly establish whether there is a potential for surface deformation.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the 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 (RG) are used by the staff for the identified acceptance criteria:

RG 1.208, "A Performance-Based Approach to Define Site-specific Earthquake Ground Motion," describes methods acceptable for conducting geologic, geophysical, seismologic, and geotechnical investigations; and guidance on assessing surface-fault rupture and associated deformation at the site (Appendix C.2.4).

RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations," discusses the major site characteristics related to public health and safety that the reviewer considers in determining the suitability of sites for nuclear power stations.

RG 1.206, “Combined License Applications for Nuclear Power Plants - LWR Edition,” discusses guidance for COL applications for nuclear power plants (light-water reactors (LWRs)).

The reviewer should confirm that information provided in the application is complete, properly documented and consistent with applicable requirements of 10 CFR 100.23. The reviewer confirms that methods described in RG 1.208, or comparable methods, are employed for identifying and characterizing surface deformation features; and that the material conforms to format suggested in RG 1.206. For evaluating completeness and acceptability of the application, the reviewer should use published and unpublished scientific information derived from various sources that present geologic, geotechnical, seismic, geophysical, and related pertinent data for the site vicinity and site area in which the site is located. These sources include the United States Geological Survey (USGS); other Federal and State agencies; and academia, industry, and non-governmental and professional organizations.

The reviewer shall ensure that investigations described in RG 1.208, and 4.7 are conducted with an appropriate level of thoroughness for the site vicinity, area, and location. The reviewer should confirm that the results of investigations in the site vicinity, area, and location are consistent with the information used to develop tectonic and ground-motion models in the probabilistic seismic hazard analysis (PSHA) in Section 2.5.2.

1. Geologic, Seismic, and Geophysical Investigations. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi),or 10 CFR 52.79(a)(1)(iii) and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met and guidance in RG 1.208, and 4.7 followed for this area of review if discussions of Quaternary tectonics, structural geology, stratigraphy, geochronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete, compare reasonably with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant. Site vicinity, site area, and site location-specific geologic maps and cross-sections constructed at scales adequate to clearly illustrate surficial and bedrock geology, structural geology, topography, and relationship of power plant foundations and site boundaries to these features should be included in the application. For sites located near bodies of water, the application should address how investigations have been conducted to detect possible surface deformation features that might be located beneath water.

2. Geologic Evidence for Surface Deformation. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met and guidance in RG 1.208, and 4.7 followed for this area of review if the applicant provides sufficient surface and subsurface information for the site vicinity, area, and location to confirm and characterize presence or absence of surface deformation (e.g., faulting, growth faulting, subsidence or collapse related to dissolution of limestone, salt or gypsum deposits, or salt diapirism and paleoliquefaction) features. The applicant should also take into account the potential for blind faults.

3. Timing of Deformation. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met for this area of review if recognized surface deformation features (e.g., tectonic faults and non-tectonic features including growth faults) and features associated with a blind fault, are investigated in sufficient detail to constrain the age of the most recent surface deformation event, and, if applicable, the ages of preceding deformation events. The application shall also provide an acceptable evaluation of sensitivity and resolution of the exploratory geologic and geophysical techniques used to determine whether or not appropriate techniques were applied to assess the age of the most recent displacement.

4. Correlation of Earthquakes with Tectonic Features. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi or 10 CFR 52.79(a)(1)(iii)), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met for this area of review if the applicant evaluates all reported historical earthquakes within the site vicinity with respect to accuracy of hypocenter location and source of origin, and with respect to correlation to tectonic features. The applicant shall evaluate the potential for historical activity on tectonic features in the site vicinity. The application should include a plot of earthquake epicenters superimposed on a map showing tectonic features in the site vicinity.

5. Relationship of Geologic Features in the Site Vicinity to Regional Geologic Features. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are satisfied for this area of review if the applicant evaluates the relationships between faults or other deformation features in the site vicinity and the regional framework. The application should provide an acceptable evaluation of the relationships between the regional (tectonic and non-tectonic) framework and deformation features in the site vicinity, including growths faults and growth fault systems. The applicant should show how this information is used in the evaluation of potential for future surface deformation at the site.

6. Potential for Surface Deformation at the Site. To meet requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), for this area of review, the applicant shall assess the potential future tectonic and nontectonic surface deformation at the site. The applicant should provide sufficient geological, seismological, and geophysical information to clearly establish whether there is a potential for future surface deformation at the site. If the potential for future surface deformation exists at the site, the application must provide information that demonstrates the potential effects of surface deformation are within the design basis of the proposed facility.

   It is important to note that no commercial nuclear power plant has ever been constructed on a tectonic feature with the potential for future surface deformation. NRC regulations do not restrict building in an area with surface faulting potential, but if that potential exists, the regulations require that surface deformation must be taken into account in the design and operation of the proposed nuclear power plant. It is questionable whether it might be feasible to design for surface deformation with any degree of confidence that safety-related structures, systems, and components would maintain their safety functions if surface displacements occur in the future. New designs under review do not consider fault related surface deformation beneath proposed sites.

Consequently, it is NRC policy (e.g., RG 1.208) to recommend that any site located on a surface or near-surface feature with a potential for future displacement be re-located to an alternate site

Technical Rationale

The technical rationale for application of these acceptance criteria to the area of review addressed by this SRP section is as follows:

Application of GDC 2 or 10 CFR 52.17(a)(1)(vi) for ESP applications, 10 CFR 52.79 for COLs and 10 CFR 100.23 provides assurance that all geologic and seismic factors that might affect the design and operation of the proposed facility have been identified and adequately investigated and characterized.

Application of 10 CFR 100.23(c) requires that the geologic and seismic characteristics of the site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site; provide sufficient information to support estimates of the SSE ground motion; and permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. Further, 10 CFR 100.23(c) specifies that all geologic and seismic factors that might affect design and operation of the proposed nuclear power plant must be investigated.

Application of 10 CFR 100.23(d)(2) requires that the geologic and seismic siting factors considered for design include a determination of the potential for surface tectonic and non-tectonic deformations.

III. REVIEW PROCEDURES

The procedures outlined below are used to review ESP and COL applications that do not reference an ESP to determine whether geologic and seismic information for the proposed site meets the Subsection II “Acceptance Criteria” of this SRP. As applicable, reviews of COLs include a determination on whether the content of technical specifications related to continued seismic surveillance is acceptable and whether the technical specifications reflect consideration of any unique geologic and seismic conditions that are identified.

For deviations from 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, “Acceptance Criteria.”

Procedures for staff review provide a process to determine that an applicant has adequately performed investigations appropriate for fulfilling applicable requirements of 10 CFR 100.23(c) and 10 CFR 100.23(d)(2). Based on 10 CFR 100.23(d)(2), applicant is required to provide an assessment of the potential for surface deformation at the site related to both tectonic and non-tectonic phenomena. General guidelines an applicant may follow to determine presence and extent of surface deformation features in the site vicinity, area or location are found in Appendix C.2.4 of RG 1.208.

Review Process

During the regulatory review process, the reviewer follows specific regulatory requirements promulgated in the *Code of Federal Regulations*, the regulatory guidelines and the acceptance criteria in this SRP. The review process, with staff's responsibilities described within each step, is applied for CP, OL, ESP or COL applications.

1. Acceptance Review

The acceptance review is a brief, high level review of the application to evaluate its completeness and identify safety issues that could cause delay in subsequent phases of the review process. Acceptance or rejection of the application for detailed review is governed by two criteria: (1) adherence to standard format for identifying and describing characteristics and features that might indicate a potential for surface deformation which might adversely affect suitability of the site; and (2) provision of adequate information and documentation as described in the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi), 10 CFR 52.79 (a)(iii) and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), RG 1.206, and 1.208 to enable an independent staff review of conclusions presented by the applicant. By acceptable, the application is deemed acceptable for docketing.

2. Detailed Review of Application

After the application is docketed, staff conducts a thorough, detailed technical review of material submitted in the application and identifies all potential safety issues related to surface deformation. The reviewer confirms that all interpretations in the application are based on generally accepted geologic practice and are supported by appropriate data and models. The reviewer confirms that alternative data sets, if available, are appropriately considered in development of the applicant's assessment and conclusions. The reviewer also considers any significant new information derived from site-specific geologic, seismic, geophysical, and geotechnical investigations that have not been considered or applied to tectonic and ground motion models used in the PSHA (Section 2.5.2).

Literature Review

The staff proceeds with a literature search and review of relevant references (e.g., published geological reports, USGS professional papers and open-file reports, university theses, physiographic and geologic maps, and aeromagnetic and gravity maps) to acquire additional information on geology and seismology at the site vicinity, area and location with respect to surface deformation potential. However, as publication of data and results commonly lags behind completion of research projects a reviewer does not rely entirely on information submitted by the applicant or in published literature. The reviewer identifies studies underway in the site region and obtains information on preliminary results of these studies. Special provisions might be required to examine proprietary data. The reviewer gives particular attention to models or data that have the potential to introduce alternative interpretations to the models or data in the application that might affect conclusions for safety or suitability of the site.

Development of Requests for Additional Information

During the detailed technical review, staff develops requests for additional information (RAI) related to issues considered to be inadequately addressed in the application and that might affect conclusions for safety or suitability of the site. If insufficient data are provided in the application to support interpretations and conclusions presented, the staff will request the applicant to provide additional clarifying information. Questions might arise from discovery of references not cited by the applicant that suggest alternative interpretations to the information and interpretations provided by the applicant. The RAIs might indicate the need to conduct additional investigations. The detailed review schedule will commonly include public meetings with the applicant to ask clarifying questions and allow the applicant to present new data or other information to justify conclusions in the application. Staff reviews the applicant's responses to questions and remaining issues may be resolved by supplemental RAIs, public meetings or by staff positions. A staff position is usually in the form of a requirement for the applicant to provide confirmatory information or to design for a specific condition in a manner deemed to be adequate and consistent with requirements of 10 CFR 100.23.

Site Audit and Confirmatory Activities

Staff will conduct a site audit to examine geologic features revealed by outcrops, trenches, test pits, surface and subsurface geophysical tests, and borehole data. For Section 2.5.3, staff will focus on geologic features within the site vicinity, area and location that may indicate surface deformation. Staff prepares a site audit report to document what staff did at the site and to aid in the development of the staff's Safety Evaluation Report (SER). The report is subsequently submitted to Agencywide Documents Access and Management System (ADAMS) and retained as a record.

As part of confirmatory activities for the site audit review, staff might conduct an independent geologic reconnaissance of the site vicinity and area as necessary to examine soil and rock samples from core borings and test pits and geologic features in trenches and excavations for other site facilities.

3. Review of Supplemental Information

The Phase 3 review is the final phase for resolving all open safety-related issues, an activity commonly associated with staff review of the applicant's responses to RAIs.

4. Geologic Mapping License Condition

Under the COL or ESP approach defined in 10 CFR Part 52, the SER might have been written by staff and a license or permit may have been granted to the applicant before site excavations and geologic mapping of the excavations begin. Thus, new geologic features might be discovered in plant excavations, which have the potential to affect site safety. To ensure that the safety implications of new information are reviewed, clear statements must be provided in the site-specific portion of the COL application that the applicant commits to:

(1) Perform detailed geologic mapping of the excavations for safety related structures;

(2) Examine and evaluate geologic features discovered in excavations for safety-related structures; and

(3) Notify the NRC once excavations for safety-related structures are open for inspection by NRC staff.

A geologic mapping license condition will be proposed in the staff SER for each COL site where plant excavations and geologic mapping have not been completed prior to a license being granted. Likewise, a geologic mapping permit condition will be proposed in the staff SER for each ESP site. For those COL or ESP sites where plant excavations and geologic mapping take place prior to a COL or ESP being granted, staff will evaluate the plant excavations and mapping as part of the application review.

5. Procedures for Staff Evaluation of Specific Areas of Review

The staff follows procedures for review based on the six specific 'Areas of Review' defined in Subsection I to determine that an applicant has acceptably performed appropriate investigations for fulfilling applicable requirements of 10 CFR 100.23(c) and 10 CFR 100.23(d)(2). While evaluating the six Areas of Review, reviewers will note all significant new information provided by an applicant regarding seismic and tectonic information (e.g., a seismic source or new tectonic model that was not included in the site PSHA) and coordinate closely with the PSHA reviewer of Section 2.5.2 to ensure consistency for information used in the hazard analyses.

(1) Geologic, Seismic, and Geophysical Investigations. The reviewer evaluates results of the applicant's geologic, seismic, and geophysical investigations by conducting a literature review on topics that affect staff's understanding of the applicant's safety analysis. The review should allow staff to determine that conclusions presented by the applicant are based on appropriate data for this review area and are consistent with both reports published by area experts and conclusions of staff. If conclusions and interpretations presented by the applicant conflict with the available literature and staff disagree with the applicant's analysis and assumptions, the reviewer will require the applicant to submit additional information to further support the conclusions in question. For coastal and inland sites near large bodies of water, similar detailed investigations should include information regarding onshore and offshore deformation features. In some cases, it might be possible to identify onshore expression of an offshore tectonic structure (i.e., a fault or fold) of potential concern. As expressed in RG 1.208, Appendix C, under this condition it is acceptable for the applicant to investigate expression of the offshore feature in the onshore environment, along with other investigations of the offshore feature when possible, to better evaluate characteristics of the deformation feature in the site vicinity, area and location.

(2) Geologic Evidence for Surface Deformation. The reviewer evaluates that the applicant provides sufficient surface and subsurface information for the site vicinity, area, and location to confirm presence or absence of surface deformation features. This includes the reviewer conducting a literature search and comparing that body of knowledge with the applicant's data, to ensure that all evidence of surface deformation (e.g., growth faulting, subsidence or

collapse related to dissolution of limestone, salt or gypsum deposits, or salt diapirism) identified in the literature has been considered by the applicant. If evidence of surface deformation is found, additional field investigations (e.g., geologic mapping, surface and borehole geophysical investigations, borings, or trenching) shall be carried out to adequately characterize the deformation features. The distinction should be made between tectonically-induced surface deformation and non-tectonic surface deformation resulting from growth faulting or collapse due to limestone or salt dissolution or salt diapirism).

In addition to geologic evidence that might indicate deformation, topographic and geomorphic evidence should be examined and their use documented (e.g., linear features interpreted from topographic maps, low and high altitude aerial photographs, satellite imagery, LiDAR). Data to assess presence of surface deformation is obtained by an applicant from surface methods such as: imagery analysis, geologic reconnaissance and mapping and subsurface methods such as geophysical surveys at ground surface as well as in boreholes; geologic and geotechnical logging of soil materials and rock core in boreholes, and geologic mapping of trenches and test pits to define paleoseismic features and fault surfaces (including growth faults) or collapse features. The nature and extent of investigations to determine whether or not shallow subsurface deformation features exist (e.g., blind faults, folds related to blind faults, growth faults, dissolution caverns, salt diapirism) are likely to exist will vary in degree of detail and extent required based on geologic context of the specific site.

In the central and eastern United States (CEUS) region, defined in NUREG-2115, earthquake-generating faults typically do not extend to the ground surface or there is insufficient overlying Quaternary soil or rock to constrain the timing of deformation. In the Western United States, many Quaternary faults are exposed at the ground surface and might be more readily characterized with respect to surface deformation potential if appropriately aged geologic formations or units exist at the site of deformation. Tectonic deformation features (including faults related to subduction zones) can exist as blind faults that might be expressed on the surface or near-surface by actively growing folds or areas of uplift and subsidence.

(3) Timing of Deformation. The reviewer evaluates the applicant's assessment for the ages of past deformation events to determine if a sufficient technical basis has been established for the age estimates. The reviewer determines whether geochronological methods used by the applicant are based on generally acceptable procedures, such as those described in NUREG/CR-5562 or 'Paleoseismology.' In cases for which the applicant employs unusual or untested age determination techniques, staff will require documentation of the techniques including verification of the precision and accuracy of associated ages. Accuracy and precision of all age-dating techniques used in the applicant's analysis should be carefully documented and considered in the analysis of deformation potential. In general, multiple samples should be analyzed, and more than one dating method applied to each geologic element that is significant in estimating age of a paleodeformation event.

(4) Correlation of Earthquakes with Tectonic Features. The reviewer assesses how the applicant has investigated correlation of earthquakes with potential tectonic sources in conjunction with consideration of SRP Section 2.5.2. Historical earthquake data derived from review of SRP Section 2.5.2 are compared with known tectonic features in the site vicinity and a determination is made regarding whether any earthquakes can reasonably be associated with these tectonic structures. This determination includes an evaluation of the hypocentral error estimates of the earthquakes. When available, earthquake source mechanisms should be evaluated with respect to fault type (reverse, normal, strike-slip) and characteristics such as orientation and slip history. The applicant shall evaluate the relationship of fault parameters to earthquake magnitude. This type of assessment will likely provide insights on the potential for future surface displacements. In addition, small earthquakes correlated to growth fault movements or fluid injection or withdrawal should be considered in appropriate areas to discern between tectonic activity and man induced events or to determine potential future movements on growth fault systems.

(5) Relationship of Geological Features in the Site Vicinity to Regional Geological Features. The reviewer evaluates relationships of tectonic structures in the site vicinity with regional tectonic structures by using a literature review to determine that the applicant's evaluation of the regional tectonic framework is reasonable. The reviewer confirms that conclusions reached by the applicant are based on acceptable geologic principles and have considered appropriate geologic and geophysical data. The reviewer considers the resolution accuracy of the investigation methods used by the applicant.

(6) Potential for Surface Deformation at the Site. The reviewer evaluates the information provided by the applicant to characterize past surface deformation events in the site region. The reviewer then assesses the applicant's approach for integrating this information into an assessment of the potential for future surface deformation at the site per 10 CFR 100.23 (d)(2). The assessment should distinguish between tectonic and nontectonic surface deformation. If the potential for future surface deformation exists at the site, information in the application must demonstrate the potential effects of surface deformation are within the design basis of the proposed facility.

Review Considerations Specific to 10 CFR Part 52 Application Type

1. Early Site Permit Reviews

10 CFR Part 52, Subpart A 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 description of geologic, seismic, geophysical, geotechnical, and hydrologic characteristics of the proposed site. The applicant shall propose geologic site characteristics that will form a set of values for design and construction of a new plant to be built at the site.

At the COL stage and in the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 "Finality of early site permit determinations" precludes the staff from imposing new site characteristics, design parameters, or terms

and conditions on the ESP. Accordingly, the reviewer, for SRP Section 2.5.3 shall ensure that all geologic characteristics that pertain to surface deformation and that could affect the design basis of safety-related SSCs, are reflected in the site characteristics, design parameters, and terms and conditions of the ESP. Nevertheless, this requirement does not relieve the applicant or permit holder from the requirements of 10 CFR Part 52.6(b) to notify the NRC of new information having a significant implication for public health and safety or common defense and security that might be developed following issuance of an ESP.

In order to verify that no geologic features or conditions exist beneath the safety-related structures at the site that could compromise plant safety, the staff proposes a permit condition requiring an applicant to: (1) perform detailed geologic mapping of the excavations for safety related structures; (2) examine and evaluate geologic features discovered in excavations for safety-related structures; and (3) notify the NRC once excavations for safety-related structures are open for inspection by NRC staff.

2. Combined License Reviews

NRC staff reviews a COL application referencing a certified standard design to determine that sufficient information is provided to demonstrate that site characteristics fall within specified site parameters of the DC rule. Should the actual geologic site characteristics not fall within the certified standard design site parameters; the COL applicant will demonstrate by some other means that the proposed site is suitable for the proposed facility.

In order to verify that no geologic features or conditions exist beneath the safety-related structures at the site that could compromise plant safety, the staff proposes a license condition requiring an applicant to: (1) perform detailed geologic mapping of the excavations for safety related structures; (2) examine and evaluate geologic features discovered in excavations for safety-related structures; and (3) notify the NRC once excavations for safety-related structures are open for inspection by NRC staff.

NRC staff reviews a COL application referencing an ESP to determine that sufficient information is provided 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), if the design parameters of the facility do not fall within the site characteristics, 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 the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 “Finality of early site permit determinations” 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 re-investigation of the site characteristics that have previously been accepted in the referenced ESP. However, long-term environmental changes and changes to the region resulting from human activities or natural causes might introduce changes to the site characteristics that are relevant to the design basis. Therefore, 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 are appropriately handled in the COL application. Per 10 CFR 52.47(a)(1), a DC will provide site parameters postulated for the design. For a COL application referencing a DC, the reviewer verifies that the applicant has provided a basis for each of site parameter as stated in the DC site parameters summary table.

IV. EVALUATION FINDINGS

The review should document the staff's evaluation of geologic and seismic 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 safety analysis report. The staff's evaluation might include verification that the applicant followed applicable regulatory guidance, performance of independent calculations, and/or confirmation of appropriate assumptions. The reviewer might state that certain information provided by the applicant was not considered significant to staff's understanding of safety and, consequently, was not reviewed in detail. Although 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.

1. Early Site Permit Reviews

A typical staff finding at the conclusion of the review can be illustrated as follows:

The staff has considered information provided by the applicant in support of the license application about the determination of the potential for surface tectonic and non-tectonic deformation at the site and site suitability. The information reviewed includes data from the site vicinity, area, and location related to geoscience investigations; geologic reconnaissance for the site vicinity; the staff's independent review of published literature; and discussions with knowledgeable geoscientists with the USGS, State Geological Surveys, local universities, consulting firms, or other non-governmental and professional organizations.

As a result of this review, staff concludes that geologic, seismic, geophysical, and geotechnical investigations and information provided by the applicant in accordance with 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d)(2) provide an adequate basis to establish the potential for future surface deformation to occur at the site, which could affect the design and operation of the proposed facility.

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

If staff completes review of geologic and seismic aspects of the site related to potential for surface deformation and confirms that the applicant has met all applicable requirements (i.e., appropriate portions of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.79(a)(iii), 10 CFR 100.23(c), and 10 CFR 100.23(d)(2)) and guidelines (i.e.,

RG 1.208, 4.7, and 1.206), the conclusion in the SER should state that investigations and analyses performed and information provided support the applicant's conclusions regarding suitability of the proposed nuclear power plant site in relation to potential for future surface deformation. Licensing conditions established by staff to resolve any significant deficiency identified in the application should be stated in sufficient detail to make clear the precise nature of the concerns and the required resolution. The application is also reviewed for any potentially significant new information derived geologic, seismic, geophysical, and geotechnical investigations in the site region that had not been previously applied to tectonic and ground motion models used in the PSHA, and that information has been identified to reviewers in SRP Section 2.5.2.

For COL applications that do not reference a previous ESP, staff evaluation findings will include the evaluation findings identified above for ESP reviews. For a COL referencing a previous ESP, staff should refer to the pervious ESP and include an evaluation of any new pertinent information that might have been discovered after the ESP was issued that affects the design and operability of the proposed facility. For a CP application, findings will be similar to the ESP findings. For an OL application, findings will include evaluation of excavations for safety related structures.

A typical staff finding at the conclusion of the review can be illustrated as follows:

Information reviewed for the proposed nuclear power plant concerning potential for surface deformation is summarized in SER Section 2.5.3. Staff concludes that the site has been adequately evaluated for the potential for future surface deformation that may affect the design and operation of the proposed facility and meets requirements of 10 CFR Part 50, Appendix A, GDC 2; 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d)(2). This conclusion is based on the applicant having met the requirements and guidelines of:

1. GDC 2 (Design Bases for Protection against Natural Phenomena) of Appendix A (General Design Criteria for Nuclear Power Plants) to 10 CFR Part 50 (Domestic Licensing of Production and Utilization Facilities) with respect to protection against natural phenomena such as faulting and resultant vibratory ground motion.

2. 10 CFR 100.23(c) ("Geological, seismological, and engineering characteristics") with respect to the adequate evaluation of geological, seismological, and engineering characteristics of a site and its environs as affecting tectonic and nontectonic deformation of the site. In complying with this regulation, the applicant also meets applicable guidance in RG 1.208 (A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion); RG 4.7 (General Site Suitability Criteria for Nuclear Power Plants); and RG 1.206 (Combined License Applications for Nuclear Power Plants - LWR Edition).

3. 10 CFR 100.23(d)(2) ("Geologic and Seismic Siting Factors") with respect to determination of the potential for surface tectonic and nontectonic deformations.

In order to verify that no geologic features or conditions exist beneath the safety-related structures at the site that could affect the design and operation of the facility, the staff proposes a license condition requiring an applicant to: (1) perform detailed geologic mapping of the excavations for safety related structures; (2) examine and evaluate

geologic features discovered in excavation for safety-related structures; and (3) notify the NRC once excavations for safety-related structures are open for inspection by NRC staff.

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

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC, COL, or ESP applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein, to evaluate conformances 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 Part 52.

2. 10 CFR 100.23, "Geologic and Seismic Siting Criteria," in 10 CFR Part 100, "Reactor Site Criteria."

3. Divisions of Geologic Time-Major Chronostartigraphic and Geochronologic Units, U.S. Department of the Interior, US Geological Survey, Fact Sheet 2010-3059, July 2010.

4. GDC 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

5. K.K.E. Neuendorf, J.P. Mehl, Jr., and J. A. Jackson, Editors, "Glossary of Geology," Fifth Edition (revised), American Geosciences Institute, Alexandria, Virginia, 2011.

6. McCalpin, James P., Paleoseismology, International Geophysics Series, Vol. 95, 613 pp, 2nd edition, Elsevier, 2009.

7. RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion," U.S. Nuclear Regulatory Commission, Washington, DC.

8. RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations," U.S. Nuclear Regulatory Commission, Washington, DC.

9. RG 1.206, "Combined License Applications for Nuclear Power Plants - LWR Edition," U.S. Nuclear Regulatory Commission, DC.

10. Sowers, J.M., et al, "Dating and Earthquakes - Review of Quaternary Geochronology and its Application to Paleoseismology," U.S. Nuclear Regulatory Commission, Washington, DC, NUREG/CR-5562, 1998.

11. Technical Report: “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities,” EPRI, Palo Alto, CA, U.S. Department of Energy, and U.S. Nuclear Regulatory Commission, Washington, DC, NUREG-2115, 2012.

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 2.5.3
Description of Changes

Section 2.5.3 "Surface Deformation"

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 4, March 2007, of this SRP. See ADAMS Accession No. ML070730597. Changes include focus on the determination of the potential for surface tectonic and nontectonic deformations and on the sufficiency of geological, seismological and geophysical data to make that determination. The technical changes incorporated in Revision 5, dated May 2013, include the following:

In general and throughout; updated text with editorial and clarifying statements and changed the title of the SRP as shown above.

Otherwise:

I. AREAS OF REVIEW

a. Clarified the link to 10 CFR 100.23(c) and removed Appendix A language

b. Clarified review interfaces especially with respect to SRP Sections 2.5.2 and 2.5.4

c. Clarified the emphasis on Quaternary aged features

d. Removed outdated EPRI references

e. Removed review of PSHA assessment, inserted direct link to SRP Section 2.5.2

II. ACCEPTANCE CRITERIA

a. Enhanced and clarified the link to 10 CFR 100.23 (c), 10 CFR 52.17 and 10 CFR 52.79

b. Removed references to RG 1.132, 1.138, 1.165, 1.198

III. REVIEW PROCEDURES

a. Modified the review process based on lessons learned from recent reviews

b. Added information regarding Site Safety Audits and RAI development based on lessons learned from recent reviews

c. Added specific detail concerning the Geologic Mapping License Condition

IV. EVALUATION FINDINGS

Clarified and updated findings based on applicable regulations (100.23(d)(2), 100.23(c), 10 CFR 52.17, 10 CFR 52.79 and GDC 2.

V. IMPLEMENTATION

Clarified and updated text according to recommendation by DARR

VI. REFERENCES

a. Removed the following references:

i. RG. 1.165
ii. RG. 1.132
iii. RG. 1.138
iv. RG. 1.198
v. UCRL-ID-115111
vi. NUREG-1488
vii. NP-4726A
viii. EPRI Report TR-102293

b. Added the following documents:

NUREG-2115

c. Updated the following references:

Geologic Time Scale, US Geological Survey, Fact Sheet 2010-3059
Glossary of Geology