U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

2.4.9 CHANNEL MIGRATION OR DIVERSION

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of issues related to hydrology

Secondary - None.

I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) discusses the site characteristics that could affect the safe design and siting of a nuclear power plant. The staff reviews information presented by the applicant for a construction permit (CP), operating license (OL), design certification (DC), early site permit (ESP), or combined license (COL) concerning the hydrological setting of the site as they relate to structures, systems, and components (SSCs) important to safety. This SRP section applies to reviews performed for each of these types of applications. The staff's review and findings are described in the appropriate section of the safety evaluation report (SER).

In this section the site characteristic flood elevation is evaluated by staff taking into account the potential flooding effects due to the migration or diversion of some type of channel of flowing

water, such as a stream or river, to ensure that SSCs important to safety can perform their intended safety functions. As used in this SRP, "channel migration" generally refers to the geomorphological process where a natural river channel laterally migrates across its floodplain. By contrast, "channel diversion" is the process in which the position of a natural river channel has been altered or diverted artificially by man. That safety function includes ensuring that the plant and its safety-related water supply systems will not be adversely affected by this particular flood-causing mechanism.

General Design Criterion (GDC) 2 of Appendix A ("General Design Criteria for Nuclear Power Plants") to 10 CFR Part 50 ("Domestic Licensing of Production And Utilization Facilities") requires that nuclear power plant SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their intended safety functions. The Commission's reactor siting criteria at §100.20(c)(3) also call for the estimation of the "… maximum probable flood … using historical data …." Floods (or flooding), as represented by the maximum probable flood (PMF), is thus one of the *site characteristics*[1] to be evaluated in the context of GDC 2. The key parameters in estimating the PMF at a nuclear power plant are the calculation of a water surface elevation that would occur across the footprint of the power plant site in relation to SSCs important to safety, duration of the flooding event, and associated effects. The scope of this SRP section involves the review of an applicant's estimate of the site characteristic flood at a power plant site due to channel migration or diversion.

In examining the site characteristic flood, staff's review approach should be hierarchical. The staff would first review the applicant's determination, based on geographic considerations, of whether there is the potential for channel migration or diversion at the power plant site. If this flood-causing mechanism is considered to be physically possible, then the staff would review the applicant's determination of whether channel or diversion could result in consequential flooding of the site. If consequential flooding is determined to be possible, then the staff would review the applicant's flood inundation map[2] depicting the extent and elevation of flooding across the powerblock due to the effects of channel migration or diversion. In addition to a flood inundation map, the staff would review applicant's calculation of the duration of the flooding event as well as any associated effects.[3] These three elements define the magnitude and extent of the PMF that might occur at a power plant site due to channel migration or diversion; the staff should review these elements consistent with the review criteria described elsewhere in this SRP.

If it is determined that channel migration or diversion cannot occur at the nuclear power plant site (i.e., this flood-causing mechanism is found to be inconsequential), then the staff would review the applicant's statement to that effect along with its supporting evidence against the review criteria described in Section II of this SRP.

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[1] Section 52.1(a) defines s*ite characteristics* "… as the actual physical, environmental and demographic features of a site. Site characteristics are specified in an early site permit or in a final safety analysis report for a combined license...."

[2] An inundation *map* delineates the area of some ground surface that would be flooded by a particular flooding event. In the case of a nuclear power plant, such a map would be expected to depict the water surface elevations of flood waters in relation to various features of the reactor powerblock including any SSCs important to safety.

[3] *Associated effects:* Can be defined to include those factors such as wind waves and run-up effects; hydrostatic loading; hydrodynamic loading, including debris and water velocities; effects caused by sediment deposition and erosion; concurrent site conditions, including adverse weather conditions; and groundwater ingress.

The scope of the staff's review activities should include the following areas, as applicable, to confirm whether channel migration or diversion is a flood-causing mechanism at a power reactor site.

1. Historical Accounts of Channel Migration or diversion: Historical reports of channel migration or diversion phenomena at or near the reactor site including evidence of cutoffs, subsidence, or tectonic uplift. In addition to historical accounts, sedimentological evidence, botanical evidence, planimetric surveys and as appropriate terrestrial photogrammetry data will be reviewed.

2. Regional Topographic and Geologic Evidence of Channel Migration: Regional topographic evidence or geologic features which suggests that channel migration or diversion may occur in the future (based on past geologic/geomorphic evidence expressed in geologic and/or topographic maps). Geomorphological evidence obtained from current and previous geomorphological studies and other floodplain studies will be reviewed.

3. Impact of Ice-induced Channel Migration or Diversion: Thermal causes of channel migration or diversion due to ice jams or ice dams, will be reviewed. These diversions may result from downstream ice blockages that may lead to flooding due to backwater effects, or they can be upstream ice blockages that can divert the channel away from the location of the service water intake structure. The review is to be coordinated with SRP Section 2.4.7 "Ice Effects."

4. Evidence of Human-Induced Channel Diversion: The potential for channel diversion due to human-induced (anthropogenic) factors such including but not limited to land-use changes, diking, channelization, river bank armoring, or potential failure of water impoundment structures will be reviewed.

If, based on an evaluation of review items (1) through (4), it is found that this flood-causing mechanism is consequential at the site, the scope of the staff's review activities should be expanded to include the following areas.

5. Flooding of Site Due to Channel Migration or Diversion: Inundation maps illustrating projected flooding levels in relation to the reactor powerblock and other structures, including those SSCs important to safety such as the service water intake structure, will be reviewed.[4] Associated flooding effects on SSCs important to safety or blockage of water supply sources resulting from channel migration- or channel diversion-induced flooding (flooding not addressed by hydro-meteorological induced flooding scenarios in other SRP sections). The review performed should be consistent with the type of review performed in SRP Section 2.4.3 "Streams and Rivers."

[4] Depending on the reactor sites' topography and geography, the powerblock and any important-to-safety intake structures may be at different elevations relative to each other. As a consequence, the staff may need to review the calculation of separate flooding elevations corresponding to these features' locations as those elevations may vary across the reactor site owing variable site topography and the presence of multiple as-built reactor structures. The staff's review of the analysis should include review of the consideration an evaluation of those associated effects in any water surface elevation estimate.

6. Alternate Water Supply Sources: Alternate water supply sources and associated operating procedures.

7. Consideration of Other Site-Related Evaluation Criteria: The potential effects of seismic and non-seismic information on the postulated the worst-case channel migration or diversion scenario for the proposed site.

8. Additional Information for 10 CFR Part 52 Applications: Additional information may be presented dependent on the type of NRC 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 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

Review Interfaces

Other SRP sections interface with scope of the review addressed in this SRP section, as noted below:

1. The identification of those SSCs important to safety that should be protected against the effects of flooding due to channel migration or diversion is performed under SRP Section 3.4.1, "Flood Protection."

2. The review of the design of seismic Category I structures to design for the effects of flooding, including that which could result from channel migration or diversion, is performed under SRP Section 3.4.2, "Analysis Procedures."

3. The review to ensure that adverse environmental conditions, including freezing, will not preclude the safety function of the ultimate heat sink source is performed under SRP Section 9.2.5, "Ultimate Heat Sink."

4. The staff is responsible for providing the site characteristics and other hydrogeologic parameters related to channel migration or diversion at or near the site to the cognizant NRC organization responsible for review of those SSCs important to safety to ascertain whether the appropriate flooding effects are properly considered in the hydraulic, mechanical, or structural design basis for the plant.

5. 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[5] 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.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

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

II. ACCEPTANCE CRITERIA

Regulatory Requirements

The acceptance criteria described in this SRP section are based on addressing the following Commission regulations:

1. 10 CFR Part 100, “Reactor Site Criteria,” as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.10(c) for applications before January 10, 1997, and in 10 CFR 100.20(c) for applications on or after January 10, 1997.

2. 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to seismically-induced floods and other impulsive water waves the site.

3. 10 CFR 52.17(a)(1)(vi), for ESP applications, and 10 CFR 52.79(a)(1)(iii), for COL applications, as they relate to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically-reported and/or instrumentally-recorded for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR Part 50, Appendix A, GDC 2, “Design Bases for Protection Against Natural Phenomena,” as it relates to: (1) appropriate 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, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) importance of the safety functions to be performed.

5. 10 CFR Part 50, Appendix A, GDC 44, “Cooling Water,” as it relates to providing an ultimate heat sink for normal operating and accident conditions.

Regulatory Guides

Regulatory Guides (RGs) are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory Guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet NRC's regulations and consistent with the scope of the review addressed in this SRP section are listed below. The following RGs should

be consulted, as applicable, in connection with the review of this particular flood-causing mechanism:

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," describes the applicable ultimate heat sink capabilities.

- RG 1.29, "Seismic Design Classification," identifies the seismic design bases for SSCs important to safety.

- RG 1.59, "Flood Design Basis for Nuclear Power Plants," as supplemented by best current practices, provides guidance for developing the hydro-meteorological design bases.

- RG 1.102, "Flood Protection for Nuclear Power Plants," describes acceptable flood protection measures intended to prevent the safety-related facilities from being adversely affected.

These acceptance criteria should be addressed to the extent this flood-causing mechanism is found to be consequential at the power reactor site:

1. Historical Accounts of Channel Migration: To meet the requirements of GDC 2, GDC 44, 10 CFR 52.17, "Contents of applications; technical information," and 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," and 10 CFR Part 100, a complete history of channel migration or diversion at and in the vicinity of the site is needed. A thorough review and identification of the types of natural processes and other destructive phenomena (landslides, channel erosion, breached dikes, etc.), locations and durations of these events, and descriptions of hydrogeological/geomorphic characteristics accompanying these events (both currently and in the past) should be included. This description should be sufficient to establish the potential for channel migration or diversion in the vicinity of the site. This review includes the reactor site and adjacent watersheds displaying similar hydraulic characteristics.

2. Regional Topographic and Geologic Evidence of Channel Migration or Diversion: To meet the requirements of GDC 2, GDC 44, 10 CFR 52.17 and 52.79, and 10 CFR Part 100, a description of regional topographic evidence as it relates to the potential for channel migration or diversion is needed. This description should be accompanied by data where possible and should be sufficient to make an assessment of the possibility of channel migration or diversion near the site that may affect SSCs important to safety.

3. Impact of Ice Effects on Channel Migration or Diversion: To meet the requirements of GDC 2, GDC 44, 10 CFR 52.17 and 52.79, and 10 CFR Part 100, estimates of the most severe ice-induced flooding effects due to channel migration or diversion are needed. These estimates should be consistent with the estimates by the applicant and associated with staff's review associated with SRP Section 2.4.7 "Ice Effects."

4. Evidence of Human-Induced Channel Diversion: To meet the requirements of GDC 2, GDC 44, 10 CFR 52.17 and 10 CFR 52.79, and 10 CFR Part 100, an assessment of the potential for human-induced channel diversion, in the vicinity of the site (e.g., land-use

changes, diking, channelization, river bank armoring or failure of such structures) is needed. An assessment of high- and low-water levels during in response to channel diversion should be provided. These assessments should be consistent with staff's review associated with SRP Sections 2.4.3 "Streams and Rivers" and 2.4.11 "Low Water Considerations."

5. Flooding of Site Due to Channel Migration or Diversion: If channel migration or diversion is found to be consequential to defining the plant's design basis flood elevation, an assessment of that flood level is needed to meet the requirements of GDC 2, GDC 44, 10 CFR 52.17 and 10 CFR 52.79, and 10 CFR Part 100. If this flood-causing mechanism if found to be consequential, then, the material to be reviewed should be consistent with that described in SRP Section 2.4.3 "Streams and Rivers." This information can be represented through the use of inundation maps of the reactor site. The water surface estimates should be sufficient to demonstrate that the SSCs important to safety can withstand these forces without loss of their ability to perform their intended safety functions. A description of mitigation measures to address the effects of flooding due to channel migration or diversion should be provided, and it should be demonstrated that these measures are consistent with the Commission's regulations regarding performance of SSCs important to safety.

6. Alternate Water Supply Sources: To meet the requirements of GDC 2, GDC 44, 10 CFR 52.17 and 10 CFR 52.79, and 10 CFR Part 100, assessments of alternate safety-related water supply sources and operating procedures are needed. These assessments should be consistent with staff's review associated with SRP Section 2.4.11 "Low Water Considerations" and with SRP Section 2.4.14 "Technical Specifications and Emergency Operation Requirements."

7. Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of GDC 1, GDC 2, 10 CFR 52.17 and 52.79, and 10 CFR Part 100, a description of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated worst-case channel migration or diversion scenario for the proposed plant site is needed. This description should be sufficient to demonstrate that the applicant's design bases appropriately account for these effects.

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:

1. Compliance with GDC 2 requires that nuclear power plant SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The GDC further specifies that the design bases for these SSCs shall reflect the following:

   A. Appropriate 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 time period in which the historical data have been accumulated;

B. Appropriate combinations of the effects of normal and accident conditions with those of the natural phenomena; and

C. The importance of the safety functions to be performed.

Channel migration and/or river diversion has the potential for causing flooding or low water elevations at certain sites, thus adversely affecting sources of surface water required for safety-related cooling the proposed plant. Accordingly, GDC 2 requirements are imposed to ensure that components and structures associated with the ultimate heat sink will continue to function, thereby keeping the plant in a safe shutdown condition.

For applications pursuant to 10 CFR Part 52, meeting the applicable requirements of 10 CFR 52.17 and 10 CFR 52.79 that correspond to GDC 2 provides a level of assurance that the most severe hydrologic site characteristics have been identified; whether GDC 2 is met with respect to the adequacy of the associated design bases will be evaluated pursuant to other SRP sections.

2. Compliance with GDC 44 requires that a system be provided to transfer heat from SSCs important to safety. The system is to function under normal and accident conditions, assuming a single failure.

GDC 44 applies to SRP Section 2.4.9 because the ultimate heat sink for the power plant can consist of complex water supply sources, including necessary retaining structures (e.g., ponds or rivers with dams) and the associated canals and conduits connecting these sources with the reactor site. Any earthwork intended as part of the water conveyance system, consisting of dams and canals, for example, should be constructed in a manner that ensures the integrity of the system and its intended safety function. In addition, it should be shown that the potential diversion, migration, or realignment of natural waterways caused by severe natural phenomena cannot cause loss of the heat sink or result in flooding at the site in excess of the design basis water surface elevation.

Meeting these requirements provide a level of assurance that, given the most severe natural phenomena capable of causing the potential diversion, migration, or realignment of natural waterways, an adequate and dependable source of cooling water can be maintained.

3. Sections 100.10(c) and 100.20(c) of 10 CFR Part 100 require that physical characteristics of a site (including seismology, meteorology, geology, and hydrology) be taken into account to determine the acceptability of a site for a nuclear power reactor.

The diversion, migration, or realignment of natural waterways posing the potential for flooding or adversely affecting the integrity of the cooling water supply for the plant, is one of the many natural phenomena specified in 10 CFR 100.10(c) and 10 CFR 100.20(c) that should be considered in designing the plant to accommodate the characteristics of a proposed site.

Meeting this requirement provides a level of assurance that the plant site is not vulnerable to flooding or to loss of cooling water that could be caused by the diversion,

migration, or realignment of natural waterways resulting from severe natural phenomena.

III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

The procedures outlined below are used to review CP and ESP applications to determine whether data and analyses for the proposed site meet the acceptance criteria given in Subsection II of this SRP. For OL and COL applications, these review procedures are used to verify that the data and analyses previously described (in either the CP or ESP, respectively) remain valid and that the facility's design specifications are consistent with these data. Reviews of OLs and COLs are to also include a determination as to technical specifications bearing on the site characteristic flood reflect consideration of any newly-identified conditions that might now be considered unique to the site and not previously considered in either the CP or the ESP.

These review procedures also apply to COL applications that do not reference an existing ESP.

These review procedures are based on the acceptance criteria identified in Subsection II of this SRP. 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 applicable NRC regulatory requirements identified in Subsection II.

The staff's review in the first instance should consist of a hierarchical bounding analysis. If the staff's preliminary assessment of channel migration or diversion effects is comparable to the licensee's preliminary analysis, the staff should concur with the applicant's findings. If the staff's preliminary bounding analysis indicates that its analysis and that prepared by the applicant are not comparable and reach different conclusions, the staff should repeat its analysis using more realistic assumptions; it may also be necessary to rely on more sophisticated analysis model. If the results of the two analyses continue to remain non-comparable then the staff should analyze the applicants' data, methods, and assumptions to determine their reasonableness. Staff may also rely on alternative analysis techniques including alternative conceptual models. Staff should also consider the need to conduct an audit with the applicant to address any differences with the applicant's findings.

Staff should be aware that there generally are no well-established predictive methods for evaluating the potential for the migration of natural watercourses in riverine environments. However, the potential for this hazard to exist at a particular location can be inferred by reviewing certain types of empirical earth-science information. Topographic maps, geologic maps, aerial photographs, and satellite imagery can be examined for evidence of past channel migration as they are generally recognized to reflect evidence of the meandering (lateral movement) of naturally-flowing water conveyance features. If there were evidence of such behavior in the past, this would be apparent based on inspection of the maps and/or

photographs reviewed.[6] The particular geomorphic features of interest generally include but are not limited to meander belts, flood plains, oxbow lakes, natural levees, and the like. [These features are defined and illustrated in Fairbridge (1968), for example.] The U.S. Geological Survey's (USGS's) historic topographic map geospatial database[7] can be accessed to identify the earliest maps published for the area and then inspecting those maps for geomorphic evidence of channel migration or diversion.

Staff could use additional sources of information to obtain historical and potential channel migration or diversion activity include aerial photographs, satellite imagery and other remotely-sensed geospatial data. When reviewed in time series, remotely-sensed geospatial data can help to illustrate temporal changes, over a span of decades, in the locations of streams and/or rivers and in doing so help to confirm whether this flood-causing mechanism is present at a particular site.

Lastly, staff should confirm that the applicant has investigated whether there are any ongoing or planned land-use or water management activities or environmental actions that might affect the course, characteristics, or flow rates of any streams and/or rivers contiguous to the power plant site. This would include activities or actions at locations above and below the power plant site. This information can be obtained from those cognizant Federal and State authorities with responsibilities for these concerns in the region of interest.

1. Historic Accounts of Channel Migration: The literature should be reviewed to determine if there are historic accounts describing past episodes of diversion, migration, or realignment of natural waterways in the region. Publications of the USGS, the U.S. Army Corps of Engineers (USACE), USACE Engineer Research, National Cooperative Highway Research Program (NCHRP) of the Transportation Research Board, State highway departments and other authoritative sources should be examined to identify past events and the potential for future channel migration or diversion in the region. The phrase "channel diversions" is not commonly used in the literature, so the literature search should include other terms, such as "channel, stream, or river migration," "channel, stream, or river meandering," "channel, stream, or river geomorphology," "physical hydrology," and initiating events such as "landslides" and "levee breaks" or "breaches."

   In any review of the literature, the potential for diversion, migration, or realignment of natural waterways should address the following locations relative to the reactor site:

   A. Upstream, and generally above-bank, due to geologic, seismic, or topographic changes, e.g., caused by hillslope failure or earthquakes.

[6] The geologic doctrine of uniformitarianism essentially states that the nature and rates of geologic processes occurring now are the same as in the past. Thus, evidence of past channel migration can be inferred based on the identification of certain types of geomorphic features depicted on topographic (and geologic) maps. See Salisbury and Atwood (1908) for example. The same interpretive principles can be applied to the examination of aerial photographs and satellite imagery. See examples in Ray (1960). Catalogs of geomorphic images as observed from space are available on the following web sites: National Atmospheric Space Administration: *https://visibleearth.nasa.gov/view_cat.php?categoryID=917*, and the European Space Agency: *https://earth.esa.int/web/guest/home*.

[7] Available online at *http://geonames.usgs.gov/apex/f?p=262:1:0.*

B. Upstream (or downstream) and within the bank, and due to erosion, deposition or channel migration or diversion, e.g., loss of a revetment, or alluvial channel meander changes.

C. Upstream (or downstream) and within the bank and due to climatic/ meteorological causes such as ice-jams.

Evaluate the geographic layout of existing channel meanders, cross-sections (widths and depths), profiles (slopes), estimated discharge properties (velocity and energy), and material compositions for beds and banks and, suspended loads.

2. Regional Topographic and Geologic Evidence of Channel Migration or Diversion: In addition to the a review of historical geologic/geomorphic information, the review should also determine if there is regional topographic as well as geologic evidence suggesting the potential for future channel migration or diversion. For example, there is the possibility that diversion effects could change existing water course paths through debris blockage, tectonic uplift, or subsidence. Potential migration or diversions effects that can result from gradual progressive causes, or from quick catastrophic changes should be considered. If considered necessary, identify the most likely types of channel migration or diversion conditions and the potential impact on plant siting and design of each type. For each type of condition, preliminary independent conservative estimates of the "worst case" should be made qualitatively.

There are geospatial databases that contain information including topographic maps and geologic maps that can be used to qualitatively determine candidate locations where geologic or human-induced events increase the likelihood of channel migration or diversion. The USACE (Cherry and others, 1994) and the NCHRP (National Research Council, 2004) have proposed recommended methods for predicting channel migration. The USGS[8] and several state Departments of Natural Resources have compiled geospatial databases depicting landslide hazards. The Federal Emergency Management Agency (FEMA, 1999) has conducted riverine erosion hazard area mapping studies.

3. Impact of Ice Effects on Channel Migration or Diversion: If ice blockage of some nearby river or estuary is possible and can impact the site, then this flood-causing mechanism is consequential to establishing the design basis flood (e.g., owing to a diverted channel as a result of an ice dam). Ice effects could also create flooding or low flow condition, resulting in adverse impacts on the operation of safety-related service water intake structure or the UHS.

Should channel migration or diversion be found to be consequential at a site owing to ice effects, there should be an estimate of the most severe ice-induced channel migration or diversion effects; that estimate should be performed consistent SRP Section 2.4.7 "Ice Effects." Flow available under the most severe channel migration or diversion conditions should be sufficient to meet safety-related water supply requirements.

[8] Available online at *http://www.ngdc.noaa.gov/seg/hazard/slideset/39/39_slides.shtml.*

4. Human-Induced Causes of Channel Diversion: In addition to the natural migration of river channels and other water courses, there also exists the potential that anthropogenic (human-induced) factors (e.g., land-use changes or the diking, channelizing, river bank armoring, and subsequent failure of such hydraulic structures) could initiate or exacerbate geomorphologic channel changes. The potential for anthropogenic-induced diversion of river channels and other water courses in the vicinity of the site should be qualitatively evaluated. The USACE and the NCHRP have proposed methods of predicting the consequences of channel migration potential near structures when the alignment of a natural river is artificially modified.

3. Flooding Effects Associated with Channel Migration or Diversion: Should channel migration or diversion be found to be consequential at a site, the estimated flood elevation prepared by the applicant should be evaluated. Water wave elevations should be reported to the nearest tenth of a foot. The geodetic reference datum used by the applicant to report the water surface elevation should also be specified. The analysis should account for the effects of flood inundation and drawdown at the site. This information should be communicated in the form of an inundation map.[9] The extent and duration of wave run-up during the inundation phase of the flooding event should also be reviewed. Separate flooding levels, corresponding to different locations within the powerblock, need to be reported as the flood water elevation may vary spatially owing to differences in the finished site grade and the presence of multiple as-built reactor structures.

   In general, this aspect of the staff's review is similar to that described in SRP Section 2.4.3 "Streams and Rivers." The geographic layout of existing channel meanders, cross-sections (widths and depths), profiles (slopes), estimated discharge properties (velocity and energy), and material compositions for beds and banks and, suspended loads should be evaluated. The staff will also need to review the following as it relates to SSCs important to safety: the static, wave, and dynamic force metrics, including the maximum inundation and drawdown depths, current speed, acceleration, inertial component, and momentum flux that quantify the anticipated forces; the debris and water-borne projectiles that accompany anticipated flood-generated currents; and the effects of sediment erosion and deposition caused by flooding that may result in blockage or loss of function.

   For any diversion, migration, or realignment events identified, historical water-flow variations should be noted, as well as the volume of any debris-blocking materials with respect to the channel geometry.

4. Alternate Water Supply Sources: Should channel migration or diversion be found to be consequential at a site, consideration should be given to evaluating alternate safety-related water supplies to the plant. Assessment of alternate water supply sources and operating procedures is addressed in, and should be coordinated with SRP Section 2.4.11 "Low Water Considerations" where the staff reviews availability of

[9] FEMA has an extensive flood inundation mapping program. See *https://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping* for information on FEMA's latest inundation mapping standard.

alternate sources of safety-related water supply to the plant according to recommendations of RG 1.27.

5. Consideration of Other Site-Related Evaluation Criteria: 10 CFR Part 100 describes site-related proximity, seismic, and non-seismic evaluation criteria for power reactor applications. Subpart A to 10 CFR Part 100 addresses the requirements for applications before January 10, 1997, and Subpart B is for applications on or after January 10, 1997. If the channel migration or diversion flood-causing mechanism is determined to be consequential to defining the design basis flood elevation, the staff's review should include evaluation of pertinent information to determine if these criteria are appropriately used in postulation of worst-case diversion, migration, or realignment scenario at the proposed plant site.

6. Review Procedures Specific to 10 CFR Part 52 Application Type

   A. 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 reactor site. Information required in an ESP application includes a description of the site characteristics and design parameters of the proposed site. The scope and level of detail of the review should be similar to that for a CP review.

      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,"p the staff from imposing new site characteristics, design parameters, or terms and conditions on the early site permit at the COL stage. Accordingly, the staff 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.

   B. 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 application must include information on the site parameters postulated for the design. Site parameters associated with this SRP section are reviewed, as applicable, to verify that:

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

      ii. 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;

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

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

C. Combined License Reviews

For a COL application referencing a certified standard design, NRC staff reviews that application to ensure sufficient information is presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. If there are site parameters associated with this SRP section and if the above condition for these parameters have not been met (i.e. the actual site characteristics do not fall within the certified standard design site parameters), the COL application must include information 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 provides sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the early site permit 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, "Exemptions and variances."

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 early site permit 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, 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 early site permit conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

IV. EVALUATION FINDINGS

The review should document the staff's evaluation of the site characteristic flood against the relevant regulations and associated acceptance criteria. The evaluation should support the staff's conclusions as to whether the applicable regulations have been met. The staff should summarize information provided by the applicant in its safety analysis report and then summarize the staff's technical evaluation of that information in its SER. The staff's evaluation may include verification that the applicant followed applicable regulatory guidance, performed independent calculations, and/or validated appropriate assumptions. While the reviewer may summarize or quote the information offered by the applicant in support of its application, the staff should clearly articulate the independent basis for the staff's conclusions that the relevant regulatory criteria have been met.

The staff verifies that the applicant has provided sufficient information to complete the review, and that the applicant's analyses and calculations (as applicable) support the conclusions described in the safety analysis report. For the purposes of the SER, the ultimate conclusion to be reached by the reviewer is that the applicant has addressed the acceptance criteria and in doing so establishes whether this flood-causing mechanism is applicable to the site. If found to be applicable, the acceptance criteria next call for a determination as whether channel migration or diversion-based flooding is consequential to defining the design basis at the site. If found to be consequential, the acceptance criteria call for the submittal of the following to establish the design basis: an inundation map depicting water surface elevations across the reactor site, information on flood event duration, and associated effects consistent with projected flooding depths and durations. As mentioned above, the staff should state the bases for confirming the conclusions reached by the applicant.

1. 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 relative to the effects of channel migration or diversion important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the potential for channel migration and/or river diversion is acceptable and meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2 and 44 and 10 CFR Part 100 (10 CFR 100.10(c) or 10 CFR 100.20(c), as applicable), with respect to determining the acceptability of the site.
>
> The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff has generally accepted the methodologies used to determine the potential for channel migration or diversion is reflected in these design bases, as documented in safety evaluation reports for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in design bases containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. The

staff concludes that the identified design bases meet the requirement(s) of 10 CFR Part 50, Appendix A, General Design Criteria 2 and 44 and 10 CFR 100.10(c) or 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety."

2. 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 sufficient information pertaining to the identification and evaluation of the potential for channel migration or diversion at the proposed site. Section 2.4.9, "Channel Migration or Diversion," of NUREG-0800, Standard Review Plan, provides that the site safety analysis report should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the potential for channel migration or diversion affecting the site. Further, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in safety evaluation reports for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.
>
> Therefore, the staff concludes that the identification and consideration of the channel migration or diversion site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).
>
> In view of the above, the staff finds the applicant's proposed site characteristics related to the potential for channel migration or diversion for inclusion in an ESP for the applicant's site, should one be issued, acceptable."

3. Design Certification Reviews

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

> "The NRC staff acknowledges that the applicant has selected the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information) and agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Channel migration or

diversion effects are 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 site parameters specified by the siting review."

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. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

Regulations

1. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities." Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 1, "Quality Standards and Records." Part 50, Title 10, "Energy."

2. *U.S. Code of Federal Regulations*, Appendix A, General Design Criterion 2, "Design Bases for Protection against Natural Phenomena." Part 50, Title 10, "Energy."

3. *U.S. Code of Federal Regulations*, Appendix A, General Design Criterion 44, "Cooling Water." Part 50, Title 10, "Energy."

4. *U.S. Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants." Part 52, Title 10, "Energy."

5. *U.S. Code of Federal Regulations*, "Reactor Site Criteria." Part 100, Title 10, "Energy."

Regulatory Guides

6. U.S. Nuclear Regulatory Commission, "Ultimate Heat Sink for Nuclear Power Plants," Regulatory Guide 1.27.

7. U.S. Nuclear Regulatory Commission, "Seismic Design Classification." Regulatory Guide 1.29.

8. U.S. Nuclear Regulatory Commission, "Flood Design Basis for Nuclear Power Plants," Historical Technical Reference. Regulatory Guide 1.59.

9. U.S. Nuclear Regulatory Commission. “Flood Protection for Nuclear Power Plants,” RG DG-1145, “Combined License Applications for Nuclear Power Plants (LWR Edition).” Regulatory Guide 1.102.

Other References

10. D.S. Cherry, P.R. Wilcock, and M.G. Wolman, “Evaluation of Methods for Predicting Planform Change and Bankline Migration in Flood Control Channels. Report to the Waterways Experiment Station,” U.S. Army Corps of Engineers, November, 1994.

11. Federal Emergency Management Agency, “FEMA Riverine Erosion Hazard Areas (REHA) Mapping Feasibility Study,” 1999 [Available online at *http://www.floodmaps.fema.gov/fhm/ft_reha.shtm http://www.msc.fema.gov*.]

12. National Research Council, “Handbook for Predicting Stream Meander Migration,” National Cooperative Highway Research Program, NCHRP Report No. 533, August 2004.

13. R.D. Salisbury and W.W. Atwood, “The Interpretation of Topographic Maps,” U.S. Geological Survey, Professional Paper 60, 1908.

14. R.G. Ray, “Aerial Photographs in Geologic Interpretation and Mapping,” U.S. Geological Survey Professional Paper 373, 1960.

15. R.W. Fairbridge (ed.), *The Encyclopedia of Geomorphology*, New York, van Nostrand Reinhold, 1968. [*Encyclopedia of the Earth Sciences Series*, Volume 3.]

PAPERWORK REDUCTION ACT

This Standard Review Plan contains voluntary information collections covered by 10 CFR Parts 50, 52, and Part 100 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget (OMB), under control numbers 3150-0011, 3150-0151, and 3150-0093, respectively. Send comments regarding this information collection to the Information Services Branch, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0011, 3150–0151, and 3150-0093) Office of Management and Budget, Washington, DC 20503.

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Standard Review Plan Section 2.4.9
Description of Changes

Section 2.4.9 "Channel Migration or Diversion"

This SRP revision affirms the technical accuracy and adequacy of the guidance previously provided in Revision 3, March 2007 of this SRP (ADAMS Accession No. ML070730434). This revision captures lessons learned from the staff's review of DC, ESP, and COL applications received during the previous decade.

Changes were made to update the text with editorial and clarifying statements, including utilizing consistent terminology within this SRP section and planned updates within the other SRP 2.4 sections. A key change to this SRP section was to introduce and define and introduce a new engineering term "consequential flooding." In reference to any consequential flooding estimate, the staff is now proposing that the staff will evaluate applications for the inclusion of inundation maps identifying the elevation of flood waters in relation to SSCs within the reactor powerblock including those SSCs important to safety. Depending on the reactor sites' topography and geography, the powerblock, and the service water intake structure, and the designated ultimate heat sink may be at different elevations relative to each other. As a consequence, the staff is also proposing to evaluate applications for separate flooding levels corresponding to these two features' locations as flood elevations may vary across the reactor site owing variable site natural topography and the presence of multiple as-built reactor structures. The staff is also proposing to evaluate applications for inclusion of an analysis estimating the duration of the flood inundation event as well as consideration of "associated effects" in any water surface elevation estimate. A definition of "associated effects" has been introduced in the SRP text.

Additional changes have been introduced to the SRP text to better clarify the staff's review responsibilities in relation to information prospective applicants are expected to submit.

The phrases "safety-related structures, systems, and components (SSCs)" and "SSCs determined to be important to safety" have been replaced in this SRP section with the phase "SSCs important to safety" to better correspond to the regulatory language cited in General Design Criteria 2.

The staff is also proposing to place greater emphasis on the use of satellite photographs, imagery, and geospatial databases in connection with any review of channel migration or diversion.

Other changes incorporated in this revision include the following:

I. AREAS OF REVIEW

Updated with editorial changes as well as content changes consistent with the discussion above.

II. ACCEPTANCE CRITERIA

Updated with editorial changes as well as content changes consistent with the discussion above.

II. REVIEW PROCEDURES

Updated with editorial changes as well as content changes consistent with the discussion above.

IV. EVALUATION FINDINGS

Updated with editorial changes as well as content changes consistent with the discussion above.

V. IMPLEMENTATION

No changes.

VI. REFERENCES

Several changes have been made to this section. The first was to re-organize the references according to type (NRC regulations, NRC regulatory guides, industry codes and standards, and other references). The references were also arranged chronologically. This change was intended to improve the readability of this section of the SRP.

The next major change to the "References Section" of this SRP was to delete those earlier technical references cited. The staff believes that in light of the current state of engineering practice in this area by applicants in particular and the broader technical community in general, the inclusion of these types of references adds no real value to this particular SRP section.

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