U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE 4.7, REVISION 4

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GENERAL SITE SUITABILITY CRITERIA FOR NUCLEAR POWER STATIONS

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes the major site characteristics related to public health and safety and environmental issues that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers in determining the suitability of sites for commercial nuclear power stations[1].

Applicability

This RG applies to applicants for commercial nuclear power reactor licenses and approvals under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1), and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2), and addresses requirements in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions" (Ref. 3), and 10 CFR Part 100, "Reactor Site Criteria" (Ref. 4).

Applicable NRC Regulations

- 10 CFR Part 50 governs the licensing of nuclear power plants, including issuance of construction permits and operating licenses. Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 provides general design criteria (GDC) for water-cooled nuclear power plants[2]. GDC 2, "Design bases for protection against natural phenomena," requires that structures, systems, and components (SSCs) important to safety be designed to withstand the effects of

1 For the purpose of this guide, the term "commercial nuclear power station" is equivalent to "nuclear power plant" and refers to the nuclear reactor unit or units, nuclear steam supply, electric generating units, auxiliary systems (including the cooling systems) and structures such as docks that are located on a given site, and any new electrical transmission towers and lines erected in connection with the facilities.

2 The General Design Criteria are also considered to be generally applicable to other types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for such other units.

expected natural phenomena when combined with the effects of normal accident conditions without loss of capability to perform their safety function.

- 10 CFR Part 51 provides regulations applicable to the NRC's preparation and processing of environmental impact statements and related documents pursuant to section 102(2)(C) of the National Environmental Policy Act of 1969, as amended (42 United States Code (U.S.C.) 4321 et seq.) (NEPA) (Ref. 5). A principal objective of NEPA is to require a federal agency to consider, in its decision making process, the environmental impacts of each proposed major Federal action and alternative actions, including alternative sites. Executive Order 11514, "Protection and Enhancement of Environmental Quality," dated March 5, 1970 (Ref. 6), as amended by Executive Order 11991, "Environmental Impact Statements," dated May 25, 1977 (Ref. 7), and the Council on Environmental Quality's regulations at 40 CFR Parts 1500–1508 (Ref. 8), provide additional direction. Regarding the Council on Environmental Quality regulations, as stated in 10 CFR 51.10, "Purpose and scope of subpart; application of regulations of Council on Environmental Quality," the NRC considers those regulations voluntarily, subject to certain conditions. The regulations in 10 CFR 51.10(c) specify the limits on the Commission's authority and responsibility pursuant to NEPA, as imposed by the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.), also known as the Clean Water Act (CWA) (Ref. 9). In 10 CFR 51.45, "Environmental report," the NRC specifies the contents that an applicant must include in its environmental report.

- 10 CFR Part 52 governs the issuance of early site permits (ESPs), standard design certifications, combined licenses (COLs), standard design approvals, and manufacturing licenses for nuclear power facilities licensed under section 103 of the Atomic Energy Act of 1954, as amended (Ref. 10), and Title II of the Energy Reorganization Act of 1974 (Ref. 11). Some of the 10 CFR Part 52 criteria are directly related to site characteristics, as well as to events and conditions outside the nuclear power unit.

- 10 CFR Part 100 requires the NRC, in determining the acceptability of a site for a nuclear power reactor, to consider population density, use of the site environs, including proximity to manmade hazards, and the physical characteristics of the site, including seismology, meteorology, geology, and hydrology. Particularly relevant sections are 10 CFR 100.20, "Factors to be considered when evaluating sites," 10 CFR 100.21, "Non-seismic site criteria," and 10 CFR 100.23, "Geologic and seismic siting criteria."

Related Guidance

- RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," (Ref. 12), identifies requirements for safety related site characteristics.

- RG 1.206, "Applications for Nuclear Power Plants," (Ref. 13), provides guidance on the format and content of applications for nuclear power plants submitted to the NRC under 10 CFR 52.

- RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," (Ref. 14), provides guidance to nuclear reactor designers, applicants, and licensees of advanced non-light-water reactor (non-LWR) designs applying for permits, licenses, certifications, and approvals under 10 CFR Part 50 and 10 CFR Part 52.

- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition” (Ref. 15), provides the criteria used by the NRC staff for reviewing safety analysis reports submitted with nuclear power plant license applications.

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan” (Ref. 16), provides the criteria used by the NRC staff for reviewing environmental reports submitted with nuclear power plant license applications. Supplement 1 to NUREG-1555 covers license renewals.

- NUREG-0625, “Report of the Siting Policy Task Force,” dated August 2, 1979 (Ref. 17), provides useful background information on the history of siting requirements.

- RG 4.2, “Preparation of Environmental Reports for Nuclear Power Stations” (Ref. 18), provides guidance to applicants for the format and content of environmental reports submitted as part of an application for a permit, license, or other authorization to site, construct, or operate a new nuclear power plant.

- RG 4.11, “Terrestrial Environmental Studies for Nuclear Power Stations” (Ref 19), provides technical guidance that NRC staff considers acceptable for terrestrial environmental studies and analyses supporting licensing decisions for nuclear power reactors.

- RG 4.24, “Aquatic Environmental Studies for Nuclear Power Stations” (Ref 20), provides technical guidance for aquatic environmental studies and analyses supporting regulatory decisions related to new nuclear power stations.

Purpose of Regulatory Guides

The NRC issues RGs to describe methods that are acceptable to the staff for implementing specific parts of the agency’s regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. Regulatory guides are not NRC regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 20, 50, 51, 52, and 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, 3150-0014, 3150-0021, 3150-0151, and 3150-0093, respectively. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch, Office of the Chief Information Officer, Mail Stop: T6-A10M, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs, (3150-0011, 3150-0014, 3150-0021, 3150-0151, 3150-0093), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW, Washington, DC, 20503.

Public Protection Notification

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

B. DISCUSSION

Reason for Revision

The NRC revised RG 4.7 to include alternative approaches to the population-density criterion and to expand the regulatory guidance developed for large LWR technology with appropriate modifications for advanced reactor designs (e.g., non-LWR technologies and light-water small modular reactors). Specifically, this revision includes a new appendix A, which provides guidance on alternatives to the existing guidance in section C.1.4 of this RG that establishes a fixed distance of 20 miles out to which population density is assessed for any new application. Readers should understand that the body of this RG was developed for large LWRs, while appendix A is intended for advanced reactor designs. This revision also removes repetition and improves clarity. Text from the discussion section and the two tables in Revision 3 of the RG were brought together in Section C, "Staff Regulatory Guidance." To present each topic in section C cohesively, the document was structured to list (1) relevant statutes and regulations, (2) related guidance, and (3) considerations, regulatory experience, and staff positions.

Scope of Regulatory Guide 4.7

This guide is intended to assist applicants in the initial stage of selecting potential sites for a commercial nuclear power station. It describes the major site characteristics related to public health and safety and environmental issues that the NRC staff considers in determining the suitability of sites for commercial nuclear power stations. This guide should be used only in the initial stage of site selection because it does not provide detailed guidance on ranking the relative suitability or desirability of possible sites. Each site that appears to be compatible with the general criteria in this guide should be examined in greater detail before being considered a "candidate" site (i.e., one of the groups of sites to be considered in selecting a "proposed" or "preferred" site). Chapter 9 of RG 4.2 and chapter 9 of NUREG-1555, as well as chapter 2 of Electric Power Research Institute document No. 3002023910, "Site Selection and Evaluation Criteria for New Nuclear Power Generation Facilities (Siting Guide)," issued November 2022 (Ref. 20), discuss the selection of a site from among alternative sites.

This guide does not discuss the details of the engineering designs required to ensure that the nuclear station and the site are compatible, or the information required to prepare the safety analysis and environmental reports. The NRC discusses these topics in RG 1.70, NUREG-0800, RG 4.2, and NUREG-1555.

Site Selection

Applicants should examine in greater detail each site that appears to be compatible with the general criteria discussed in this guide before it can be considered a "candidate" site (i.e., one of the groups of sites to be considered further in selecting a "proposed" or "preferred" site). The "proposed" or "preferred" site submitted by an applicant for a construction permit, ESP, or COL is that site chosen from a number of "candidate" sites on which the applicant proposes to construct a commercial nuclear power station.

Selecting a suitable site for a commercial nuclear power station may require a significant commitment of time and resources. Site selection involves consideration of the human environment,[3] public health and safety, engineering and design, economics, institutional requirements, environmental impacts, and other factors. The potential impacts of the construction and operation of commercial nuclear power stations on the human environment and on social, cultural, and economic features (including environmental justice) are usually similar to the potential impacts of any major industrial facility, but commercial nuclear power stations are unique in the degree to which the environment may affect their safety. Safety requirements are the primary determinants of site suitability, although environmental impacts are also important and need to be evaluated.

In the site selection process, coordination between applicants for commercial nuclear power stations and various Federal, State, local, and Tribal agencies will be useful in identifying potential problem areas.

Information Limitations at Site Selection Stage

The information needed to evaluate potential sites at the initial stage of site selection is assumed to be limited to that obtainable from published reports, public records, public and private agencies, and individuals knowledgeable about the locale of a potential site. Although in some cases, applicants may have conducted on-the-spot investigations, this RG assumes that such investigations would be limited to reconnaissance-type surveys at this stage.

Safety and Environmental Issues in Site Selection

In accordance with 10 CFR Part 100, the safety issues to be addressed in site selection include geologic/seismic, hydrologic, and meteorologic characteristics of proposed sites, exclusion area and low population zone (LPZ), population considerations as they relate to protecting the general public from the potential hazards of serious accidents, potential effects on a station from accidents associated with nearby industrial, transportation, and military facilities, emergency planning, and security plans. NEPA covers the environmental issues to be addressed in site selection. These issues include potential impacts from the construction and operation of commercial nuclear power stations on ecological systems, water use, land use, the atmosphere, aesthetics, socioeconomics, and environmental justice.

Geology and Seismology

Commercial nuclear power stations must be designed to prevent the loss of safety related functions. Generally, the most restrictive safety related site characteristics considered in determining the suitability of a site are potential surface faulting, ground motion, foundation conditions[4] (including liquefaction, settlement, and landslide potential), and seismically induced floods and water waves.

Atmospheric Extremes and Dispersion

The atmospheric characteristics at a site are an important consideration in evaluating the dispersion of radioactive effluents from both postulated accidents and routine releases in gaseous

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3 The "human environment" is defined as the natural and physical environment and the relationship of people to that environment. The human environment includes, but is not limited to, geology, geomorphology, surface and ground water hydrology, climatology, air quality, limnology, water quality, fisheries, wildlife habitat, scenic resources, recreation resources, archeological and historical resources, community (environmental justice) resources, and land use.

4 See NUREG-0800, Section 2.5.1, "Basic Geologic and Seismic Information."

effluents. Radiation doses associated with airborne radioactive materials from routine releases and anticipated operational occurrences must be kept as low as is reasonably achievable (ALARA) and must comply with effluent concentration limits, dose limits for members of the public, and the environmental radiation standards of the U.S. Environmental Protection Agency (EPA). In addition to meeting the NRC requirements for the dispersion of airborne radioactive material in 10 CFR Part 20, "Standards for Protection against Radiation," and Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light Water Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50, the station must meet the State and Federal requirements of the Clean Air Act of 1970 (42 U.S.C. 7401 et seq.), as amended (Ref. 22).

Local fogging and icing can result from water vapor discharged into the atmosphere from cooling towers, lakes, canals, or spray ponds but can generally be acceptably mitigated by station design and operational practices.

Cooling towers produce cloudlike plumes that vary in size and altitude depending on the atmospheric conditions. The plumes often extend a few miles in length before dissipating; the plumes themselves or their shadows could have aesthetic impacts and in rare occasions can result in mist or light snow reaching the ground downwind of the cooling towers. Visible plumes emitted from cooling towers in the vicinity of airports could pose a hazard to aviation.

Exclusion Area and Low Population Zone

A reactor licensee is required by 10 CFR 100.21(a) to designate an exclusion area and to have authority to determine all activities within that area, including removal of personnel and property. In selecting a site for a commercial nuclear power station, it is necessary to provide for an exclusion area in which the applicant has such authority. A reactor licensee is also required by 10 CFR 100.21(a) to designate an area immediately surrounding the exclusion area as an LPZ.

In 10 CFR 100.3, "Definitions," the NRC states that transportation corridors such as highways, railroads, and waterways are permitted to traverse the exclusion area provided that (1) these are not so close to the facility as to interfere with normal operation of the facility, and (2) in case of emergency, appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway to protect public health and safety.

Population Considerations

Locating reactors away from densely populated centers is part of the NRC's defense in depth philosophy and facilitates emergency planning and preparedness. It also reduces potential doses and property damage in the event of a severe accident. As stated in 10 CFR 100.21(h), reactors should be located away from very densely populated centers; areas of low population density are generally preferred. In addition, 10 CFR 100.21(h) states that, in determining the acceptability of a particular site located away from a very densely populated center but not in an area of low density, safety, environmental, economic, or other factors that may result in the site being found acceptable must be considered. The numerical values in this guide are generally consistent with past NRC practice and reflect consideration of severe accidents for large LWRs, as well as the demographic and geographic conditions of the United States.

Emergency Planning

To ensure that members of the public can be protected in an emergency, 10 CFR Part 100 requires that the applicant identify the physical characteristics of the site that could significantly impede the development of emergency plans.

Security

In 10 CFR Part 100, the NRC also requires that potential sites be examined to determine whether any site characteristics would prevent the development and implementation of adequate security plans and measures. This should include examination of any existing or potential natural or manmade hazards at or near the site.

Hydrology

Flooding

In 10 CFR Part 100, the NRC requires that potential sites be examined for suitability with respect to flooding hazards. The number and types of flood-causing phenomena, flooding mechanisms, and flooding hazards to consider will depend on the site. The potential for site-scale flooding due to intense local precipitation affects all sites. Sites near streams or rivers may be affected by riverine flooding due to rainfall or snowmelt, dam failure, river blockage, or channel diversion. Storm surges, seiches, or tsunamis may affect sites near lakes, reservoirs, estuaries, or oceans. Where applicable, the potential for flooding events due to the combined effects of multiple flooding mechanisms (e.g., rainfall with snowmelt, rainfall with dam failure, storm surge with wind waves and tides) should be considered. The potential for sea level rise and other global climate change effects should also be considered.

Water Availability

Nuclear power stations require reliable sources of water for steam condensation, service water, the emergency core cooling system, and other functions. Limitations imposed by existing laws or allocation policies govern the use and consumption of cooling water at potential sites for normal operation. Based on plant design, consumption of water may necessitate an evaluation of existing and future water uses in the area to ensure adequate water supply during droughts for both station operation and other water users (i.e., commercial nuclear power station requirements versus public water supply). It may be necessary to consult other Federal, State, or local regulatory agencies to avoid potential conflicts.

Water Quality

Thermal and chemical effluents discharged to navigable streams are governed by the CWA and regulated by Federal and State water quality standards. The States administer significant portions of the CWA. In some instances, State approvals or permits are needed before the NRC can issue a license.

Radionuclide Retention and Transport

Aquifers that are or may be used for domestic, municipal, industrial, or irrigation water supplies provide potential pathways for the transport of radioactive material to the population in the event of an accident. The retardation, dispersion, and dilution capabilities and potential contamination pathways of the ground water environment under operating and accident conditions, with respect to present and future users, are important factors in site selection.

Industrial, Military, and Transportation Facilities

Accidents at present or projected nearby industrial, military, and transportation facilities may affect the safety of a commercial nuclear power station.

Accidents at nearby industrial facilities, such as chemical plants, refineries, mining and quarrying operations, oil or gas wells, or gas and petroleum product storage installations, may produce missiles, blast overpressure, fires, flammable vapor clouds, or toxic chemicals. These accidents may affect the station itself or the station operators in a way that jeopardizes station safety.

Accidents at nearby military facilities, such as munitions storage areas and ordnance test ranges, may threaten station safety.

An accident during the transport of hazardous materials (e.g., by air, waterway, railroad, highway, or pipeline) near a commercial nuclear power station may generate blast overpressure, missiles, and toxic or corrosive gases that could affect safe station operation. The consequences of such an accident will depend on the proximity of the transportation facility to the site, the nature and maximum quantity per shipment of the hazardous material, and the layout of the nuclear station.

Airports and airways including military training routes and military airspaces pose hazards to nearby commercial nuclear power stations. Potential threats to stations from aircraft include aircraft impact and the secondary effects of a crash (e.g., fire).

Ecological Systems and Biota

The potential impact of station construction and operation on biota (plant or animal species) and on their habitats and supporting ecological systems needs to be assessed to fulfill NEPA requirements. Considerations may include (among others) habitat loss and degradation; preservation of migratory routes; and entrainment, impingement, and entrapment of aquatic biota.

A species, whether animal or plant, is important (for the purposes of this guide) if a specific causal link can be identified between the commercial nuclear power station and the species and if at least one of the following applies:

(1) The species is commercially or recreationally valuable.

(2) The species is endangered or threatened.

(3) The species affects the well-being of some important species under either criterion (1) or (2), is critical to the structure and function of a valuable ecological system or is a biological indicator of radionuclides in the environment.

The Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended (Ref. 23), provides the following definitions:

> The term “endangered species” means any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man. The term “threatened species” means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The Secretary of the Interior periodically publishes lists of endangered and threatened species in the *Federal Register*.

When the ecological sensitivity of a site under consideration cannot be established from existing information, more detailed studies, as discussed in RG 4.2, may be necessary. Design and operational practices may mitigate the impacts of station construction and operation on biota and ecological systems.

Land Use and Aesthetics

Site suitability may be limited by the existence of nearby established public resource areas, prospective designated resource areas, zoning, land use plans adopted by Federal, State, regional, or local agencies, or aesthetic considerations.

Socioeconomics

Social and economic issues are important determinants of siting policy. The siting, construction, and operation of a commercial nuclear power station might have significant impacts on the socioeconomic structure of nearby communities (e.g., population and income distributions, access to private and public services).

Environmental Justice

Siting decisions should reflect fair treatment and meaningful involvement of all people, regardless of race, ethnicity, culture, income, or educational level, to ensure equitable consideration. Decisions should include an analysis to determine whether any significant impacts would fall disproportionately on minority or low-income communities. This could involve the assembly and analysis of considerable quantitative data.

Noise

Based on location, noise levels at nuclear stations during both construction and operation could have undesirable impacts. For example, cooling towers (if present), turbines, and transformers contribute to noise during station operation, and such noise could have varying levels of environmental impact, depending on the site. Estimating the impact level for a particular site is important when comparing different sites.

Limited Work Authorization

The limited work authorization (LWA) process allows applicants to request approval to perform certain construction activities before the issuance of a construction permit or COL. The regulations in 10 CFR 50.10, "License required; limited work authorization," govern the issuance of LWAs and specify the information to be included in an LWA application. These regulations clarify that activities defined as "construction," for purposes of an LWA, are those that fall within the NRC's regulatory authority because they have a reasonable nexus to radiological health and safety or the common defense and security. Activities not considered "construction" may be performed without an NRC licensing action.

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety

Requirements and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports, reflects an international perspective on what constitutes a high level of safety. To inform its development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides pursuant to the Commission's International Policy Statement (Ref. 24) and Management Directive and Handbook 6.6, "Regulatory Guides" (Ref. 25).

The following IAEA Safety Requirements and Guides were considered in the development of this guide:

- IAEA Safety Standards Series, Safety Guide No. NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants," issued 2003 (Ref. 26)

- IAEA Safety Standards, Specific Safety Requirements No. SSR-1, "Site Evaluation for Nuclear Installations," issued 2019 (Ref. 27)

- IAEA Safety Standards, Specific Safety Requirements No. SSR-2/1, "Safety of Nuclear Power Plants: Design" (Rev. 1), issued 2016 (Ref. 28)

- IAEA Safety Standards, Specific Safety Guide No. SSG18, "Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations," issued 2011 (Ref. 29)

- IAEA, Safety Standards, Specific Safety Guide No. SSG21, "Volcanic Hazards in Site Evaluation for Nuclear Installations," issued 2012 (Ref. 30)

C. STAFF REGULATORY GUIDANCE

Site selection can be facilitated by establishing limits for various parameters based on the best judgment of specialists knowledgeable about the region under consideration. For example, limits can be chosen for the fraction of water that can be diverted in certain situations without adversely affecting the local populations of important species. Although simplistic (because they do not account for factors such as the distribution of important species in the water body), such limits can be useful in a screening process for site selection.

1. Safety Considerations for Assessing Site Suitability for Commercial Nuclear Power Stations

1.1 Geology and Seismology

Information on the geologic structures and features underlying the site location, and in the region, surrounding the facility site should be evaluated. This evaluation should include the potential for surface deformation, and the history and potential for damaging seismic ground motions that could impact reactor safety.

1.1.1 Relevant Regulations

- 10 CFR 50, Appendix A, Criterion 2, “Design bases for protection against natural phenomena,”
- 10 CFR 52.17 “Contents of applications: technical information,”
    - 10 CFR 52.17(a)(1)(vi),
- 10 CFR 100.20, “Factors to be considered when evaluating sites,”
- 10 CFR 100.21, “Non-seismic site criteria,”
- 10 CFR 100.23, “Geologic and seismic siting criteria.”

1.1.2 Related Guidance

- RG 1.29, “Seismic Design Classification for Nuclear Power Plants” (Ref. 31),
- RG 1.132, “Geologic and Geotechnical Site Characterization Investigations for Nuclear Power Plants” (Ref. 32),
- RG 1.138, “Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants” (Ref. 33),
- RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites” (Ref. 34),
- RG 1.206, “Applications for Nuclear Power Plants,”
- RG 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion” (Ref. 35),

- RG 4.26, “Volcanic Hazards Assessment for Proposed Nuclear Reactor Sites” (Ref. 36),
- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,”
- NUREG-2213, “Updated Implementation Guidelines for SSHAC Hazard Studies” (Ref. 37),
- NUREG-2115, “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities” **(**Ref. 38),
- ANSI/ANS-2.27-2020, “Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessment” (Ref. 39),
- ANSI/ANS 2.29-2020, “Probabilistic Seismic Hazard Analysis (Ref. 40).”

1.1.3 Considerations, Regulatory Experience, and Staff Position

Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi), and 10 CFR 100.23 present the principal geologic and seismic considerations that guide the NRC in its evaluation of the suitability of a proposed site. RG 1.206 provides guidance on the format and content of applications for nuclear power plant submitted to the NRC under 10 CFR 52. RG 1.208, RG 1.132, and RG 1.198 contain guidance for addressing these characteristics. NUREG 2213 provides guidance on a suitable approach for capturing the uncertainties associated with determining the safe shutdown earthquake ground motion, as required by 10 CFR Part 100.23. ANS 2.27 provides the most recent guidance on the geologic investigations necessary to perform a probabilistic seismic hazard analysis (PSHA) for nuclear power facilities and ANS 2.29 provides the most recent guidance on performing a suitable PSHA for nuclear power facilities.

1.2 Atmospheric Extremes and Dispersion

The potential effect of natural atmospheric extremes on the safety-related structures of a nuclear station should be considered. Site atmospheric conditions important to site suitability also relate to the calculation of radiation doses resulting from the airborne release of fission products from routine operations, anticipated operational occurrences, and postulated design-basis accidents.

1.2.1 Atmospheric Extremes

The potential effect of natural atmospheric extremes (e.g., tornadoes, hurricanes, and exceptional icing conditions), regional climatology, and local meteorology on the safety-related structures of a nuclear station should be considered.

1.2.1.1 Relevant Regulations

- 10 CFR Part 50, Appendix A, Criterion 2, “Design bases for protection against natural phenomena,”
- 10 CFR 52.17, “Contents of applications; technical information,”
- 10 CFR 52.79, “Contents of applications; technical information in final safety analysis report.”

1.2.1.2 Related Guidance

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (Ref. 41),

- RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Ref. 42),

- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants" (Ref. 43), and

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

1.2.1.3 Considerations, Regulatory Experience, and Staff Position

NUREG-0800, Section 2.3.1, "Regional Climatology," contains the NRC staff's review procedures for examining the general climate of a region, such as 100-year return periods for extreme weather conditions for winter precipitation, maximum straight-line windspeed, and ambient temperature and humidity, that define a site's meteorological characteristics.

An evaluation of the water requirements for the ultimate heat sink should consider a minimum 30-year weather record, if available, and should follow the guidance provided in RG 1.27. The applicability of these and other climatological data to represent site conditions during the expected period of reactor operation should be substantiated.

Data and studies on longer term weather cycles should be examined because climate change may affect parameters used to characterize a site and may have an impact on nuclear safety and the environment.

Atmospheric extremes that may occur at a site should be considered, even though they are not necessarily critical in determining site suitability, because safety related SSCs can be designed to withstand most atmospheric extremes (with associated site-specific costs). Current literature on possible weather changes in the site region should also be reviewed to confirm that the methods used to predict weather extremes are reasonable.

1.2.2 Atmospheric Dispersion

The atmospheric characteristics at a site are an important consideration in evaluating the dispersion of radioactive effluents from both postulated accidents and routine releases in gaseous effluents. Radiation doses associated with airborne radioactive materials from routine releases and anticipated operational occurrences must be ALARA and must comply with effluent concentration limits. In addition to meeting the NRC requirements for the dispersion of airborne radioactive material, the station must meet the State and Federal requirements of the Clean Air Act.

1.2.2.1 Relevant Statutes and Regulations

- Clean Air Act,

- 10 CFR 50.34, "Contents of applications; technical information,"

- 10 CFR 50.34a, "Design objectives for equipment to control releases of radioactive material in effluents—nuclear power reactors,"

- 10 CFR Part 50, Appendix I, “Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents,”

- 10 CFR Part 51, “Environmental protection regulations for domestic licensing and related regulatory functions,”

- 10 CFR 52.17, “Contents of applications; technical information,”

- 10 CFR 52.79, “Contents of applications; technical information in final safety analysis report,”

- 10 CFR Part 20, Appendix B, “Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage,”

- 10 CFR 20.1301, “Dose limits for individual members of the public,”

- 10 CFR 20.1302, “Compliance with dose limits for individual members of the public,”

- 10 CFR 20.1101, “Radiation protection programs,”

- 10 CFR 100.21, “Non-seismic site criteria,”

    - 10 CFR 100.21(c)(1), and

- 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations” (Ref. 44).

1.2.2.2 Related Guidance

- RG 1.23, “Meteorological Monitoring Programs for Nuclear Power Plants” (Ref. 45),

- RG 1.145, “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants” (Ref. 46),

- RG 1.109, “Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I” (Ref. 47),

- RG 1.111, “Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors” (Ref. 48),

- NUREG-0800, Section 2.3.3, “Onsite Meteorological Measurements Programs,” Section 2.3.4, “Short-Term Atmospheric Dispersion Estimates for Accident Releases,” Section 2.3.5, “Long-Term Atmospheric Dispersion Estimates for Routine Releases,” and Section 15.0.3, “Design Basis Accident Radiological Consequences of Analyses for Advanced Light Water Reactors,” and

- RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors” (Ref. 49).

1.2.2.3 Considerations, Regulatory Experience, and Staff Position

In 40 CFR Part 190, the EPA limits the radiation releases and doses to the public from the normal operations of commercial nuclear power plants and other uranium fuel cycle facilities (the facilities involved in the manufacture and use of uranium fuel for generating electrical power). In addition, the regulation specifies limits on the quantity of radioactive materials entering the general environment per gigawatt-year of electricity produced. The NRC has developed regulations (10 CFR part 20) and guidance (RG 1.109, RG 1.111) to ensure that these limits are not exceeded.

The atmospheric conditions at a site should provide sufficient dispersion of radioactive materials released during a postulated accident to reduce the radiation exposures of individuals at the exclusion area and LPZ boundaries to the values in 10 CFR 50.34, "Contents of applications; technical information;" 10 CFR 52.17, "Contents of applications; technical information;" and 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report."

The atmospheric conditions at a site should also be characterized to appropriately model dispersion of radioactive materials from airborne release of fission products during routine operations and anticipated operational occurrences, to show compliance with the effluent concentration limits of Appendix B to 10 CFR Part 20 and with dose limits for members of the public under 10 CFR 20.1301 and 10 CFR 20.1302.

The concentration of radioactive materials in the atmosphere downwind from a release source is determined using an atmospheric dispersion factor known as a χ/Q value or relative concentration factor. It is defined as the airborne concentration χ (in curies per cubic meter) at the downwind location of interest, divided by the rate of release of radioactive materials from the source, Q (in curies per second). A similar term, the atmospheric deposition factor or D/Q value, is used to determine the rate of ground-level deposition at a downwind location of interest. It is defined as the rate of ground-level deposition D (curies per square meter per second) at the downwind location of interest, divided by the rate of release of radioactive materials from the source, Q. The standard practice has been to evaluate χ/Q and D/Q values because they depend only on atmospheric variables, distance from the source, radionuclide chemical and physical characteristics, and whether airborne releases occur from a single plant stack or through multiple building vents or plant stacks. If the dispersion of radioactive material released following a design basis accident is insufficient at the boundary of the exclusion area (see section C.1.3 of this RG) or at the outer boundary of the LPZ, the plant design will not satisfy the requirements in 10 CFR 50.34(a)(1). In this case, the design will be required to include appropriate and adequate compensating engineered safety features. In addition, meteorological conditions are to be determined (1) for use in the environmental report required by 10 CFR Part 51, (2) for verification of the criteria in the design control document for a certified plant design, and (3) for use in demonstrating that airborne radiological effluent release limits can be met for any individual located off site, as required by 10 CFR 100.21(c)(1).

RG 1.23 describes atmospheric data that the staff considers acceptable for the required assessment of the potential dispersion of radioactive material. NUREG-0800, section 2.3.3, describes the NRC staff's review procedures for onsite meteorological measurements programs.

Evaluations of potential sites should consider available atmospheric data for the local site area. Atmospheric variables for canyons or deep valleys often differ substantially from those measured for the general region. Other topographical features, such as hills, mountain ranges, and lake or ocean shorelines, can affect the local atmospheric conditions at a site and can cause the dispersion characteristics at the site to be less favorable than those in the general region. Such cases might require more stringent design or effluent objectives. In some areas, local atmospheric conditions cause inversion, which severely limits local atmospheric dispersion capabilities. Therefore, siting decisions should consider the likelihood of inversion due to local conditions.

Engineered safety features can compensate for safety-related design-basis atmospheric dispersion characteristics that are unfavorable. Accordingly, section C.1.3 of this RG describes the NRC staff's regulatory position on atmospheric dispersion of radiological effluents.

1.3 Exclusion Area and Low Population Zone

In the event of a postulated accident at a commercial nuclear power station, radiological consequences for individual members of the public outside the station must be acceptably low. Defining exclusion areas and LPZs around the station is integral in achieving this goal. A reactor licensee is required to designate an exclusion area and to have authority to determine all activities within that area, including removal of personnel and property. In selecting a site for a commercial nuclear power station, it is necessary to provide an exclusion area in which the applicant has such authority. A reactor licensee is also required to designate an area immediately surrounding the exclusion area as an LPZ. The site selection process should account for this as well.

1.3.1 Relevant Regulations

- 10 CFR 50.34a, "Design objectives for equipment to control releases of radioactive material in effluents— nuclear power reactors,"
    - 10 CFR 50.34(a)(1)(ii)(D)(*1*),
    - 10 CFR 50.34(a)(1)(ii)(D)(*2*),
- 10 CFR 52.17 "Contents of application: technical information,"
    - 10 CFR 52.17(a)(1)(ix)(A),
    - 10 CFR 52.17(a)(1)(ix)(B),
- 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report,"
    - 10 CFR 52.79(a)(1)(vi)(A),
    - 10 CFR 52.79(a)(1)(vi)(B, and
- 10 CFR 100.21, "Non-seismic site criteria,"
    - 10 CFR 100.21(a).

1.3.2 Related Guidance

- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors;"
- RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," and

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

1.3.3 Considerations, Regulatory Experience, and Staff Position

The regulations in 10 CFR 100.21(a) require an "exclusion area" surrounding the reactor, in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property. Transportation corridors such as highways, railroads, and waterways are permitted to traverse the exclusion area, provided that (1) these are not so close to the facility as to interfere with normal operation of the facility, and (2) in case of emergency, appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway in order to protect public health and safety.

A reactor licensee is also required by 10 CFR 100.21(a) to designate an area immediately surrounding the exclusion area as an LPZ. The size of the LPZ must be such that the distance from the reactor to the boundary of the nearest densely populated center containing more than about 25,000 residents is at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. The boundary of the population center is determined by population distribution, not political boundaries.

In accordance with 10 CFR 50.34(a)(1)(ii)(D)(*1*), 10 CFR 52.17(a)(1)(ix)(A), and 10 CFR 52.79(a)(1)(vi)(A), the exclusion area is required to be of such a size that an individual located at any point on its outer boundary would not receive a radiation dose above 25 rem total effective dose equivalent (TEDE) over any 2-hour period following a postulated fission product release. The required exclusion area size depends on the atmospheric characteristics of the site, as well as on plant design.

In accordance with 10 CFR 50.34(a)(1)(ii)(D)(*2*), 10 CFR 52.17(a)(1)(ix)(B), and 10 CFR 52.79(a)(1)(vi)(B), the LPZ must be of such a size that an individual located on its outer boundary during a postulated accident would not receive a radiation dose above 25 rem TEDE. The required LPZ size depends on the atmospheric dispersion characteristics and population characteristics of the site, as well as on plant design.

The regulations in 10 CFR 52.17 for ESPs and 10 CFR 52.79 for COLs require an applicant's site safety analysis report and final safety analysis report, respectively, to include information on site location, the facility location on the site, population characteristics, locations of nearby facilities, postulated releases in the event of an accident, and other technical factors. NUREG-0800, Section 2.1.1, "Site Location and Description," and section 2.1.2 describe the NRC staff's review procedures for the site location, description, and exclusion area authority and control.

Based on the assumptions in the radiological consequence analyses for the design-basis accident, the required distances to the exclusion area boundary and the outer boundary of the LPZ will depend on aspects of the plant design, such as the reactor power level, allowable containment leak rate, and engineered safety features, as well as the atmospheric dispersion characteristics of the site.

RG 1.183 provides useful information on the design-basis accident radiological consequences analyses performed to show compliance with the siting dose requirements for the exclusion area boundary and LPZ.

1.4 Population Considerations

Locating reactors away from densely populated centers is part of the NRC's defense in depth philosophy and facilitates emergency planning and preparedness, as well as reducing potential doses and property damage in the event of a severe accident.

1.4.1 Relevant Regulations

- 10 CFR 50.34, "Contents of applications; technical information,"
- 10 CFR 52.17, "Contents of applications; technical information,"
- 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," and
- 10 CFR 100.21 "Non-seismic site criteria,"
    - 10 CFR 100.21(h).

1.4.2 Related Guidance

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," and
- American National Standards Institute/American Nuclear Society (ANSI/ANS) Standard ANSI/ANS-2.6-2018, "Standard Guidelines for Estimating Present & Projecting Future Population Distributions Surrounding Power Reactor Sites" (Ref. 50).

1.4.3 Considerations, Regulatory Experience, and Staff Position

As stated in 10 CFR 100.21(h), reactor sites should be located away from very densely populated centers. Areas of low population density are generally preferred. In addition, 10 CFR 100.21(h) states that, for a site located away from a very densely populated center but not in an area of low density, acceptability will be determined after consideration of safety, environmental, economic, and other factors.

The numerical values in this guide are generally consistent with past NRC practice for large LWRs and reflect consideration of severe accidents, as well as the demographic and geographic conditions of the United States.

ANSI/ANS-2.6-2018 provides information on performing population counts and estimating future population.

Preferably, a reactor should be located so that, at the time of initial site approval and for about 5 years thereafter, the population density, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the area at that distance), is at most 500 persons per square mile. A reactor should not be located at a site where the population density is well in excess of this value.

The NRC staff has developed additional guidance in Appendix A of this RG on alternatives to the established population-density criterion to support licensing for non-LWRs and light-water small modular reactors with attributes that could support siting a commercial nuclear power station closer to population centers than is typical for large LWRs. Appendix A includes alternative population density criteria based on estimates of radiological consequences from design-specific events and provides additional ways that applicants can meet the requirements of 10 CFR 100.21(h). An applicant can demonstrate compliance with 10 CFR 100.21(h) by siting a nuclear reactor in a location where the population density does not exceed 500 persons per square mile out to a distance equal to twice the distance at which a hypothetical individual could receive a calculated TEDE of 1 rem over a period of 30 days from the release of radionuclides following postulated accidents (see appendix A for more details).

If the population density of the proposed site exceeds, but is not well in excess of, the preferred value, the analysis of alternative sites should pay particular attention to alternative sites with lower population density. Other factors, such as safety, environmental, or economic characteristics, may render the site with higher population density acceptable. For example, the site with higher population density may have superior seismic characteristics, better rail or highway access, or shorter transmission line requirements, or construction there may have less environmental impact on undeveloped areas, wetlands, or endangered species.

Transient population should be included for those sites where many people (other than those just passing through the area) work, reside part-time, or engage in recreational activities but are not permanent residents. Calculations should weight members of the transient population according to the fraction of time they spend in the area.

As noted above, population data should be estimated for the time of initial plant approval. Population projections through the lifetime of the facility should be considered, with further population projections made by decade for a 40-year period beyond the start of plant operation. For an ESP, an applicant should assume that plant approval occurs at the end of the term of the permit.

Evaluations of the proposed site and any alternative sites considered should include projected changes in population within about 5 years after initial plant approval. Population growth near the site after initial plant approval is normal and expected and should periodically be factored into the emergency plan for the site, but population increases after initial plant approval should not be a factor in license renewal or, by themselves, be used to impose other license conditions or restrictions on an operating plant.

1.5 Emergency Planning

Development of emergency plans is a site-specific task in which the physical characteristics of the site and its surroundings play a significant role. To ensure that adequate measures can be taken to protect members of the public in an emergency, the characteristics of the site should not preclude development of such plans.

1.5.1. Relevant Regulations

- 10 CFR 50.47 “Emergency plans,”

- 10 CFR 50.160, “Emergency preparedness for small modular reactors, non-light-water reactors, and non-power production or utilization facilities,”

- 10 CFR Part 50, Appendix E “Emergency Planning and Preparedness for Production and Utilization Facilities,”

- 10 CFR Part 52, Subpart A “Early Site Permits,” §52.17 “Contents of applications; technical information,”
- 10 CFR Part 52, Subpart A “Early Site Permits,” §52.18 “Standards for review of applications,”
- 10 CFR Part 52, Subpart A “Early Site Permits,” §52.39 “Finality of early site permit determinations,”
- 10 CFR Part 52, Subpart C “Combined Licenses,” §52.79 “Contents of applications; technical information in the final safety analysis report,” and
- 10 CFR 100.21, “Non-seismic siting criteria.”

1.5.2 Related Guidance

- NUREG-0654/FEMA-REP-1, Revision 2, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants,” issued December 2019 (Ref. 51),
- RG 1.183, which provides information on the appropriate use of accident source terms in establishing emergency response procedures such as those for emergency dose projections, protective measures, and severe accident management,
- RG 1.242, “Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization,” (Ref. 52) provides guidance on implementing a performance-based, technology-inclusive, risk-informed, and consequence-oriented approach to EP that provides an alternative to the EP requirements under 10 CFR 50.47(b) and Appendix E to 10 CFR Part 50, and
- NUREG/CR-7002, Revision 1, “Criteria for Development of Evacuation Time Estimate Studies,” issued February 2021 (Ref. 53).

1.5.3 Considerations, Regulatory Experience, and Staff Position

NRC requirements pertaining to emergency planning were first developed in 10 CFR Part 50 (§50.47 and Appendix E) with respect to construction permits and operating licenses. Emergency planning requirements for ESPs and COLAs are contained in 10 CFR Part 52 Subpart A, and 10 CFR Part 52 Subpart C, respectively. NRC reviews and approves emergency plans in consultation with the Federal Emergency Management Agency (FEMA), as described in NUREG-0654/FEMA-REP-1.

In 10 CFR 50.47(a)(1), the NRC requires a reasonable assurance finding that adequate protective measures can and will be taken in a radiological emergency. Emergency plans must include information at sufficient levels to allow the Commission to make its determination. The regulation in 10 CFR 50.47(b) includes 16 elements that must be included in the emergency plans. These elements include, but are not limited to, procedures for requesting offsite assistance, communications, and the conduct of exercises that demonstrate the ability to respond to emergencies. 10 CFR 50.47(d) allows issuance of an operating license authorizing only fuel loading or low-power testing and training (up to 5 percent of the rated power) without certain NRC or Federal Emergency Management Agency reviews, findings, or determinations concerning the state of offsite emergency preparedness.

Adequate plans must be developed for two areas, or emergency planning zones (EPZs): the plume exposure pathway EPZ and ingestion pathway EPZ. As stated in 10 CFR 50.47, the plume exposure pathway EPZ for nuclear power plants generally consists of an area about 16 kilometers (km) (10 miles (mi)) in radius, and the ingestion pathway EPZ generally consists of an area about 80 km (50 mi) in radius. The exact size and configuration of the EPZs should be determined in relation to local emergency response needs and capabilities, as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries.

Under 10 CFR 100.21(g), an applicant must identify physical characteristics unique to the proposed site that could significantly impede the development of emergency plans. The site and its vicinity, including the population distribution and transportation routes, should be examined and evaluated to determine whether any characteristics would significantly impede actions to protect the public in an emergency. Other factors should also be addressed when identifying significant impediments to the development of emergency plans; these include the availability of adequate shelter facilities, local building practices and land use (e.g., outdoor recreation facilities, including camps, beaches, and hunting or fishing areas), and the presence of large institutional or other special needs populations (e.g., schools, hospitals, nursing homes, prisons).

An evacuation time estimate (ETE) may be used to identify favorable and unfavorable physical characteristics. The ETE analysis is an emergency planning tool that systematically assesses the feasibility of taking protective measures for the surrounding population. Its value lies in the methodology used for the analysis rather than in the calculated ETEs. While lower ETEs may reflect site characteristics that are favorable for emergency planning, there is no requirement for an applicant to meet a minimum evacuation time. NUREG/CR-7002 gives information on performing ETE analyses.

The regulations in 10 CFR 52.17(b)(1) require an ESP applicant's safety analysis report to identify physical characteristics of the proposed site, such as egress limitations from the area surrounding the site, that could significantly impede the development of emergency plans. If such physical characteristics are identified, the application must identify measures whose implementation would mitigate or eliminate the impediment.

10 CFR 52.17(b)(2) through 10 CFR 52.17(b)(4) describe requirements depending upon whether the ESP application proposes only major features of the emergency plans or proposes complete and integrated emergency plans. Conditions under which emergency plans approved in an ESP may need to be modified are described in 10 CFR 52.39 "Finality of early site permit determinations."

The NRC incorporated a technology-inclusive and consequence-oriented approach to emergency planning into the regulations by adding 10 CFR 50.160, "Emergency preparedness for small modular reactors, non-light-water reactors, and non-power production or utilization facilities." The requirements include a scalable emergency planning zone around a facility. Applicants and licensees for small modular reactors (SMRs) and other new technologies can use the rule in developing a performance-based emergency preparedness program as an alternative to the radiological emergency planning requirements in 10 CFR 50.47 and Appendix E to 10 CFR Part 50. Guidance for using the rule is provided in RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities."

1.6 Security

Applicants should analyze whether potential sites are suitable for the development and implementation of security plans and whether site characteristics may adversely affect response activities related to security operations.

1.6.1 Relevant Regulations

- 10 CFR 50.34, "Contents of applications; technical information,"
  - o 10 CFR 50.34(c),
- 10 CFR 52.17, "Contents of applications; technical information,"
  - o 10 CFR 52.17(a)(1)(x),
- 10 CFR Part 73, "Physical Protection of Plants and Materials" (Ref. 54), and
- 10 CFR 100.21, "Non-seismic site criteria,"
  - o 10 CFR 100.21(f).

1.6.2 Related Guidance

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

1.6.3 Considerations, Regulatory Experience, and Staff Position

The applicant must analyze site characteristics and hazards to determine whether adequate security plans and measures can be developed. The characteristics and hazards of natural features and of existing or projected manmade features at or near a proposed site must not preclude development of adequate security plans and should not prevent security operations from meeting NRC requirements (see also 10 CFR Part 73).

Applicants must comply with 10 CFR 50.34(c), which requires that security plans describe how the applicant will meet the requirements of 10 CFR Part 73. The security plans must list tests, inspections, audits, and other means to be used to demonstrate compliance with the requirements of 10 CFR Part 11, "Criteria and Procedures for Determining Eligibility for Access to or Control over Special Nuclear Material," and 10 CFR Part 73, if applicable.

ESP applicants must comply with 10 CFR 52.17(a)(1)(x) and 10 CFR 100.21(f), which require that site characteristics allow for the development of adequate security plans and measures. NUREG-0800, Section 13.6.1, "Physical Security—Combined License and Operating Reactors," and Section 13.6.3, "Physical Security—Early Site Permit and Reactor Siting Criteria," address in part the location of transportation routes (e.g., rail, water, and roads), pipelines, airports, hazardous material facilities, and pertinent environmental features whose effects on security plans and response activities should be considered.

In 10 CFR 52.17(a)(1)(xii), the NRC requires, in part, that an ESP applicant's site safety analysis report include "an evaluation of the site against applicable sections of the Standard Review Plan (SRP) revision in effect 6 months before the docket date of the application."

1.7 Hydrology

Hydrologic site suitability criteria relate to potential flooding hazards, safety related water supply, and radionuclide transport.

1.7.1 Flooding

Potential sites should be examined for suitability with respect to flooding hazards. The number and types of flood-causing phenomena, flooding mechanisms, and flooding hazards to consider will depend on the site. The potential for site-scale flooding due to intense local precipitation applies to all sites. Riverine flooding due to rainfall or snowmelt, dam failure, river blockage, or channel diversion may affect sites near streams or rivers. Sites near lakes, reservoirs, estuaries, or oceans may be affected by storm surges, seiches, or tsunamis. King (spring) tides may cause flooding in some coastal or estuary locations. In some coastal areas, sea level rise may result in progressively longer and more frequent coastal flooding events. Where applicable, the potential for flooding events due to the combined effects of multiple flooding mechanisms (e.g., rainfall with snowmelt, rainfall with dam failure, storm surge with wind waves and tides) should be considered.

1.7.1.1 Relevant Regulations

- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants", GDC 2 "Design Bases for Protection Against Natural Phenomena,"
- 10 CFR 52.17, "Contents of applications; technical information,"
- 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report,"
- 10 CFR 100.10, "Factors to be considered when evaluating sites,"
- 10 CFR 20, "Standards for Protection Against Radiation," and
- 10 CFR 100.23, "Geologic and seismic siting criteria."

1.7.1.2 Related Guidance

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,"
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (Ref. 55),
- RG 1.206, "Applications for Nuclear Power Plants,"
- ANSI/ANS-2.8-2019, "Probabilistic Evaluation of External Flood Hazards for Nuclear Facilities" (Ref. 56),

- DOE-STD-1020-2016, “Natural Phenomena Hazards Analysis and Design Criteria for DOE” (Ref. 57), and

- DOE-HDBK-1220-2017, “Natural Phenomena Hazards Analysis and Design Handbook for DOE Facilities.” (Ref. 58)

1.7.1.3 Considerations, Regulatory Experience, and Staff Position

The regulations in 10 CFR 100.10 and 10 CFR 100.20, both titled “Factors to be considered when evaluating sites,” outline the physical characteristics to consider when evaluating site suitability. The regulations in 10 CFR 100.23 require determination of the size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity, while 10 CFR 100.21 requires that the physical site characteristics, including non-seismic flood hazards, be evaluated and site parameters established.

RG 1.59 describes an acceptable method for determining the design basis floods for sites along streams or rivers and discusses the phenomena producing comparable design basis floods for coastal, estuary, and Great Lakes sites. This method accounts for sea level rise and other global climate change effects.

It is generally possible to control the effects on station safety functions of a probable maximum flood (as defined in RG 1.59), seiche, surge, or seismically induced flood (such as might be caused by a dam failure or tsunami) through engineering design or protection of the safety-related SSCs identified in RG 1.29.

NUREG-0800, section 2.4, describes how the NRC staff will review design -basis flooding and flood mechanisms at power reactor sites.

ANSI/ANS-2.8-2019, DOE-STD-2020, and DOE-HDBK-1220 give more information on estimating flooding hazards.

1.7.2 Water Availability

Nuclear power stations require reliable sources of water for steam condensation, service water, the emergency core cooling system, and other functions. Where water is in short supply, closed-cycle cooling or the recirculation of the hot cooling water through cooling towers, artificial ponds, or impoundments has been practiced.

1.7.2.1 Relevant Regulations

- 10 CFR 100.10, “Factors to be considered when evaluating sites,”

- 10 CFR 100.20, “Factors to be considered when evaluating sites,” and

- 10 CFR 100.23, “Geologic and seismic siting criteria.”

1.7.2.2 Related Guidance

- RG 1.59, “Design Basis Floods for Nuclear Power Plants,”

- RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants,”

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

1.7.2.3 Considerations, Regulatory Experience, and Staff Position

A safety related water supply is required for normal or emergency shutdown and cooldown, and for fire protection.

An applicant should show that a highly dependable system of water sources is available under postulated occurrences of natural phenomena and site-related accidental phenomena, or combinations of such phenomena, as discussed in RG 1.59. RG 1.27 provides guidance on water supply for the ultimate heat sink and discusses the related safety requirements.

NUREG-0800, Section 2.4.1, "Hydrologic Description," notes that the applicant should identify the sources of hydrometeorological, and stream flow data used to determine that an adequate water supply exists for safety-related SSCs. NUREG-0800, Section 2.4.4, "Potential Dam Failures," describes NRC staff review procedures related to potential loss of water supply due to dam failures and the effects of this loss on safety-related SSCs.

For a site to be suitable, there should be reasonable assurance that the applicant can obtain, from the appropriate State, local, or regional agency, permits for water use and for water consumption in the quantities needed for a commercial nuclear power plant of the stated approximate capacity and type of cooling system.

For both safety and environmental reasons, when identifying potential sites on rivers, small shallow lakes, or coastlines, it is important to consider whether essential water will be available and flow requirements can be met during periods of low flow or low water level. Both the frequency and duration of periods of low flow or low water level should be determined from the historical record and, if the cooling water is to be drawn from impoundments, for projected operating practices. If stream flow records do not cover a period sufficiently long to encompass major droughts or the probable minimum flow for the region, statistical techniques or numerical models may be used to extend and complement the period of record in order to identify the expected minimum flow for the region. The U.S. Geological Survey 7Q10 calculation is an accepted screening-level method for estimating potential low-flow conditions from regional stream flow historical records. This statistical method identifies the minimum value as the lowest 7-day average flow in a 10-year period. If the 7Q10 is too low to supply adequate water for the plant, then other sources of water for non-safety related and safety related structures and ultimate heat sink requirements need to be identified. Bedient et al. (Ref. 59) and Riggs (Ref. 60) provide hydrologic frequency analysis of regional stream gauges with sufficient record lengths to represent expected minimum flows.

1.8 Industrial, Military, and Transportation Facilities

Potential sites should be evaluated for possible safety impacts of operations at nearby industrial, military, and transportation facilities.

1.8.1 Relevant Regulations

- 10 CFR 50.34, "Design objectives for equipment to control releases of radioactive material in effluents— nuclear power reactors,"
    - 10 CFR 50.34(a)(1),

- 10 CFR Part 50, Appendix A, GDC 4, "Environmental and dynamic effects design bases,"
- 10 CFR 52.17, "Contents of applications; technical information,"
    - 10 CFR 52.17(a)(1),
- 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report,"
    - 10 CFR 52.79(a)(1), and
- 10 CFR Part 100, "Non-seismic site criteria,"
    - 10 CFR Part 100.21(e).

1.8.2 Related Guidance

- RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release" (Ref. 61),
- RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants,"
- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,"
- RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants" (Ref. 62),
- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,"
- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,"
    - Section 2.2.3, "Evaluation of Potential Accidents,"
    - Section 3.5.1.4, "Missiles Generated by Tornadoes and Extreme Winds,"
    - Section 3.5.1.5, "Site Proximity Missiles (Except Aircraft),"
    - Section 3.5.1.6, "Aircraft Hazards," and
- DOE-STD-3014-2006, "Accident Analysis for Aircraft Crash into Hazardous Facilities" (Ref. 63).

1.8.3 Considerations, Regulatory Experience, and Staff Position

Accidents at present or projected nearby industrial, military, and transportation facilities may affect the safety of a commercial nuclear power station.

The regulation in 10 CFR 100.21(e) states the following:

Potential hazards associated with nearby transportation routes, industrial and military facilities must be evaluated, and site parameters established such that potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed to be located at the site.

Potentially hazardous facilities and activities including military training routes and transportation routes within 8 kilometers (5 miles) and major airports within 16 kilometers (10 miles) of a proposed site should be identified. If a preliminary evaluation of potential accidents at these facilities or transportation routes indicates that the potential hazards from aircraft crashes, blast overpressure from explosion of flammable vapor clouds, fires, or release of toxic vapors exist, the suitability of the site should be determined through detailed evaluation of the potential hazard. RG 1.91 describes a method acceptable to the NRC staff for determining distances from a plant to a railway, highway, and navigable waterway, or a pipeline carrying hazardous chemicals beyond which any possible explosion on these routes or pipeline is not likely to adversely affect plant operation or to prevent a safe shutdown. Section 3.5.1.6 of NUREG-0800 and DOE-STD-3014-2006 describe methods acceptable to the NRC staff for assessing potential aircraft hazards.

The acceptability of a site depends on establishing that (1) a postulated accident at a nearby industrial, military, or transportation facility will not result in radiological consequences that exceed the dose specified in 10 CFR 50.34, or (2) such a postulated accident poses no undue risk because the annual frequency of its occurring is sufficiently low (less than about $1x10^{-7}$ per year). The identification of design basis events resulting from the presence of hazardous materials or activities near the plant or plants is acceptable if it includes all postulated types of accidents for which it is estimated that the expected rate of occurrence of exposures resulting in radiological doses above those in 10 CFR 50.34(a)(1) (as it relates to the requirements of 10 CFR Part 100) exceeds the order of magnitude of $1x10^{-7}$ per year, which is the NRC staff objective, as described in Sections 2.2.1–2.2.3 of NUREG-0800 and in Section C of RG 1.91.

The frequency of occurrence of initiating events leading to potential consequences in excess of the dose specified in 10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1), and 10 CFR 52.79(a)(1) should be estimated using assumptions that are as realistic as practicable. Because the events under consideration are of such low probability, valid statistical data are often not available to permit accurate quantitative calculation of probabilities. Accordingly, a conservative calculation showing that the annual frequency of occurrence of doses above the value specified in 10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1), and 10 CFR 52.79 (a)(1) is approximately $1x10^{-6}$ per year is acceptable if, through reasonable qualitative arguments, the realistic frequency can be shown to be lower. Because it is difficult to assign precise numerical values to the frequency of occurrence of the relevant types of hazards, judgment should be used as to whether each event presents an acceptable overall risk.

NUREG-0800, section 2.2.3, describes the staff's evaluation procedures and criteria for potential accidents in the site vicinity. The hazards described there should be evaluated in detail to determine site suitability with respect to potential accidents at nearby industrial and military facilities, and transportation routes. Design-basis events have been appropriately considered if analyses have been performed of the effects of such events on the safety related features of a proposed nuclear station, and if appropriate measures (e.g., hardening, fire protection) have been proposed to mitigate the consequences of such events, if necessary. If there are unusual site characteristics, plant design features, or other factors, then different assumptions may be made on a case-by-case basis. In such cases, analyses should conform to the recommendations in RG 1.183 for alternative radiological source terms for evaluating design-basis accidents.

RG 1.78 describes assumptions acceptable to the NRC staff for use in assessing the habitability of the control room during and after a postulated external release of hazardous chemicals. It also describes criteria acceptable to the staff for the protection of control room operators.

An otherwise unacceptable site may be shown to be acceptable if the cognizant organization agrees to change the installation or mode of operation to reduce to an acceptable level the likelihood or severity of potential accidents involving the nuclear station.

2. Environmental Protection Considerations for Assessing Site Suitability for Commercial Nuclear Power Stations

2.1 Atmospheric Dispersion

The atmospheric characteristics at a site are an important consideration in evaluating the dispersion of radioactive effluents from both postulated accidents and routine releases in gaseous effluents.

2.1.1 Dispersion of Airborne Radioactive Material

Radiation doses associated with airborne radioactive materials from routine releases and anticipated operational occurrences must be ALARA and must comply with effluent concentration limits, dose limits for members of the public, the EPA's environmental radiation standards, and Clean Air Act requirements.

2.1.2 Relevant Statutes and Regulations

- Clean Air Act,
- 10 CFR Part 20, Appendix B, "Radiation Protection Programs,"
- 10 CFR 20.1101, "Radiation protection programs,"
    - 10 CFR 20.1101(b),
- 10 CFR 20.1301, "Dose limits for individual members of the public,"
    - 10 CFR 20.1301(e),
- 10 CFR 20.1302, "Compliance with dose limits for individual members of the public,"
- 10 CFR 50.34a, "Design objectives for equipment to control releases of radioactive material in effluents— nuclear power reactors,"
- 10 CFR 50.36a, "Design objectives for equipment to control releases of radioactive material in effluents— nuclear power reactors,"
    - 10 CFR 50.36a(a), and
- 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Plant Operations."

2.1.2.1 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," and

- RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants."

2.1.2.2 Considerations, Regulatory Experience, and Staff Position

Radiation doses associated with airborne radioactive materials from routine releases and anticipated operational occurrences must be ALARA (see 10 CFR 20.1101(b)) and must comply with the effluent concentration limits of Appendix B to 10 CFR Part 20 and the dose limits for members of the public under 10 CFR 20.1301 and 10 CFR 20.1302. In addition, 10 CFR 20.1301(e) requires compliance with the EPA's generally applicable environmental radiation standards of 40 CFR Part 190.

The requirements for design objectives for equipment to control releases of radioactive material in effluents from nuclear power reactors are in 10 CFR 50.34a. Further, 10 CFR 50.36a(a) states that, to keep power reactor effluent releases ALARA, each license authorizing operation of such a facility must include technical specifications for the establishment of effluent control equipment and reporting of actual releases.

In addition to meeting the NRC requirements for the dispersion of airborne radioactive material, the station must meet the State and Federal requirements of the Clean Air Act, as amended. Clean Air Act compliance is unlikely to be an important consideration for commercial nuclear power station siting unless (1) a site is in an area where existing air quality is near or exceeds standards, (2) the cooling system plume may interact with a plume from a nearby facility and form noxious or toxic substances, or (3) the auxiliary (fossil-fueled) generators are expected to operate routinely.

2.1.3 Local Fogging and Icing

Local fogging and icing can result from water vapor discharged into the atmosphere from cooling towers, lakes, canals, or spray ponds. In rare occasions, mist or light snow can reach the ground downwind of the cooling towers.

2.1.3.1 Relevant Regulations

- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions"

2.1.3.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan"

2.1.3.3 Considerations, Regulatory Experience, and Staff Position

Depending on the plant's cooling system design, water and water vapor released to the atmosphere from recirculating cooling systems can lead to ground fog and ice, resulting in transportation hazards and damage to electric transmission systems and vegetation.

In NUREG-1555, Section 5.1.1, “The Site and Vicinity,” describes the NRC staff’s review procedures for evaluation of fogging and icing induced by a nuclear power plant, while Section 5.3.3.1, “Heat Dissipation to the Atmosphere,” addresses the physical and aesthetic impacts of cloud formation, cloud shadowing, additional precipitation, icing and fogging, and increased ground-level humidity.

The hazards for transportation routes from fog or ice resulting from station operation should be evaluated. The evaluation should include estimates of the frequency of occurrence of station-induced fogging and icing and their impact on transportation, electrical transmission, vegetation, and other activities and functions. It should also address the potential increase in the number of hours of fogging or icing caused by station operation.

Some sites are prone to severe fogging or icing because of local atmospheric conditions. For example, these conditions are most likely in areas of unusually high moisture content that are protected from large-scale airflow patterns. The greatest impact is generally on transportation or electrical transmission systems in the vicinity of a site.

2.1.4 Cooling Tower Plume Drift

Cooling tower plume drift could affect nearby transportation and industrial activities or have environmental or aesthetic impacts.

2.1.4.1 Relevant Regulations

- 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions”

2.1.4.2 Related Guidance

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan”

2.1.4.3 Considerations, Regulatory Experience, and Staff Position

Plumes often extend a few miles in length before dissipating; the plumes themselves or their shadows could have aesthetic impacts. Visible plumes emitted from cooling towers may affect nearby transportation or industrial activities. For example, plumes in the vicinity of airports could pose a hazard to aviation.

Depending on the plant’s cooling system design, concentrations of chemicals, dissolved solids, and suspended solids in cooling tower drift could affect terrestrial biota and cause unacceptable damage to vegetation and other resources.

Water vapor from cooling tower plumes can interact with emissions from nearby industrial facilities (e.g., plumes from nearby fossil-fueled units) to form noxious or toxic substances that could adversely affect public health or cause unacceptable levels of damage to biota, structures, and other resources. The degree of impact will depend on the distance between the nuclear and industrial sites, the hours per year of plume interaction, the type and concentration of chemical reaction products, the area of chemical fallout, and the local atmospheric conditions.

The hazards for transportation routes from plume drift resulting from station operation should be evaluated. The evaluation should include estimates of frequency of occurrence of station-induced effects and their impact on transportation, electrical transmission, vegetation, and other activities and functions.

The percent drift loss from recirculating condenser cooling water, particle size distribution, salt deposition rate, local atmospheric conditions, and loss of sensitive terrestrial biota affected by salt deposition from cooling tower drift should be considered. The potential loss of important terrestrial species and other resources should be considered.

The hazards to public health, structures, and other resources from potential interaction between cooling tower plumes and emissions from nearby industrial facilities should be considered.

If a potential impact is judged to be significant, the site selection should provide a basis for evaluating mitigation measures or alternative heat-transfer system designs, predicting and assessing the following:

- length and frequency of elevated plumes,
- frequency and extent of ground-level fogging and icing in the site vicinity,
- solids deposition (e.g., drift deposition) in the site vicinity,
- cloud formation, cloud shadowing, and additional precipitation,
- interaction of the vapor plume with existing pollutant sources located within 2 kilometers (1.24 miles) of the plant, and
- ground-level humidity increase in the site vicinity.

If the natural vegetation or crops near the site are vulnerable to damage from airborne salt particles, a cooling system designed with special consideration for reducing drift may be needed. The vulnerability of existing industries or other nearby facilities to corrosion by cooling tower or spray system drift should be considered. Important factors in assessing drift effects include not only the amount, direction, and distance of the drift from the cooling system, but also the salt concentration above the natural background salt deposition at the site. Salt drift may necessitate special cooling system design features or a larger site to confine drift effects within the site boundary. The environmental effects of salt drift are most severe when condenser cooling water is saline or has high mineral content.

2.2 Hydrology

The hydrologic characteristics of potential sites should be evaluated from the perspectives of water quality, water availability, and radionuclide transport.

2.2.1 Water Quality

The impact of station construction and operation on water quality in the vicinity of potential sites should be evaluated.

2.2.1.1 Relevant Statutes and Regulations

- Clean Water Act,
- 40 CFR Part 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System" (Ref. 64,
- 40 CFR Part 423, "Steam Electric Power Generating Point Source Category" (Ref. 65),
- Applicable State water quality standards approved by the EPA,
- 10 CFR 20.1101, "Radiation protection programs,"
    - o 10 CFR 20.1101(b),
- 10 CFR 20.1301, "Dose limits for individual members of the public,"
    - o 10 CFR 20.1301(e),
- 10 CFR 20.1302, "Compliance with dose limits for individual members of the public,"
- 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," and
- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

2.2.1.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan"

2.2.1.3 Considerations, Regulatory Experience, and Staff Position

The potential impacts of commercial nuclear power stations on water quality are likely to be acceptable if they satisfy effluent limitations, water quality criteria for receiving waters, and other requirements under the CWA. The applicant should also identify any other relevant Federal, State, or local regulations current at the time when it is considering sites.

Thermal and chemical effluents discharged to navigable streams are governed by the CWA and are regulated under 40 CFR Part 122, 40 CFR Part 423, and State water quality standards. The State typically administers section 316(a) of the CWA, which specifies maximum impacts allowed on water quality based on flow volume and thermal loading of plant discharge.

Section 401(a)(1) of the CWA requires, in part, that any applicant for an NRC-issued construction permit, ESP, or COL for a commercial nuclear power station provide to the NRC certification from the State that any discharge will comply with applicable effluent limitations and other water pollution control requirements. Without such certification, the NRC cannot issue a construction permit, ESP, or COL, unless the State waives the requirement or fails to act within a reasonable period.

A National Pollutant Discharge Elimination System permit to discharge effluents to navigable streams pursuant to section 402 of the CWA may be required for a commercial nuclear power station to operate in compliance with the CWA, but it is not a prerequisite for an NRC construction permit, operating license, ESP, or COL.

Where station construction or operation could degrade water quality to the detriment of other users, more detailed analyses and evaluation of water quality may be necessary.

The NRC staff will use the criteria in 10 CFR Part 20 and 10 CFR Part 50 to determine permissible concentrations of radioactive materials discharged to surface water or to ground water. Appendix I to 10 CFR Part 50 provides guidance on the requirements for design objectives and technical specifications for limiting conditions for operation of light-water-cooled nuclear power stations.

2.2.2 Water Availability

The impact of station operation on the availability of water resources should be evaluated. Limitations imposed by existing laws or allocation policies govern the use and consumption of cooling water at potential sites for normal operation.

2.2.2.1 Relevant Statutes and Regulations

- Clean Water Act, section 316(b), as implemented by the EPA through:
  - 40 CFR Part 9, “OMB Approvals Under the Paperwork Reduction Act,”
  - 40 CFR Part 122, “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System,”
  - 40 CFR Part 123, “State Program Requirements,”
  - 40 CFR Part 124, “Procedures for Decisionmaking,”
  - 40 CFR Part 125, “Criteria and Standards for the National Pollutant Discharge Elimination System.”

2.2.2.2 Related Guidance

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan.”

2.2.2.3 Considerations, Regulatory Experience, and Staff Position

Adequate capacity is required to limit the impacts of withdrawing cooling water from the cooling water source. The consumptive use of water for cooling may be restricted by statute, may be inconsistent with water use planning, or may have an unacceptable impact on the water resource.

Water use and consumption must comply with Federal, State, and local requirements and must be compatible with water use plans of cognizant water resource planning agencies. For a site to be suitable, there should be reasonable assurance that the applicant can obtain the appropriate State, local, or regional agency permits for consumptive use of water in the quantities needed to operate a power plant with the approximate capacity and type of cooling envisioned, in accordance with the agency’s programs and policies, which may incorporate and administer applicable Federal policies. Where required by law, an application for a construction permit, operating license, ESP, or COL should include demonstration of a request for certification of the rights to withdraw or consume water and an indication that the request is consistent with appropriate State, local, and regional programs and policies. In the absence of a water use plan, the effect on other water users should be evaluated, considering flow or volume reduction and the resultant ability of all users to obtain adequate supply and to meet applicable water quality standards (see section C.2.2.1 of this RG).

Consumptive use should be restricted so that the supply of other users is not impaired and applicable surface water quality standards can be met, assuming normal station operational discharges and extreme low-flow conditions as defined by generally accepted engineering practices.

For multipurpose impounded lakes and reservoirs, consumptive use should be restricted so that the magnitude and frequency of drawdown will not cause unacceptable damage to important habitats or be inconsistent with the management goals for the water body.

In areas with complex ground water hydrology, or with aquifers that are or may be used for domestic or industrial water supplies or for irrigation water, the suitability of a site for a specific plant design can be determined only after a reliable assessment of the potential impacts of the reactor on the ground water. Site environmental parameters, which include hydrological and meteorological characteristics, should be comparable to those used in the plant probabilistic risk assessment and environmental analysis.

Statistical techniques and numerical modeling (e.g., the 7Q10 low-flow condition) should be used, if applicable, to extend and complement the period of record to help identify the expected minimum flow for the region. If the water supply is not adequate for the plant, then other sources of water need to be identified.

CWA section 316(b) identifies criteria based on type of water body in order to reduce environmental impact. It is typically administered by State programs. If applicable, potential sources of cooling water should also be screened by their capacity to meet intake flow limitations specified in CWA section 316(b), as implemented by the EPA in 40 CFR Parts 9, 122, 123, 124, and 125. Specifically, 40 CFR 125 Subpart I provides requirements applicable to cooling water intake structures for new facilities under CWA section 316(b).

Although management of surface water quality is important, water quality is not generally a determining factor in assessing the suitability of a site, since adequate design alternatives can be developed to meet CWA requirements and the Commission’s regulations implementing NEPA. The following are examples of potential environmental effects of station construction and operation that should be assessed:

- physical and chemical environmental alterations in habitats of important species, including plant-induced rapid changes in environmental conditions,
- changes in normal current direction or velocity of the cooling water source and receiving water,
- scouring and siltation due to construction and cooling water intake and discharge,
- alterations due to dredging and spoil disposal, and

- interference with shoreline processes.

Where water is in short supply, closed-cycle cooling (the recirculation of the hot cooling water through cooling towers, artificial ponds, or impoundments) has been practiced.

2.2.3 Radionuclide Retention and Transport

The retardation, dispersion, and dilution capabilities and potential contamination pathways of the ground water environment under operating and accident conditions, with respect to present and future users, are important factors in site selection.

2.2.3.1 Relevant Statutes and Regulations

- Clean Water Act,
- Applicable State water quality standards approved by the EPA,
- 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” and
- 10 CFR 100.20, “Factors to be considered when evaluating sites.”
    - 10 CFR 100.20(c)(3).

2.2.3.2 Related Guidance

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,”
- ASTM International C1733, “Standard Test Method for Distribution Coefficients of Inorganic Species by the Batch Method” (Ref. 66), and
- RG 4.21, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning” (Ref. 67).

2.2.3.3 Considerations, Regulatory Experience, and Staff Position

As specified in 10 CFR 100.20(c), the site’s physical characteristics (including seismology, meteorology, geology, and hydrology) must be considered when determining its acceptability for a nuclear power reactor. Special precautions should be planned if a reactor is to be located at a site where a significant amount of radioactive effluent might find ready access to ground water. According to 10 CFR 100.20(c)(3), factors important to hydrological radionuclide transport (such as soil, sediment, and rock characteristics, adsorption and retention coefficients, ground water velocity, and distances to the nearest surface body of water) must be obtained from onsite measurements. To satisfy the hydrologic requirements of 10 CFR Part 100, applicants should verify ground water conditions at a proposed site and assess how plant construction and operation will affect those conditions. This provides assurance that the release of radioactive effluents from the plant will not significantly affect ground water at or near the plant site.

To assess radionuclide retention and transportation through ground water, the following information should be determined for the site:

- soil, sediment, and rock characteristics (e.g., grain size, hydraulic conductivity, fracturing),
- chemistry of the subsurface media,
- source of radioactivity, radionuclide, and radioactivity inventories, and assumed release mechanism from the nuclear island, considering plant design features,
- site-specific adsorption coefficients for radionuclides of concern in the subsurface soils and backfills/structural fills (ASTM C1733 provides guidance for obtaining distribution coefficients, especially for radionuclides),
- preferential flow in the subsurface and other physiographic conditions (to evaluate the most severe impact on people and the environment and to conservatively estimate contaminant travel time),
- ground water velocity if ground water is affected,
- dispersion and dilution processes in surface water bodies if surface water is affected,
- distance to the nearest offsite point of entry to a surface water body or ground water resources, and
- environmental transport mechanisms and exposure pathways leading to direct uses (e.g., as drinking water) or indirect uses (e.g., crop and pasture irrigation, livestock watering, or use of water as a food ingredient) of surface water, ground water, or both.

Aquifers that are or could be used by large populations for domestic, municipal, industrial, or irrigation water supplies provide potential pathways for the transport of radioactive material to people in the event of an accident or of chronic leaks. When choosing sites within an area that the EPA has designated (or could designate in the future) as a sole source aquifer, applicants should provide detailed justification based on potential community impact.

To identify potential migration and ground water transport pathways for events that could cause environmental contamination, a conceptual ground water site model should be developed. If a surface water body is assumed to be impacted, the evaluation should consider the characteristics and associated parameters of the receiving water body. These characteristics include, among others, direction and flow rate of currents, near- and far-field mixing and dispersion patterns, thermal differences between the assumed release event and the receiving water body, tidal effects (if applicable), types and rates of surface water use, and location downstream from the point of entry. Alternate conceptual models should be developed that reasonably bound hydrogeological conditions at the site. A bounding set of plausible surface and subsurface pathways from potential points of accidental release should be developed, to determine the critical pathways that may have the most severe impact on existing uses and known and likely future uses of ground and surface water resources near the site.

The basis of the assumed liquid radioactive source term should be clearly stated and should include sufficient information for the staff to perform an independent evaluation or confirmation. The discussions should indicate the type of reactor design forming the basis of the source term. They should state whether the radioactive material inventories are based on a design's certification or have been adjusted (e.g., upward, or downward), in whole or in part, for designs whose certifications the NRC has not yet approved at the time of submission of the application. The site conceptual model should consider whether the ground and surface water environment could delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport. The model should assess scenarios combining accidental release of radioactive effluents with hydrologic extreme events such as floods or low flows, as well as with seismic and non-seismic events (e.g., it should assess the effects of structural or operational failures of hydraulic structures located upstream and downstream of the plant and the ensuing sudden changes in the flow regime).

Applicants need to minimize contamination and radioactive waste generation over the total life cycle of a facility, from initial layout and design through operation and final decontamination and dismantlement at the time of decommissioning, in accordance with 10 CFR 20.1406, "Minimization of contamination." RG 4.21 provides guidance on addressing these requirements.

2.3 Ecological Systems and Biota

The potential impact of station construction and operation on biota (plant or animal species) and on their habitats and supporting ecological systems needs to be assessed. The ecological systems and biota at potential sites and their environs should be sufficiently well known to allow reasonable certainty that the construction or operation of a commercial nuclear power station at the site would have no unacceptable or unnecessary deleterious impacts on populations of important species or on the ecological systems with which they are associated.

Section 2.4, "Ecology," of NUREG-1555 provides the NRC staff with guidance on determining the adequacy of a site with respect to ecological systems and biota, RG 4.11, and RG 4.24 provide guidance to applicants. They list recommended studies of ecological systems and biological resources and discuss potential species and habitat protection under State, local, and Tribal governance.

If justifiable in terms of costs and benefits, it is generally possible to mitigate the potential impacts of plant construction and operation on biota and ecological systems through engineering design and site planning and through proper construction and operations, given adequate information about the vulnerability of important species and ecological systems.

2.3.1 Preservation of Important Habitats

In areas of great importance to the local aquatic and terrestrial ecosystems, it may be difficult to assess potential impacts on important species or ecological systems. Such areas include those used for breeding (e.g., nesting and spawning), wintering, and feeding, as well as areas where there may be seasonally high concentrations of individuals of important species.

2.3.1.1 Relevant Statutes and Regulations

- Fish and Wildlife Coordination Act, as amended (Ref. 68),
- Bald and Golden Eagle Protection Act (Ref. 69),
- Migratory Bird Treaty Act of 1972, as amended (Ref. 70),
- Marine Mammal Protection Act of 1972, as amended (Ref. 71),
- Magnuson-Stevens Fishery Conservation and Management Act, as amended (Ref. 72), and

- Clean Water Act section 316(b), as implemented in 40 CFR Parts 9, 122, 123, 124, and 125.

2.3.1.2 Related Guidance

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,”
- RG 4.2, “Preparation of Environmental Reports for Nuclear Power Stations,”
- RG 4.11, “Terrestrial Environmental Studies for Nuclear Power Stations,” and
- RG 4.24, “Aquatic Environmental Studies for Nuclear Power Stations.”

2.3.1.3 Considerations, Regulatory Experience, and Staff Position

The construction and operation of commercial nuclear power stations (including new transmission lines and access corridors constructed in conjunction with the station) can destroy or alter habitats of important species, affecting the abundance of a species or the species composition of a community.

Applicants should determine whether any important species inhabit or use the proposed site or its environs. If so, the relative abundance and distribution of their populations should be considered. Potential adverse impacts on important species should be identified and assessed. The relative abundance of individuals of an important species inhabiting a potential site should be compared to the total local population, as estimated in the available literature. Any predicted impacts on the species should be evaluated relative to effects on the local population and the total population of the species. The destruction of, or sublethal effects on, a number of individuals that would not adversely affect the reproductive capacity and vitality of a population, or the harvestable crop of an economically or recreationally important population, should generally be acceptable, except in the case of certain endangered species. If a site contains endangered or threatened species, the potential effects should be evaluated relative to the local population and the estimated total population over the entire range of the species as noted in the literature.

Important habitats are those that are essential to maintaining the reproductive capacity and vitality of populations of important species or the harvestable crop of economically or recreationally important species. Such habitats include breeding areas (e.g., nesting and spawning areas): nursery, feeding, resting, and wintering areas, wetlands, and other areas having seasonally high concentrations of individuals of important species.

RG 4.2 provides a streamlined approach to defining important species and habitats as illustrated in the following table (this represents updated guidance developed by the NRC after the publication of RG 4.11, Revision 2):

Species	Habitat
Federally threatened or endangered and proposed species for listing by Fish and Wildlife Service (FWS) or National Marine Fisheries Service (NMFS) that occupy habitat or have an ecosystem function that may be affected by the proposed project	Federally designated or proposed critical habitat or essential fish habitat. Protected areas such as sanctuaries, parks, refuges, or preserves, including marine protected areas

Candidate species for Federal listing by the FWS or NMFS of particular interest to the review that occupy habitat or have an ecosystem function that may be affected by the proposed project Representative State status species of particular interest to the review Other species for which a Federal or State agency has established a monitoring requirement at or near the site Representative commercially or recreationally valuable species Potentially significant nuisance or invasive species Other species of known or indicated interest	Habitats identified by Federal or State agencies as unique, rare, or of priority for protection (e.g., areas that have been designated as habitat for an evolutionary significant unit, distinct population segment, critical habitat, or essential fish habitat) Other habitats of known or indicated interest, e.g., known breeding, spawning, nesting, or nursery grounds

The alteration of existing environmental conditions may render a habitat unsuitable as a breeding or nursery area. In some cases, organisms use identical breeding and nursery areas each year; changes in the characteristics of the areas may substantially reduce or enhance breeding success. Destruction of part or all of a breeding or nursery area may cause population shifts that result in increased competition for the remaining suitable areas. Such population shifts cannot compensate for the reduced size of the breeding or nursery areas if members of the species already occupy the remaining suitable areas. Some species will desert a breeding area because of human activities nearby, even if these activities do not physically disturb the actual breeding area.

Of special concern in site selection are those unique or especially rich feeding areas that station construction or operation might destroy, degrade, or make inaccessible to important species. Evaluations of potential effects of construction or operation on feeding areas should consider the size of the feeding area on site in relation to that of the total feeding area off site, food density, time of use, location in relation to other habitats, topography relative to access routes, and other factors (including human activities). Site modification may reduce the quality of feeding areas by destroying part of the food base, destroying cover, or both.

In balancing costs and benefits, it is important to consider the uniqueness of a habitat or ecological system within the region under consideration, the amount of the habitat or ecological system that would be destroyed or disrupted relative to the total amount in the region, and the vulnerability of the reproductive capacity of important populations to the effects of construction and operation of the station and ancillary facilities. The proportion of an important habitat that would be destroyed or significantly altered, in relation to the total habitat within the region, is a useful parameter for estimating potential impacts of station construction or operation. This proportion varies across species and habitats; it is determined based on the normal geographic range of the population in question. In general, a detailed justification should be provided for the proposed destruction or significant alteration of more than a few percent of important habitat types.

The reproductive capacity of important populations and the harvestable crop of economically or recreationally important populations should be maintained unless proposed or probable changes can be justified.

If sites contain, are adjacent to, or could affect important ecological systems or habitats (e.g., wetlands and estuaries) that are unique, limited in extent, or necessary to the productivity of populations of important species, they cannot be evaluated as to suitability for a commercial nuclear power station until adequate assessments have been completed to reliably predict impacts and facility design characteristics have been defined that would satisfactorily mitigate these impacts. In areas where reliable and sufficient data are not available, it may be necessary to collect and evaluate appropriate seasonal data.

When early site inspections and evaluations indicate a need to study critical or exceptionally complex ecological systems in detail to determine the appropriate plant designs, proposals to use such sites should be deferred unless sites with less complex characteristics are not available.

2.3.2 Migratory Routes of Important Species

Migration routes of important species that pass through the site or its environs should be identified. Construction and operation of commercial nuclear power stations can create barriers to migration.

2.3.2.1 Relevant Statutes and Regulations

- Fish and Wildlife Coordination Act, as amended,
- Migratory Bird Treaty Act of 1972, as amended, and
- Magnuson-Stevens Fishery Conservation and Management Act, as amended.

2.3.2.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,"
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations," and
- RG 4.11, "Terrestrial Environmental Studies for Nuclear Power Stations."

2.3.2.3 Considerations, Regulatory Experience, and Staff Position

Generally, the most critical migratory routes relevant to commercial nuclear power station siting are those of aquatic species in water bodies associated with cooling systems. In assessing potential impacts on aquatic migratory species, five site conditions should be identified and evaluated: (1) narrow zones of passage, (2) migration periods that coincide with maximum ambient temperatures, (3) the potential for major modification of currents by station structures, (4) the potential for increased turbidity during construction, and (5) the potential for entrapment, entrainment, or impingement by or in the cooling water system and for blocking of migration by facility structures or effluents.

Seasonal or daily migrations are essential to the reproductive capacity of some important species. Disruption of migratory patterns can result from partial or complete blockage of migratory routes by structures, discharge plumes, environmental alterations, or human activities (e.g., transportation or transmission corridor clearing and site preparation).

Narrow zones of passage for migratory animals in some rivers and estuaries may be restricted or blocked by station operation. Partial or complete blockage of a zone of passage may result from the discharge of heat or chemicals to receiving water bodies or from the construction and placement of power station structures in the water body. Strong-swimming aquatic animals often avoid waters of adverse quality, but larval and immature forms are usually moved and dispersed by water currents. It is therefore important in site selection to consider potential effects on the routes and times of movement of immature individuals.

Some species migrate in central, deeper areas, while others use marginal, shallow areas. Rivers, streams, and estuaries are seldom laterally homogeneous in depth, current velocity, and habitat type. Thus, the determination of adequate zones of passage should be based on both width or cross-sectional area criteria and knowledge of the specific migratory requirements of important species.

Narrow reaches of water bodies should be avoided as sites for intake or discharge structures. A zone of passage should be provided that will permit normal movement of important species and maintenance of the harvestable crop of economically important populations. The width or cross-sectional area of a water body at a proposed site, relative to the general width or cross-sectional area in the portion of the water used by migrating species, should be estimated. Suggested minimum zones of passage range from one-third to three-fourths of the width or cross-sectional areas of narrow water bodies.[5]

Site evaluations should also assess the potential for blockage of movements of important terrestrial animal populations and the availability of alternative routes that would allow the species to maintain their breeding populations.

2.3.3 Entrainment and Impingement of Aquatic Organisms

Several variables, including site characteristics and intake structure design and placement, determine the potential for impingement of organisms on cooling water intake structures and entrainment of organisms through the cooling system.

2.3.3.1 Relevant Statutes and Regulations

- Fish and Wildlife Coordination Act, as amended,
- Magnuson-Stevens Fishery Conservation and Management Act, as amended,
- Clean Water Act section 316(b), as implemented in
    - 40 CFR Part 9, “OMB Approvals Under the Paperwork Reduction Act,”
    - 40 CFR Part 122, “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System,”
    - 40 CFR Parts 123, “State Program Requirements,”
    - 40 CFR Parts 124, “Procedures for Decisionmaking,

5 See EPA/505/2-90-001, “Technical Support Document for Water Quality-Based Toxics Control,” Washington, DC, issued March 1991.

- 40 CFR Parts 125; "Criteria and Standards for the National Pollutant Discharge Elimination System," and

- Clean Water Act section 316(a).

2.3.3.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan", Section 2.4, and

- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations,"

2.3.3.3 Considerations, Regulatory Experience, and Staff Position

Plankton, including eggs, larvae, and juvenile fish, can be killed or injured by entrainment through power station cooling systems or in discharge plumes. Fish and other aquatic organisms can be killed or injured by impingement on cooling water intake screens[6] or by entrainment in discharge plumes.

The reproductive capacity of important populations may be impaired by lethal stresses or by sublethal stresses that affect the reproduction of individuals or result in increased predation on the affected population.

Site evaluations should consider the depth of the water body at the point of intake relative to the general depth of the water body in the vicinity of the site. The simplistic parameter (proportion of water withdrawal) is suitable for use in a screening process or site selection. However, other factors, such as distribution of important species, should be considered, and in all cases, experts on the local fisheries should be consulted to ensure that proposed withdrawals will not be excessive.

The site should allow for placement of intake structures where the relative abundance of important species is small and where low approach velocities can be attained. (Deep regions are generally less productive than shallow areas. It is not implied that benthic intakes are necessary.)

Important habitats should be avoided as locations for intake structures.

2.3.4 Entrapment of Aquatic Organisms

To limit the potential for entrapment of aquatic organisms by intake or discharge structures, evaluations of potential sites should consider the entrainment, impingement, and heat shock requirements of applicable Federal, State, and local regulations.

2.3.4.1 Relevant Statutes and Regulations

- Fish and Wildlife Coordination Act, as amended,

- Magnuson-Stevens Fishery Conservation and Management Act, as amended,

6 Approach velocity and screen-face velocity are design criteria that may affect the impingement of larger organisms, principally fish, on intake screens. Acceptable approach and screen-face velocities are based on the swimming speeds of fish, which will vary with the species, site, and season.

- Clean Water Act section 316(a), as implemented in 40 CFR Part 125, "Criteria and Standards for the National Pollutant Discharge Elimination System", and

- Clean Water Act section 316(b), as implemented in

  - 40 CFR Part 9, "OMB Approvals Under the Paperwork Reduction Act,"

  - 40 CFR Part 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System,"

  - 40 CFR Parts 123, "State Program Requirements,"

  - 40 CFR Parts 124, "Procedures for Decisionmaking," and

  - 40 CFR Parts 125, "Criteria and Standards for the National Pollutant Discharge Elimination System."

2.3.4.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan", Section 2.4, and

- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations,"

2.3.4.3 Considerations, Regulatory Experience, and Staff Position

Cooling water intake and discharge system features, such as canals and thermal plumes, can attract and entrap organisms, principally fish. This can increase the concentration of important fish species near the station site, leading to higher mortalities from station-related causes such as impingement, cold shock, or gas bubble disease. Entrapment can also interrupt normal migratory patterns.

Site evaluation should consider the design and placement of cooling system features and the risk that the cooling system will hold fish in an area for longer than the normal period of migration or will entrap them in areas where direct or indirect factors, such as limited food supply or unfavorable temperatures, may adversely affect them. The unnatural warmth of canals or areas where cooling waters are discharged may induce fish to remain there; if the station ceases to operate during the winter, the abrupt drop in water temperature may be lethal to these fish.

Site characteristics should therefore accommodate design features that mitigate or prevent entrapment.

Sites requiring the construction of intake or discharge canals should be avoided unless it would be possible to prevent or limit the entry of important species into the canal through screening.

Section 316(a) of the CWA required EPA to issue regulations regarding point sources with thermal plumes, while section 316(b) required regulations for the design and operation of intake structures. State programs that specify maximum impacts allowed on source water volume and discharge water quality typically administer these programs.

2.4 Land Use and Aesthetics

Site suitability may be limited by the proximity of established public resource areas or prospective designated resource areas, by land use plans of Federal, State, regional, or local agencies, or by aesthetic considerations.

2.4.1 Established Public Resource Areas

Locating a commercial nuclear power station adjacent to lands devoted to public use might be unacceptable to Federal, State, or local jurisdictions.

2.4.1.1 Relevant Statutes and Regulations

- National Environmental Policy Act,
- National Historic Preservation Act, as amended (Ref. 73),
- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," and
- 7 CFR Part 1491, "Farm and Ranch Lands Protection Program" (Ref. 74).

2.4.1.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," and
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations,"

2.4.1.3 Considerations, Regulatory Experience, and Staff Position

The siting of commercial nuclear power stations near established public resource areas could cause the loss or deterioration of important public resources and therefore generally requires extensive evaluation and justification. Such evaluations should consider how the specific plant design and station layout may affect the public resource area.

Locating commercial nuclear power stations, transmission lines, or transportation corridors close to special areas administered by Federal, State, or local agencies for scenic or recreational use might have unacceptable impacts regardless of design parameters. Such cases are most apt to arise near natural-resource-oriented areas (e.g., national forests), as opposed to recreation-oriented areas such as national parks, forests, or wildlife refuges. Some significant historical and archeological sites might also fall into this category.

Another class of impacts involves the preempting of existing land use at the site itself. For example, commercial nuclear power station siting in areas uniquely suited for growing specialty crops may be considered a type of land conversion involving unacceptable economic dislocation. Under 7 CFR Part 1491, working agricultural lands are protected from conversion to nonagricultural use. Since power reactor sites under consideration are likely to be in rural areas and potentially under cultivation, this regulation may apply in determining site suitability.

To determine whether it would be acceptable to locate a commercial nuclear power station near a special area of public use, the applicant should consult the responsible government agency. The Council on Environmental Quality has published a list of Federal agencies that have jurisdiction or expertise in land use planning, regulation, or management.[7]

The following are some of the Federal agencies that should be consulted for the special areas listed:

- Advisory Council on Historic Preservation,
- National Park Service (U.S. Department of the Interior),
- Bureau of Sport Fisheries and Wildlife (U.S. Department of the Interior) (for national wildlife refuges), and
- Forest Service (U.S. Department of Agriculture) (for national forest wilderness areas, primitive areas, and national forests).

Individual state and local governments administer parks, recreation areas, and other public use and benefit areas. Information on these areas should be obtained from State and local agencies. Information on local historic areas should be obtained from the State or Tribal historic preservation officer.

2.4.2 Prospective Designated Resource Areas

Some areas might be unsuitable for siting a commercial nuclear power station because of public interest in reserving land for future scenic, recreational, or cultural use.

2.4.2.1 Relevant Statutes and Regulations

- National Environmental Policy Act, and
- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

2.4.2.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," and
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations."

2.4.2.3 Considerations, Regulatory Experience, and Staff Position

Areas containing important resources for scenic, recreational, or cultural use might not currently be designated as such by public agencies, but their conversion to power generation might constitute a net loss to the public. For example, this may be true of relatively rare land types such as sand dunes and large wetland areas. Whether it will be acceptable to site commercial nuclear power stations in these areas in the future will depend on the existing impacts of industrial, commercial, and other developments.

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7 See "National Environmental Policy Act (NEPA) Implementation Procedures; Appendixes I, II, and III," U.S. Council on Environmental Quality (49 FR 49750; December 21, 1984).

Land use conflicts might make a site unsuitable for a commercial nuclear power station (e.g., if a community has planned to use the site for other purposes or has restricted it to uses that would be compatible with existing adjacent land use). Applicants should therefore consult land use plans developed by local governments and regional agencies for possible conflicts.

Surveys can identify archeological and historic sites so that potential effects on these resources can be avoided or mitigated. If areas of concern are identified, applicants should contact the State archeologist and the State historic preservation officer, both of whom are responsible for the preservation and protection of historic properties in the State under the National Historic Preservation Act.

Public resource areas that are distinctive, unique, or rare in a region should be avoided as sites for commercial nuclear power stations. Applicants should consult local agencies when there are potential areas containing important resources for scenic, recreational, or cultural use that might not currently be designated as such by public agencies.

2.4.3 Public Planning

Land use for a commercial nuclear power station should be compatible with established land use or zoning plans of governmental agencies.

2.4.3.1 Relevant Statutes and Regulations

- National Environmental Policy Act,
- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," and
- 7 CFR Part 1491, "Farm and Ranch Lands Protection Program."

2.4.3.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," and
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations."

2.4.3.3 Considerations, Regulatory Experience, and Staff Position

Commercial nuclear power stations can preempt large areas, especially when large cooling lakes are constructed. This is likely to be an important issue when a proposed site is on productive land (e.g., agricultural land) that is locally limited in availability and is important to the local economy, or that may be needed to meet foreseeable national demand for agricultural products. For a potential site on land devoted to specialty crop production where changes in land use might cause market dislocation, a detailed investigation should be conducted to demonstrate that potential impacts have been identified. For example, under 7 CFR Part 1491, working agricultural lands are protected from conversion to nonagricultural use. Since power reactor sites under consideration are likely to be in rural areas and potentially under cultivation, this regulation may apply in determining site suitability.

Applicants must examine land use plans adopted by Federal, State, regional, or local agencies and must resolve any conflict between these plans and use of a proposed site by consulting the appropriate governmental entity. Individual state and local governments administer parks, recreation areas, and other public use and benefit areas. Information on these areas should be obtained from State and local agencies. Information on local historic areas should be obtained from the State or Tribal historic preservation officer.

If a preliminary evaluation indicates that the use of productive land for a commercial nuclear power station could cause significant economic dislocation, the NRC staff will require a detailed evaluation of the potential impact, together with a justification for the use of the site based on a cost-effectiveness comparison of alternative station designs and site-station combinations. The staff will also need to know whether and to what extent the land use would affect national requirements for agricultural products.

2.4.4 Visual Resources

The presence of power station structures may have an adverse visual impact on residential, recreational, scenic, or cultural areas or on other areas where desirable viewing characteristics are important.

2.4.4.1 Relevant Statutes and Regulations

- National Environmental Policy Act, and
- 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

2.4.4.2 Related Guidance

- NUREG-1555. "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,"
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations," and
- Bureau of Land Management Manual H-8410-1, "Visual Resource Inventory," January 17, 1986 (Ref. 75).

2.4.4.3 Considerations, Regulatory Experience, and Staff Position

To assess the potential adverse visual impact on residential, recreational, scenic, or cultural areas or on other areas where desirable viewing characteristics are important, the solid angle subtended by station structures at critical viewing points is a relevant parameter.

It is important to consider the potential aesthetic impact of commercial nuclear power stations at sites near natural-resource-oriented public use areas and to consider the specific station design layout when evaluating such sites. Aesthetic considerations need to include all five senses, since land use and aesthetics are interrelated (see Bureau of Land Management Manual H-8410-1).

The visual intrusion of commercial nuclear power station structures as viewed from nearby residential, recreational, scenic, or cultural areas should be controlled by selecting sites where existing topography and forests can screen station structures from areas where visual impacts would be unacceptable.

Appropriate facility designs and operational practices can also mitigate the land use and aesthetic effects of the construction and operation of plants, transmission lines, and transportation corridors. For example, the restoration of natural vegetation, creative landscaping, and the integration of structures with the environment can mitigate adverse visual impacts. However, station protection requirements for nuclear safeguards may constrain landscape design and clearing of vegetation.

NUREG-1555 offers guidance for analyzing power plant siting suitability in relation to land use and aesthetics.

2.4.5 Noise

Undesirable noise levels at commercial nuclear power stations could occur during both construction and operation.

2.4.5.1 Relevant Statutes and Regulations

- National Environmental Policy Act,
- 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” and
- Applicable Federal, State, and local noise regulations.

2.4.5.2 Related Guidance

- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,” and
- RG 4.2, “Preparation of Environmental Reports for Nuclear Power Stations.”

2.4.5.3 Considerations, Regulatory Experience, and Staff Position

Undesirable noise levels at commercial nuclear power stations could occur during both construction and operation and could have unacceptable impacts near the plant.

Noise levels at proposed sites must comply with applicable Federal, State, and local noise regulations.

2.5 Socioeconomic Impacts

The siting, construction, and operation of a commercial nuclear power station significantly affect the socioeconomic structure of a community.

2.5.1 Relevant Statutes and Regulations

- National Environmental Policy Act,
- 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” and
- Applicable Federal, State, and local socioeconomic policies and initiatives.

2.5.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," and
- RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations."

2.5.3 Considerations, Regulatory Experience, and Staff Position

The siting, construction, and operation of a commercial nuclear power station might significantly affect the socioeconomic structure of a community and might place severe stresses on the local labor supply, transportation facilities, and community services. The tax basis and community expenditures might change, and problems might arise in determining equitable compensation for persons relocated as a result of the station siting. Section 4.4.2, "Social and Economic Impacts," of NUREG-1555 contains guidance for NRC staff reviews of socioeconomic issues.

Certain communities near a site might be subject to unusual impacts that would be excessively costly to mitigate. Among such communities are towns of distinctive cultural character (i.e., towns that have preserved or restored numerous places of historic interest, specialized in an unusual industry or vocational activity, or otherwise markedly distinguished themselves from other communities).

An investigation should be made to identify and analyze problems that may arise from the proximity of a distinctive community to a proposed site. The evaluation should include the construction and operation of the station (including transmission lines and transportation corridors) and any potential problems arising in relation to community services (such as schools, police and fire protection, water and sewage, and health facilities) that could adversely affect the distinctive character of the community or disproportionately affect minority or low-income populations.

Proper coordination with the affected communities can resolve many difficulties; however, some impacts might be locally unacceptable and impossible to mitigate through any reasonable program.

2.6 Environmental Justice

The use of a proposed site could disproportionately affect minority or low-income communities.

2.6.1 Relevant Statutes, Regulations, and Other Issuances

- applicable Federal, State, and local statutory and regulatory requirements,
- Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," (59 FR 7629, February 11, 1994) (Ref. 76), and
- "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions," (69 FR 52040, August 24, 2004) (Ref. 77).

2.6.2 Related Guidance

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan", and

- RG 4.2, “Preparation of Environmental Reports for Nuclear Power Stations.”

2.6.3 Considerations, Regulatory Experience, and Staff Position

Siting decisions should reflect fair treatment and meaningful involvement of all people and should include analysis of whether any significant impacts will fall disproportionately on minority or low-income communities. Because of the depth of this analysis, the discussion of environmental justice in the evaluation of a proposed site often rivals, in length and complexity, the discussion of socioeconomic effects on the general population. The construction of commercial nuclear power stations should be avoided on sites where this would have significant impacts falling disproportionately on minority or low-income communities.

The NRC’s policy statement in this area expresses the Commission position that the agency is committed to the general goals of Executive Order 12898 and “will strive to meet those goals through its normal and traditional NEPA review process.” Executive Order 12898 requires an agency to analyze whether its programs, policies, and activities have disproportionately high and adverse human health or environmental effects on minority or low-income populations. The order is not binding on the NRC because the NRC is an independent regulatory agency. NUREG-1555 contains more information on NRC staff reviews of environmental justice issues.

3 Limited Work Authorizations

The LWA process allows applicants to request approval to perform certain limited construction activities before the issuance of a construction permit, ESP or COL.

3.1 Relevant Statutes and Regulations

- National Environmental Policy Act,
- 10 CFR 50.10, “License required; limited work authorization,”
- 10 CFR 51.14, “Definitions,”
- 10 CFR Part 52.77, “Contents of applications; general information,” and
- 40 CFR 1508.7, “Cumulative impacts.”

3.2 Related Guidance

- RG 1.206, “Applications for Nuclear Power Plants,” and
- NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan.”

3.3 Considerations, Regulatory Experience, and Staff Position

The LWA process allows applicants to request approval to perform certain construction activities before the issuance of a COL. The regulations in 10 CFR 50.10 govern the issuance of LWAs and specify the information to be included in an LWA application. The regulations clarify that activities defined as “construction” are those that fall within the NRC’s regulatory authority, and they require an LWA because they have a reasonable nexus to radiological health and safety or the common defense and security. Activities not considered "construction" may be performed without an NRC licensing action.

Activities not within the definition of "construction" include (1) preparation of a site for construction (clearing, grading, installation of environmental mitigation measures, and construction of temporary roads and borrow areas), (2) excavation, (3) erection of support buildings, and (4) building of service facilities (paved roads, parking lots, railroad spurs, sewage treatment facilities, and transmission lines).

The activities above are not under the NRC's regulatory jurisdiction and are evaluated as part of a cumulative impact analysis. Cumulative impact is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of which agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impact can result from individually minor but collectively significant actions taking place over a period of time. (This definition of cumulative impact appears in the regulations of the Council on Environmental Quality implementing NEPA (40 CFR 1508.7). NRC regulations state that the agency will use the definitions in 40 CFR 1508.7 in implementing NEPA (10 CFR 51.14(b)).).

The resource areas to be evaluated for cumulative impacts are generally the same as those evaluated in NUREG-1555. For each project identified as contributing to the cumulative impacts, applicants should briefly describe the contribution to the cumulative impact for the resource area being discussed. A table giving the project, the resource affected, and a short description is generally sufficient. However, if the evaluation finds that the proposed action has no impact on a given resource area, then there is no need to evaluate cumulative impacts for that resource area. For each resource area on which there is a direct or indirect impact, applicants should do the following:

- Identify the geographic area and period to be considered in evaluating the cumulative impact.
- Collect information on the relevant impacts of the proposed action within the identified geographic area.
- Identify other past, present, or reasonably foreseeable actions that would contribute to the cumulative impact when added to the proposed action.
- Determine the cumulative impact on the resource area.
- Identify plans or actions (if any) to avoid, minimize, or mitigate adverse cumulative impacts.

D. IMPLEMENTATION

The methods described in this regulatory guide will be used in evaluating applications for construction permits, early site permits, combined licenses, and limited work authorizations, which includes information under 10 CFR 51.49(b) or (f), with respect to compliance with applicable regulations governing the siting of new nuclear power plants, unless the applicant proposes an acceptable alternative method for complying with those regulations. Methods that differ from those described in this regulatory guide may be deemed acceptable if the applicant provides sufficient basis and information for the NRC staff to verify that the proposed alternative complies with the applicable NRC regulations.

REFERENCES[8]

1. *U.S. Code of Federal Regulations* (CFR), "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."

2. CFR, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter I, Title 10, "Energy."

3. CFR, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," Part 51, Chapter I, Title 10, "Energy."

4. CFR, "Reactor Site Criteria," Part 100, Chapter I, Title 10, "Energy."

5. National Environmental Policy Act of 1969 (NEPA), as amended, 42 United States Code (U.S.C.) 4321 et seq. [9]

6. Executive Order 11514, "Protection and Enhancement of Environmental Quality." *Federal Register*, 35 FR 4247, March 5, 1970, Office of the President, Washington, DC.[10]

7. Executive Order 11991, "Environmental Impact Statements," *Federal Register*, 42 FR 26967, May 25, 1977, Office of the President, Washington, DC.

8. CFR "Chapter V—Council on Environmental Quality—Parts 1500 Through 1508," Parts 1500–1508, Title 40, "Protection of Environment."

9. Federal Water Pollution Control Act of 1972 (also referred to as Clean Water Act), 33 U.S.C. 1251 et seq.

10. Atomic Energy Act of 1954, as amended, 42 U.S.C. 2011 et seq.

11. Energy Reorganization Act of 1974, as amended, 42 U.S.C. 5801 et seq.

12. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Washington, DC.

13. NRC, RG 1.206, "Applications for Nuclear Power Plants," Washington, DC.

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8 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public website at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. For problems with ADAMS, contact the Public Document Room staff at 301-415-4737 or (800) 397-4209, or email pdr.resource@nrc.gov. The NRC Public Document Room (PDR), where you may also examine and order copies of publicly available documents, is open by appointment. To make an appointment to visit the PDR, please send an email to PDR.Resource@nrc.gov or call 1-800-397-4209 or 301-415-4737, between 8 a.m. and 4 p.m. eastern time (ET), Monday through Friday, except Federal holidays.

9 The United States Code (USC) can be obtained electronically from the Office of the Law Revision Counsel of the House of Representatives at http://uscode.house.gov/.

10 Publicly available executive orders and similar documents may be obtained through the National Archives and Records Administration at their website (http://www.archives.gov/), by telephone (866-272-6272), fax (301-837-0483), or U.S. mail at The National Archives and Records Administration, 8601 Adelphi Rd., College Park, MD 20740-6001.

14. NRC, RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," Washington, DC.

15. NRC, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Washington, DC.

16. NRC, NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," Washington, DC.

17. NRC, NUREG-0625, "Report of the Siting Policy Task Force," Washington, DC, August 2, 1979.

18. NRC, RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations," Washington, DC.

19. NRC, RG 4.11, "Terrestrial Environmental Studies for Nuclear Power Stations," Washington, DC.

20. NRC, RG 4.24, "Aquatic Environmental Studies for Nuclear Power Stations," Washington, DC.

21. Electric Power Research Institute, No. 3002023910, "Site Selection and Evaluation Criteria for New Nuclear Power Generation Facilities (Siting Guide)," Palo Alto, CA, November 2022.[11]

22. Clean Air Act of 1970, 42 U.S.C. 7401 et seq.

23. Endangered Species Act of 1973, 16 U.S.C. 1531 et seq.

24. NRC, "Nuclear Regulatory Commission International Policy Statement," *Federal Register*, Vol. 79, No. 132, July 10, 2014, pp. 39415–39418.

25. NRC, Management Directive 6.6, "Regulatory Guides," Washington, DC.

26. IAEA, Safety Standards Series, Safety Guide No. NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants," Vienna, Austria, 2003.[12]

27. IAEA, Safety Standards, Specific Safety Requirements No. SSR-1, "Site Evaluation for Nuclear Installations," Vienna, Austria, 2019.

28. IAEA, Safety Standards, Specific Safety Requirements No. SSR-2/1, "Safety of Nuclear Power Plants: Design" (Rev. 1), Vienna, Austria, 2016.

29. IAEA, Safety Standards, Specific Safety Guide No. SSG18, "Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations," Vienna, Austria, 2011.

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11 Copies of Electric Power Research Institute documents may be obtained by contacting the Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304; telephone: 650-855-2000; or online at http://epri.com.

12 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through its website at WWW.IAEA.Org/ or by writing to the International Atomic Energy Agency, P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria; telephone (+431) 2600-0, Fax (+431) 2600-7, or email at Official.Mail@IAEA.Org.

30. IAEA, Safety Standards, Specific Safety Guide No. SSG21, "Volcanic Hazards in Site Evaluation for Nuclear Installations," Vienna, Austria, 2012.

31. NRC, RG 1.29, "Seismic Design Classification for Nuclear Power Plants," Washington, DC.

32. NRC, RG 1.132, "Geologic and Geotechnical Site Characterization Investigations for Nuclear Power Plants," Washington, DC.

33. NRC, RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Washington, DC.

34. NRC, RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," Washington, DC.

35. NRC, RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," Washington, DC.

36. NRC, RG 4.26, "Volcanic Hazards Assessment for Proposed Nuclear Reactor Sites," Washington, DC.

37. NUREG-2213, "Updated Implementation Guidelines for SSHAC Hazard Studies."

38. NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities."

39. ANSI/ANS-2.27-2020, "Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessment."

40. ANSI/ANS 2.29-2020, "Probabilistic Seismic Hazard Analysis."

41. NRC, RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," Washington, DC.

42. NRC, RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Washington, DC.

43. NRC, RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," Washington, DC.

44. CFR, "Environmental Radiation Protection Standards for Nuclear Power Operations," Part 190, Chapter I, Title 40, "Protection of Environment."

45. NRC, RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," Washington, DC.

46. NRC, RG 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Washington, DC.

47. NRC, RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Washington, DC.

48. NRC, RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Washington, DC.

49. NRC, RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Washington, DC.

50. American National Standards Institute/American Nuclear Society, ANSI/ANS-2.6-2018, "Standard Guidelines for Estimating Present & Projecting Future Population Distributions Surrounding Power Reactor Sites," La Grange Park, IL.[13]

51. NRC, NUREG-0654/FEMA-REP-1, Revision 2, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," Washington, DC, December 2019 (ML19347D139).

52. NRC, RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization," Washington, DC.

53. NRC, NUREG/CR-7002, Revision 1, "Criteria for Development of Evacuation Time Estimate Studies," Washington, DC, February 2021 (ML21013A504).

54. CFR, "Physical Protection of Plants and Materials," Part 73, Chapter I, Title 10, "Energy."

55. NRC, RG 1.59, "Design Basis Floods for Nuclear Power Plants," Washington, DC.

56. American National Standards Institute/American Nuclear Society, ANSI/ANS-2.8-2019, "Probabilistic Evaluation of External Flood Hazards for Nuclear Facilities," La Grange Park, IL.

57. DOE-STD-1020-2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE."

58. DOE-HDBK-1220-2017, "Natural Phenomena Hazards Analysis and Design Handbook for DOE Facilities."

59. Bedient, P.B., W.F. Huber, and B.E. Vieux, *Hydrology and Floodplain Analysis*, Fourth Edition, Prentice Hall, Upper Saddle River, NJ, July 2007.

60. Riggs, H.C., "Hydrologic Analysis and Interpretation," *Techniques of Water-Resources Investigations*, Book 4, U.S. Geological Survey, Washington, DC, 1972.[14]

61. NRC, RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release," Washington, DC. 2021.

62. NRC, RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Washington, DC.

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13 Copies of ANSI/ANS standards may be purchased from the ANS website (http://www.new.ans.org/store/), or by writing to the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60526 (telephone: 800-323-3044).

14 Copies of U.S. Geological Survey (USGS) publications may be obtained from the USGS National Center, 12201 Sunrise Valley Drive, Reston, VA 20192; through the USGS website: https://www.usgs.gov/; or from the USGS publications warehouse at https://pubs.er.usgs.gov/.

63. DOE, DOE-STD-3014-2006, "Accident Analysis for Aircraft Crash into Hazardous Facilities," Washington, DC.

64. CFR, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System," Part 122, Chapter I, Title 40, "Protection of Environment."

65. CFR, "Steam Electric Power Generating Point Source Category," Part 423, Chapter I, Title 40, "Protection of Environment."

66. ASTM International, ASTM C1733, "Standard Test Method for Distribution Coefficients of Inorganic Species by the Batch Method," West Conshohocken, PA.[15]

67. NRC, RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," Washington, DC.

68. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.

69. Bald and Golden Eagle Protection Act, 16 U.S.C. 668 et seq.

70. Migratory Bird Treaty Act of 1972, as amended, 16 U.S.C. 703 et seq.

71. Marine Mammal Protection Act of 1972, as amended, 16 U.S.C. 1361 et seq.

72. Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 U.S.C. 1801 et seq.

73. National Historic Preservation Act, as amended, 16 U.S.C. 470 et seq.

74. CFR, "Farm and Ranch Lands Protection Program," Part 1491, Chapter XIV, Title 7, "Agriculture."

75. U.S. Department of the Interior, Bureau of Land Management Manual H-8410-1, "Visual Resource Inventory," Grand Junction, CO, January 17, 1986.[16]

76. Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," *Federal Register*, Vol. 59, No. 32, February 11, 1994, pp. 7629–7633.[17]

77. NRC, "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions," *Federal Register*, Vol. 69, No. 163, August 24, 2004, pp. 52040–52048.

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15 Copies of ASTM International standards may be purchased from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959; telephone (610) 832-9585. Purchase information is available through the ASTM website at http://www.astm.org.

16 Copies of U.S. Department of the Interior reports can be obtained from the Department at 1849 C Street, NW., Washington, DC 20240; telephone: (202) 208-3100; or electronically through the Department's website at http://www.doi.gov.

17 Executive orders of the President of the United States are available electronically at http://www.whitehouse.gov.

APPENDIX A

Alternative Approaches to Address Population-Related Siting Considerations

To demonstrate compliance with the United States Nuclear Regulatory Commission's (NRC) regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) 100.21, 10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1)(ix), and 10 CFR 52.79(a)(1)(vi), as applicable, commercial nuclear power reactor siting analyses should account for the potential for radiological releases due to possible accident conditions. Historically, analyses for such releases have been based on regulatory guidance developed for large light-water reactor (LWR) technology (e.g., Regulatory Guide (RG) 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,") which may not be applicable for many of the advanced reactor (e.g., non-LWR technologies and light-water small modular reactor) designs being developed. Because of the wide variety of potential advanced reactor designs and safety approaches, the variety of accident conditions does not lend itself to prescriptive guidance similar to that developed for LWR designs (e.g., RG 1.183). Rather, the guidance in this appendix identifies a set of attributes that should be addressed as part of proposing an alternative approach in the siting analysis for advanced reactors. This appendix provides guidance for three different approaches to estimating offsite consequences to inform the alternative population-related siting considerations for advanced reactors.

A-1. Background

The NRC has a longstanding policy of considering the siting of commercial nuclear power reactors as a factor in ensuring that multiple levels of defense in depth are provided to protect public health and safety in the event of an accident. Requirements related to siting commercial nuclear power reactors are included in NRC regulations in 10 CFR Part 100, "Reactor Site Criteria," 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."[a] Useful background information on the history of siting requirements appears in the *Federal Register* notice, "Final Rule: Reactor Site Criteria Including Seismic and Earthquake Engineering Criteria for Nuclear Power Plants" (61 FR 65157, December 11, 1996), and documents such as NUREG-0625, "Report of the Siting Policy Task Force," issued August 1979, ORNL/TM-2019/1197, "Advanced Reactor Siting Policy Considerations,"[b] issued June 2019, and SECY-20-0045, "Population-Related Siting Considerations for Advanced Reactors,"[c] dated May 8, 2020.

Section C.1.3 of this RG provides guidance on meeting the requirements in 10 CFR Part 100 for nuclear reactor licensees to establish an exclusion area, a low population zone (LPZ), and a minimum distance to the nearest densely populated center containing more than about 25,000 residents.

Section C.1.4 of this RG provides guidance on meeting the requirements in 10 CFR 100.21(h), which states the following:

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a Siting is also a significant focus of 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," but 10 CFR Part 51 requirements, including the need to assess severe accident mitigation alternatives, are outside the scope of this guidance.

b ORNL/TM-2019/1197 "Advanced Reactor Siting Policy Considerations," June 2019.

c SECY-20-0045, "Population-Related Siting Considerations for Advanced Reactors," May 8, 2020 (ML19262H055)

> "Reactor sites should be located away from very densely populated centers. Areas of low population density are, generally, preferred. However, in determining the acceptability of a particular site located away from a very densely populated center but not in an area of low density, consideration will be given to safety, environmental, economic, or other factors, which may result in the site being found acceptable."

The guidance in the body of this RG shows one way that an applicant can meet the requirements of 10 CFR 100.21(h) if the population density averaged over any radial distance out to 20 miles from the nuclear plant preferably does not exceed 500 persons per square mile (ppsm). In Staff Requirements Memorandum SECY-20-0045,[d] issued July 13, 2022, the Commission approved the NRC staff's recommended option to revise the guidance in this RG to provide technology-inclusive, risk-informed, and performance-based criteria to assess population-related issues in siting advanced reactors. The revised guidance in this appendix provides alternative population-related siting criteria where instead of locating a reactor in an area where the population density preferably does not exceed 500 ppsm out to 20 miles from the reactor, an applicant can demonstrate compliance with 10 CFR 100.21(h) by siting a nuclear reactor in a location where the population density preferably does not exceed 500 ppsm out to a distance equal to twice the distance at which a hypothetical individual could receive a calculated total effective dose equivalent (TEDE) of 1 rem over a period of 30 days from the release of radionuclides following postulated accidents.

A-2. Discussion

The alternative population-related siting criteria are independent of reactor design, but the calculation of potential doses from postulated accidents to be considered for comparison to the criteria are expected to reflect specific reactor designs and analytical approaches. The approach described in this appendix addresses consideration of design features and attributes and associated event analyses. It considers modeling for the potential release of radionuclides when determining the area in which population density is evaluated to meet the siting criteria and contributes to ensuring that defense in depth is provided for the protection of populations near commercial nuclear power plants. For the alternative approach, the consideration of transient populations and the gathering and prediction of population data are the same as described in section C.1.4 of this RG.

A-3. Staff Regulatory Guidance

The NRC staff has published guidance for two general approaches for the development of accident radiological consequence analyses to address regulatory requirements related to reactor designs and reactor sites. One approach developed for non-LWR technologies involves the use of the methodology described in RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," which is often referred to as the licensing modernization project (LMP) methodology for identifying and analyzing licensing-basis events, determining appropriate special treatments for plant structures, systems, and components (SSCs), and assessing defense in depth. The LMP methodology includes the assessment of potential consequences for a spectrum of event sequences using probabilistic risk assessment approaches and as needed, event-specific or mechanistic consideration of the movement of radionuclides past various barriers. The second approach is the prescriptive and conservative source term design-basis accident (DBA) consequence analysis described in RG 1.183, which involves the modeling of containment performance to ensure that it limits offsite consequences assuming the introduction of a prescribed mix of radionuclides. For LWRs,

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d SRM-SECY-20-0045, "Staff Requirements – SECY-20-0045 – Population-Related Siting Criteria for Advanced Reactors," dated July 13,2022 (ML22194A885) various studies and analyses have defined the prescribed isotopic mix, magnitude, and physical and chemical forms of radionuclides released to the containment or "source term" to bound events involving the breach of barriers upstream of the containment structure. In Figure 1, the two paths represent the two approaches to determining the releases of radionuclides for possible atmospheric dispersion and resultant doses to members of the public.

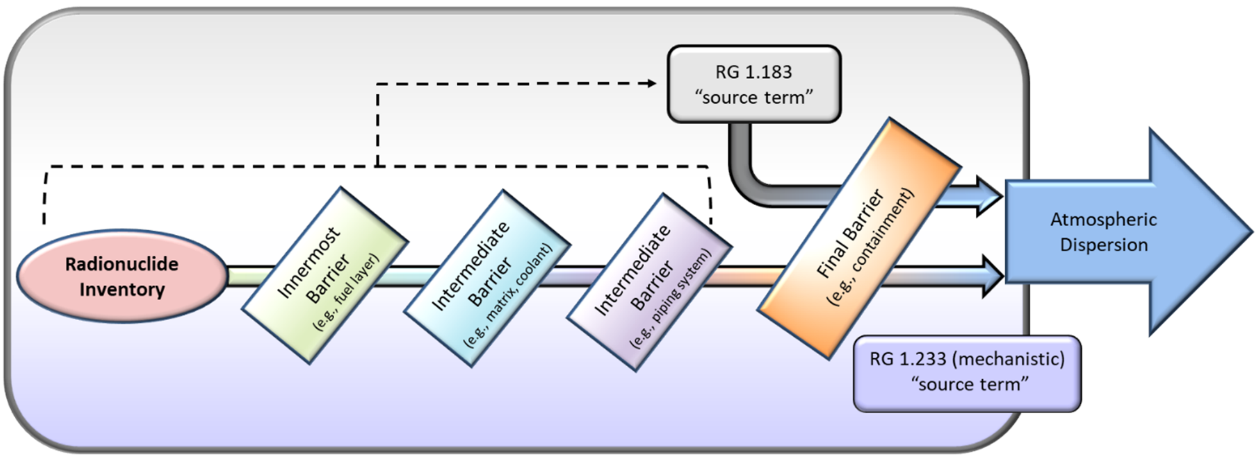

Figure 1: Approaches for estimating radiological releases

The following sections outline how these two approaches may be applied to advanced reactor designs to support estimating offsite consequences to inform alternative population-related siting considerations.

Acceptable analyses, in general, can be thought of along a continuum of realism and rigor of the analysis, ranging from bounding assumptions and simple modeling to a high level of realism and detail. At the same time, the analysis should balance the degree of conservatism and margin imposed between expected conditions and analytical assumptions to address considerations such as uncertainty or operational flexibility. More conservative analyses often lead to large safety margins on various design features. Such an approach can simplify the analyses while still demonstrating adequate conservatism to address uncertainty. More realistic and rigorous analyses involve more complex modeling of event sequences and contributions from various barriers, but such an approach may justify flexibility in plant design or needed programmatic controls. Therefore, the NRC staff provides the following list of key actions for siting analyses that should be considered regardless of the approach taken:

- Perform a comprehensive event assessment to identify all credible events.

- Select an event or events that bound the credible events in terms of parameters (e.g., temperatures, stresses) to determine conservative estimates of the radionuclide release(s) from the first barrier (and potentially intermediate barriers) that should be used for the siting evaluation.

- Consider uncertainties related to the performance of the barriers commensurate with the scope of the analysis performed.

- Demonstrate adequate defense in depth for confining and retaining radionuclides considering the uncertainties related to barrier performance.

The NRC anticipates three types of advanced reactor applications: (1) non-LWR technologies using the LMP methodology (RG 1.233); (2) LWR technologies using a traditional major accident approach or a deterministic approach to assess the potential consequences from reactor accidents; and (3) non-LWR technologies not using the LMP methodology and choosing to use a traditional or a deterministic approach to establish the requirements for a containment-type barrier for limiting the release of radionuclides.[e] The following sections provide guidance for estimating offsite consequences to inform the alternative population-related siting considerations for each of these types of applications.

A-3.1 Regulatory Guide 1.233 Approach (non-LWRs)[f]

For an applicant using a methodology like that described in RG 1.233, the results from the DBA analyses should be used to determine or confirm the boundaries of the exclusion area and LPZ by comparing the calculated consequences against the requirements in 10 CFR 50.34(a)(1)(ii)(D) or the corresponding requirements in 10 CFR Part 52 (10 CFR 52.17(a)(1)(ix) for early site permits or 10 CFR 52.79(a)(1)(vi) for combined licenses). An applicant using this approach may need to request an exemption from the regulations in 10 CFR 50.34, "Contents of applications; technical information," 10 CFR 52.17, "Contents of applications; technical information," or 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," if the DBA does not involve the equivalent of significant core damage such as that resulting from a major accident. Those regulations require an assumed "major accident"[g] for demonstrating the adequacy of traditional containment structures to confirm that doses at the boundaries of the exclusion area and LPZ are below the siting reference values provided in the regulations, a dose of 25 rem TEDE.

Applicants using a methodology like that described in RG 1.233 would use the licensing-basis events categorized as design-basis events (DBEs) and beyond-design-basis events (BDBEs) to estimate potential offsite doses for use in determining the distance out to which the population considerations are assessed in accordance with Section C.1.4 of this RG.[h] The estimated doses from DBEs and BDBEs are calculated for the 30-day period following the initiation of the release to determine the distance at which the dose to a hypothetical individual would exceed 1 rem TEDE. The calculation of offsite doses should be in accordance with NRC-accepted methodologies, including associated computer models for the plant response to an accident, the performance of various barriers to the release of radioactive materials, and the atmospheric dispersion of any released radioactive materials to areas surrounding the plant.[i]

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e Although population densities will ultimately be considered in a site-specific licensing application, some supporting analyses could be provided in generic documents such as a topical report, standard design approval, or standard design certification and subsequently referenced within a site-specific application with the appropriate confirmations that the generic analyses were applicable to the subject site. In the absence of generic analyses supporting the use of the alternative siting guidance in this appendix, the scope and fidelity of the required site-specific analyses to justify an alternative distance for assessing population density would need to satisfy the requirements for the specific type of application (e.g., construction permit or operating license).

f The scope of RG 1.233 is limited to non-LWRs. In the future, the staff may expand the applicability of RG 1.233 to LWRs as part of the guidance development for ongoing rulemakings.

g The term "major accident" is described in 10 CFR 50.34(a)(1)(ii)(D), footnote 6 as follows: "The fission product release assumed for this evaluation should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products."

h The methodology endorsed in RG 1.233 also includes specific steps to assess defense in depth provided by the combination of plant design, siting, and programmatic controls.

i The NRC can accept methodologies and computer models via endorsement of generally accepted methods, standards, and practices (e.g., regulatory guide for a consensus standard or approval of generic topical report) or as part of specific applications. Such acceptances can be for broad methodologies such as RG 1.247, "TRIAL—Acceptability of Probabilistic

Demonstrating that the population density for a subject site is considered in accordance with Section C.1.4 of this RG within the circular area defined by a radius of twice the distance at which the 1 rem TEDE is estimated for potential DBEs and BDBEs is sufficient to meet the requirements of 10 CFR 100.21(h). If an applicant could show that no DBEs or BDBEs result in an offsite dose exceeding 1 rem TEDE for the 30-day exposure period, the siting of a reactor might not be determined by population density considerations but would instead be governed by the regulatory requirement in 10 CFR 100.21(b) for reactors to be located distant from densely populated centers with more than about 25,000 residents. An advanced reactor with estimated doses below 1 rem at the site boundary over the 30 days following the assumed postulated accident could be sited within towns with populations of no more than approximately 25,000 residents.

A-3.2 Regulatory Guide 1.183 Plus Severe Accidents Approach (LWRs)

Section C.1.3 of this RG and RG 1.183 address the siting assessments and determination or confirmation of the boundaries of the exclusion area and LPZ based on the assumption of a major accident, the performance of containment and other systems included in a design to limit fission product release, and the characteristics of the subject site. An applicant may also use the analyses of a major accident using guidance such as RG 1.183 plus the evaluation of potential severe accidents that challenge the containment to evaluate an alternative to the assumed 20-mile distance from the plant for which population considerations are addressed in accordance with Section C.1.4 of this RG.

LWR applicants using this method would evaluate the radiological consequences of DBAs described in RG 1.183 and severe accidents that challenge containment to estimate the distance at which a hypothetical individual would experience a dose of 1 rem TEDE over the 30-day period following the initiation of a release. The radiological source term from RG 1.183 could be used along with insights from generic or design-specific analyses to address the performance of containment and other systems included to limit the release of radionuclides from severe accidents. At a minimum, the containment leakage would be assumed to be the same as that used for the evaluation of the exclusion area boundary and LPZ. The magnitude and timing of possibly greater releases to the environment should be assumed based on the analyses of accident progression and containment performance from the assessment of severe accidents for the as-designed plant (including potential severe accident design features). Demonstrating that the population considerations are assessed in accordance with Section C.1.4 of this RG out to twice the calculated distance at which the 1 rem TEDE is estimated for a major accident with consideration of containment performance during severe accidents is sufficient to meet the requirements of 10 CFR 100.21(h). In the case that an applicant could show that the calculated offsite dose does not exceed 1 rem TEDE for the 30-day exposure period, the siting of a reactor might not be determined by population density considerations but would instead be governed by the regulatory requirement in 10 CFR 100.21(b) for reactors to be located distant from densely populated centers with more than about 25,000 residents. An advanced reactor with estimated doses below 1 rem at the site boundary over 30 days following the assumed postulated accident could be sited within towns with populations of no more than approximately 25,000 residents.

A-3.3 For Non-LWRs Not Using RG 1.233 and Using Traditional Analysis of a Containment-Type Barrier

Non-LWR applicants choosing not to use a methodology like that in RG 1.233 and the related event-specific modeling of mechanistic source terms may use a traditional or deterministic approach to

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Risk Assessment Results for Non-Light-Water Reactor Risk-Informed Activities," or combinations of individual computer codes and related simulations.

establish the requirements for a containment-type barrier for limiting the release of radionuclides.[j] Since this approach will be seen as limiting for the required safety analyses compared to a more fully developed mechanistic source term for a range of event sequences, the applicant would need to develop a conservative, design-specific bounding core damage accident source term like that given in RG 1.183 for LWRs. The source term based on an estimate of a mixture of radionuclides breaching barriers upstream of the containment, along with associated energy additions (e.g., accounting for increased temperatures and pressures) from DBAs, should be used to confirm or establish performance requirements, including maximum leak rates, for the containment features using the existing criteria for doses at the exclusion area boundary and LPZ. (See for example, the discussion in RG 1.183, Section C.2, "Attributes of an Acceptable AST [alternative source term].") The non-LWR source term for the traditional siting analyses should be expressed in terms of times and rates of appearance of radioactive fission products released into the containment-type feature, the types and quantities of the radioactive species released, and the chemical forms for those radionuclides expected to significantly influence the public dose.

Similar to the traditional approach described above for LWRs (section A-3.2), the conservative source term introduced to the interior of a containment-type feature should also be used in combination with an assessment of containment performance under severe accidents. Demonstrating that the population considerations are assessed in accordance with Section C.1.4 of this RG out to twice the calculated distance at which the 1 rem TEDE is estimated for a major accident with consideration of containment performance during severe accidents is sufficient to meet the requirements of 10 CFR 100.21(h). If an applicant can show that the calculated offsite dose does not exceed 1 rem TEDE for the 30-day exposure period, the siting of a reactor might not be determined by population density considerations but would instead be governed by the regulatory requirement in 10 CFR 100.21(b) for reactors to be located distant from densely populated centers with more than about 25,000 residents. An advanced reactor with estimated doses below 1 rem at the site boundary over 30 days following the assumed postulated accident could be sited within towns with populations of no more than approximately 25,000 residents.

Similar to the description in section C.2 of RG 1.183 for LWRs, non-LWR applicants should also provide a defensible technical basis for the deterministic source term used for the siting analysis and justification of an alternative to the existing guidance in section C.1.4 of this RG (i.e., limited population density out to 20 miles from a reactor). The technical basis should be supported by sufficient experimental and empirical data, be verified and validated, be documented in a scrutable form that facilitates public review and should be peer reviewed by qualified subject matter experts. The following subsections offer guidance on specific elements to consider in developing such a source term for use in the siting analyses, including performing an event assessment, establishing a radionuclide release, considering uncertainty, and demonstrating adequate defense in depth.

(a) Performance of an Event Assessment and Selection of an Event or Events to be used for the Siting Analysis

To adequately justify the source term used for the siting analysis, an event assessment should be performed for the plant design basis. For the siting analysis, an applicant is required by 10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1)(ix), or 10 CFR 52.79(a)(1)(vi), as applicable, to provide an assessment and evaluation of the SSCs that bear significantly on the offsite dose evaluation factors. In performing this assessment, an applicant is required (e.g., by 10 CFR 50.34(a)(1)(ii)(D)) to assume a fission product

j This approach is provided to address non-LWRs using a containment-type barrier that encloses other barriers similar to the essentially leak tight structures used for LWRs. The consideration of multiple barriers and event-specific mechanistic source terms are supported in the LMP methodology (see section A-3.1). Hybrid approaches may be justified but are outside the scope of this guidance.

release from the core into the containment using the expected demonstrable containment leak rate and any fission product cleanup systems intended to mitigate the consequences of accidents.

When performing a comprehensive evaluation of postulated accidents, it is important to establish that what is analyzed is bounding for the siting analysis in terms of parameters (e.g., temperatures, stresses) to determine conservative estimates of the radionuclide release(s) from the first barrier (and potentially intermediate barriers). This can be done by performing a systematic assessment of the potential accidents and hazards and demonstrating that these events adequately envelope the facility design such that the analyses that are used are limiting. For example, the International Atomic Energy Agency Safety Guide, Specific Safety Requirements No. SSR-2/1, "Safety of Nuclear Power Plants: Design"[k] includes information on a systematic search for hazards that should be conducted for nuclear reactor sites. The Safety Guide identifies the following as Requirement 16, "Postulated initiating events":

> The design for the nuclear power plant shall apply a systematic approach to identifying a comprehensive set of postulated initiating events such that all foreseeable events with the potential for serious consequences and all foreseeable events with a significant frequency of occurrence are anticipated and are considered in the design.

It is important to note that applicants should document all anticipated hazards, including those excluded from consideration. If an event is precluded by some aspect of the design or an analytical assumption, that should be noted and justified.

(b) Establish Radionuclide Release(s) from the First Barrier

Applicants should provide a safety analysis that demonstrates compliance with the requirements in 10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1)(ix), or 10 CFR 52.79(a)(1)(vi), as applicable, to justify a finding of reasonable assurance of adequate protection of public health and safety even under the worst credible accident conditions. Recognition of the potential for a radiological source term—including activation of coolant/deposits, fission gas release, local failures (defects that are unlikely but credible over a sufficient sample size, channel blockages, etc.) and other relevant phenomena—is an important aspect of defense in depth to ensure that both prevention and mitigation of the full spectrum of credible adverse conditions that bear on public health and safety are considered. (Additional discussion on defense in depth considerations is provided in Section A-4, "Defense in Depth," below.) Therefore, the siting analysis should assume a radionuclide release from the innermost barrier (typically the fuel). Methods for determining the release of radionuclides should use conservative estimates of the radionuclide release(s) from the first barrier (and potentially intermediate barriers) to result in a source term and offsite consequences that are bounding for all credible events.

In many cases, a single analysis may adequately bound all other DBA analyses, and a single source term can be used for the siting analysis, similar to the approach used for non-power reactor applications submitted to the NRC that have used a maximum hypothetical accident analysis, as described in NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors."[l] Use of a single, bounding accident analysis does not prevent an applicant from providing analyses for multiple postulated accidents for siting, the set of which bounds the plant behavior. Such an

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k IAEA, Safety Standards, Specific Safety Requirements No. SSR-2/1, "Safety of Nuclear Power Plants: Design" (Rev. 1), Vienna, Austria, 2016.

l NUREG–1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Format and Content," and NUREG–1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria.", February 1996 (ML12156A069 and ML12156A075).

approach could allow reduced conservativism in the plant design by considering multiple source terms based on release mechanisms and plant conditions for different types of events while not fully adopting the methodology described in RG 1.233.

(c) Consideration of Uncertainty

The radiological releases proposed for use in the siting analysis should provide margin to all design-basis safety analyses. If using a single analysis or derived value, a justification should be provided for why this value adequately bounds the design basis. The more conservative the siting analysis, the simpler this justification can be.

The degree to which uncertainty should be considered in the siting analysis depends on both the reactor design and the details of the radiological consequence analysis used to satisfy the regulatory requirements in 10 CFR 50.34(a)(1) (also referenced by 10 CFR 100.21), 10 CFR 52.17(a)(1)(ix), or 10 CFR 52.79(a)(1)(vi), as applicable. A simpler design with relatively coarse assumptions might require less accounting for uncertainty at the cost of design margin (e.g., through the use of more conservative assumptions). Conversely, a finely refined analysis could be used to capture design margin (with an associated lower margin between the analysis and acceptance criteria) at the cost of quantifying the uncertainty and justifying how the analysis meets the applicable NRC requirements. The need to provide assurances that safety functions will be fulfilled, and uncertainties are addressed is reflected in requirements such as 10 CFR 50.43(e), which requires demonstration of safety feature performance by analysis, appropriate test programs, experience, or a combination of all three.

If not captured directly by conservatism in the analyses, uncertainties should be established, where applicable, and quantified if possible. Subjectivity in establishing these uncertainties is ideally avoided through the use of quantitative tools that address uncertainties such as a probabilistic risk assessment or consideration of experimental or dataset uncertainty. However, use of a non-probabilistic hazard assessment technique coupled with provisions of defense in depth (multiple means of satisfying a safety function to reduce or eliminate the likelihood of phenomena) can satisfactorily address phenomenological uncertainties associated with specific internal and external hazards.

A-4. Defense in Depth

Defense in depth involves using multiple independent and redundant layers of defense to compensate for potential failures so that no single layer, no matter how robust, is relied on exclusively. More specifically, when evaluating defense in depth for the siting analysis, no single feature should be relied on exclusively for performance of a safety function.

The consideration of defense in depth as part of developing a source term for use in the siting analyses for non-LWRs is difficult to quantify and is somewhat narrower than the full defense in depth concept referred to elsewhere, such as in guidance from the International Atomic Energy Agency. For the purposes of the siting analysis, an accident is deemed to have occurred (so prevention and control of accident conditions are neglected once the release is established) and the regulatory requirements associated with this guidance are based on radiological consequences at a set boundary given the accident has occurred. NRC regulations, such as 10 CFR 50.47, "Emergency plans," address other elements of defense in depth by requiring additional assessments and appropriate offsite mitigation capabilities.

When considered together, the population density alternative approach described in this appendix, and the other layers of defense in depth provided by compliance with the NRC's requirements for plant design and programmatic controls (e.g., 10 CFR 50.36), demonstrate adequate defense in depth. Defense in depth is adequate if the overall redundancy and diversity among the plant's systems and barriers are sufficient, and the siting analysis demonstrates compliance with NRC requirements (e.g., 10 CFR 50.34(a)(1)) to justify a finding of reasonable assurance of adequate protection of public health and safety. Compliance with the NRC's requirements for emergency preparedness (e.g., 10 CFR 50.47) provides additional defense in depth and reasonable assurance that protective actions can and will be taken to protect public health and safety but does not need to be demonstrated for the siting analysis.