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REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

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DESIGN BASIS FLOODS FOR FUEL REPROCESSING PLANTS AND FOR PLUTONIUM PROCESSING AND FUEL FABRICATION PLANTS

A. INTRODUCTION

Paragraph (a)(1) of §50.34, "Contents of applications: Technical information," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, among other things, that each application for a construction permit for a production or utilization facility, including fuel reprocessing plants, include a description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design. Paragraph 70.22(f) of 10 CFR Part 70, "Special Nuclear Material," requires that each application for a license to possess and use special nuclear material in a plutonium processing and fuel fabrication plant contain, among other things, a description and safety assessment of the design bases of the principal structure, systems, and components of the plant, including provisions for protection against natural phenomena. Paragraph 70.23(b) of 10 CFR Part 70 provides that the Commission will approve construction of the principal structures, systems, and components of a plutonium processing and fuel fabrication plant when it has determined, among other things, that the design bases of the principal structures, systems, and components provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

This guide describes methods of determining the design basis floods that fuel reprocessing plants and plutonium processing and fuel fabrication plants[1] should be designed to withstand without loss of safety-related functions. It does not identify structures, systems, and components that should be designed to withstand the effects of floods or discuss the design requirements for flood protection.

The methods described in this guide result from review and action on a number of specific cases, and as such, reflect the latest general approaches to the problem NRC has approved. If an applicant desires to employ new information that may be developed in the future or to use an alternative method, NRC will review the proposal and approve its use, if found acceptable.

The flood analysis described in this guide need not be considered by applicants in their submittals for special nuclear material licenses or construction permit applications for nuclear facilities located at sites above the design basis flood level where it is obvious that safety-related structures, systems, and components are not affected by flooding.

B. DISCUSSION

Nuclear facilities should be designed to prevent a release of radioactivity resulting from the effects of the most severe flood conditions that can reasonably be predicted to occur at a site as a result of severe hydrometeorological conditions, seismic activity, or both.

The Corps of Engineers for many years has studied conditions and circumstances relating to floods and flood control. As a result of these studies, it has developed a definition for a Probable Maximum

[1] The term "nuclear facility" will be used in this guide to refer to fuel reprocessing plants and to plutonium processing and fuel fabrication plants.

Flood (PMF)[2] and attendant analytical techniques for estimating, with an acceptable degree of conservatism, flood levels on streams resulting from hydrometeorological conditions. An acceptable degree of conservatism, for estimating seismically induced flood levels and for evaluating the effects of the initiating event, is provided in Appendix A to 10 CFR Part 100.

The conditions resulting from the worst site-related flood probable at the nuclear facility (e.g., PMF, seismically induced flood, seiche, surge, severe local precipitation) with attendant wind-generated wave activity constitute the design basis flood conditions that safety-related structures, systems, and components, whose failure during such conditions would constitute a threat to the public health and safety, should be designed to withstand and remain functional.

For sites along streams, the PMF generally provides the design basis flood. For sites along lakes or seashores, a flood condition of comparable severity could be produced by the most severe combination of hydrometeorological parameters reasonably possible, such as may be produced by a Probable Maximum Hurricane (Refs. 1, 2) or by a Probable Maximum Seiche. On estuaries, a Probable Maximum River Flood, a Probable Maximum Surge, a Probable Maximum Seiche, or a reasonable combination of less severe phenomenologically caused flooding events should be considered in arriving at design basis flood conditions comparable in frequency of occurrence with PMF on streams.

In addition to floods produced by severe hydrometeorological conditions, the most severe seismically induced floods reasonably possible should be considered for each site. Along streams and estuaries, seismically induced floods may be produced by dam failures or landslides. Along lakeshores, coastlines, and estuaries, seismically induced or tsunami-type flooding should be considered. Consideration of seismically induced floods should include the same range of seismic events as is postulated for the design of the nuclear facility. For instance, the analysis of floods caused by dam failures, landslides, or tsunami requires consideration of seismic events equivalent in severity to the Safe Shutdown Earthquake[3] occurring at the location that would produce the worst such flood at the nuclear facility site.

In the case of seismically induced floods along rivers, lakes, and estuaries which may be produced by events less severe than a Safe Shutdown Earthquake, consideration should be given to the coincident occurrence of floods due to severe hydrometeorological conditions. But this should be considered only where the effects on the nuclear facility are worse, and the probability of such combined events may be greater, than an individual occurrence of the most severe event of either type. For example, a seismically induced flood produced by an earthquake equivalent in severity to an Operating Basis Earthquake[3] coincident with a runoff-type flood of Standard Project Flood[4] severity may be considered to have approximately the same severity as the seismically induced flood from an earthquake of Safe Shutdown severity coincident with about a 25-year flood. For the specific case of seismically induced floods due to dam failures, an evaluation should be made (a) of flood waves that may be caused by domino-type dam failures triggered by a seismically induced failure of a critically located dam and (b) of flood waves that may be caused by multiple dam failures in a region where dams may be located close enough together that a single seismic event can cause multiple failures.

Each of the severe flood types discussed above should represent the upper limit of all potential phenomenologically caused flood combinations considered reasonably possible. Analytical techniques are available and should generally be used for prediction at individual sites. Those techniques applicable to PMF and seismically induced flood estimates on streams are presented in Appendices A and B to Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants." Similar appendices for coastal, estuary, and Great Lakes sites, reflecting comparable levels of risk, will be issued as they become available. Appendix C to Regulatory Guide 1.59 contains an acceptable method of estimating hurricane-induced surge levels on the open coasts of the Gulf of Mexico and the Atlantic Ocean.

Analyses of only the most severe flood conditions may not indicate potential threats to safety-related systems that might result from combinations of flood conditions thought to be less severe. Therefore, reasonable combinations of less-severe flood conditions should also be considered to the extent needed

[2] Corps of Engineers' Probable Maximum Flood definition appears in many publications of that agency such as Engineering Circular EC 1110-2-27, Change 1, "Engineering and Design-Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams," February 19, 1968. The Probable Maximum Flood is also directly analogous to the Corps of Engineers "Spillway Design Flood" as used for dams whose failures would result in a significant loss of life and property.

[3] Determined in a manner analogous to that outlined in Appendix A to 10 CFR Part 100.

[4] The Standard Project Flood (SPF) is the flood resulting from the most severe flood-producing rainfall depth-area-duration relationship and isohyetal pattern of any storm that is considered reasonably characteristic of the region in which the watershed is located. If snowmelt may be substantial, appropriate amounts are included with the Standard Project Storm rainfall. Where floods are predominantly caused by snowmelt, the SPF is based on critical combinations of snow, temperature, and water losses. See "Standard Project Flood Determinations," EM 1110-2-1411, Corps of Engineers, Department of the Army (revised March 1965).

for a consistent level of conservatism. Such combinations should be evaluated in cases where the probability of their existing at the same time and having significant consequences is at least comparable to that associated with the most severe hydrometeorological or seismically induced flood. For example, a failure of relatively high levees adjacent to a nuclear facility could occur during floods less severe than the worst site-related flood, but would produce conditions more severe than those that would result during a greater flood (where a levee failure elsewhere would produce less severe conditions at the nuclear facility site).

Wind-generated wave activity may produce severe flood-induced static and dynamic conditions either independent of or coincident with severe hydrometeorological or seismic flood-producing mechanisms. For example, along a lake, reservoir, river, or seashore, reasonably severe wave action should be considered coincident with the probable maximum water level conditions.[3] The coincidence of wave activity with probable maximum water level conditions should take into account the fact that sufficient time can elapse between the occurrence of the assumed meteorological mechanism and the maximum water level to allow subsequent meteorological activity to produce substantial wind-generated waves coincident with the high water level. In addition, the most severe wave activity at the site that can be generated by distant hydrometeorological activity should be considered. For instance, coastal locations may be subjected to severe wave action caused by a distant storm that, although not as severe as a local storm (e.g., a Probable Maximum Hurricane), may produce more severe wave action because of a very long wave-generating fetch. The most severe wave activity at the site that may be generated by conditions at a distance from the site should be considered in such cases. In addition, assurance should be provided that safety systems are designed to withstand the static and dynamic effects resulting from frequent flood levels (i.e., the maximum operating level in reservoirs and the 10-year flood level in streams) coincident with the waves that would be produced by the Probable Maximum Gradient Wind[4] for the site (based on a study of historical regional meteorology).

[3] Probable Maximum Water Level is defined by the Corps of Engineers as "the maximum still water level (i.e., exclusive of local coincident wave runup) which can be produced by the most severe combination of hydrometeorological and/or seismic parameters reasonably possible for a particular location. Such phenomena are hurricanes, moving squall lines, other cyclonic meteorological events, tsunami, etc., which, when combined with the physical response of a body of water and severe ambient hydrological conditions, would produce a still water level that has virtually no risk of being exceeded." (See Appendix A to Regulatory Guide 1.59).

[4] Probable Maximum Gradient Wind is defined as a gradient wind of designated duration, of which there is virtually no risk of being exceeded.

C. REGULATORY POSITION

1. The conditions resulting from the worst site-related flood probable at a nuclear facility (e.g., PMF, seismically induced flood, hurricane, seiche, surge, heavy local precipitation) with attendant wind-generated wave activity constitute the design basis flood conditions that structures, systems, and components important to safety must be designed to withstand without impairing their capability to perform safety functions.

a. On streams, the PMF, as defined by the Corps of Engineers and based on the analytical techniques summarized in Appendices A and B of Regulatory Guide 1.59, provides an acceptable level of conservatism for estimating flood levels caused by severe hydrometeorological conditions.

b. Along lakeshores, coastlines, and estuaries, estimates of flood levels resulting from severe surges, seiches, and wave action caused by hydrometeorological activity should be based on criteria comparable in conservatism to those used for PMFs. Criteria and analytical techniques providing this level of conservatism for the analysis of these events will be summarized in subsequent appendices to Regulatory Guide 1.59. Appendix C of Regulatory Guide 1.59 presents an acceptable method for estimating the stillwater level of the Probable Maximum Surge (PMS) from hurricanes at open-coast sites on the Atlantic Ocean and Gulf of Mexico.

c. Flood conditions that could be caused by dam failures from earthquakes should also be considered in establishing the design basis flood. A simplified analytical technique for evaluating the hydrologic effects of seismically induced dam failures discussed herein is presented in Appendix A of Regulatory Guide 1.59. Techniques for evaluating the effects of tsunami will also be presented in a future appendix to Regulatory Guide 1.59.

d. Where upstream dams or other features that provide flood protection are present, in addition to the analyses of the most severe floods that may be induced by either hydrometeorological or seismic mechanisms, reasonable combinations of less severe flood conditions and seismic events should also be considered to the extent needed for a consistent level of conservatism. The effect of such combinations on the flood conditions at the nuclear facility site should be evaluated in cases where the probability of such combinations occurring at the same time and having significant consequences is at least comparable to the probability associated with the most severe hydrometeorological or seismically induced flood. On relatively large streams, examples of acceptable combinations of runoff floods and seismic events that could affect the flood conditions at the nuclear facility include the Safe Shutdown Earthquake (see footnote 3) with the 25-year flood and the Operating Basis Earthquake (see footnote 3) with the Standard Project Flood. Less severe flood conditions, associated with the above seismic events, may be acceptable for small streams that exhibit relatively short periods of flooding. The above combinations of independent events are specified here only with respect to the determination of the design basis flood level.

e. The effects of coincident wind-generated wave activity to the water levels associated with the worst site-related flood possible (as determined from paragraphs a, b, c, or d above) should be added to generally define the upper limit of flood potential. An acceptable analytical basis for wind-generated wave activity coincident with probable maximum water levels is the assumption of a 40-mph overland wind from the most critical wind-wave-producing direction. However, if historical windstorm data substantiate that the 40-mph event, including wind direction and speed, is more extreme than has occurred regionally, historical data may be used. If the mechanism producing the maximum water level, such as a hurricane, would itself produce higher waves, these higher waves should be used as the design basis.

2. As an alternative to designing hardened protection[7] for all safety-related structures, systems, and components as specified in Regulatory Position 1 above, it is permissible to curtail operation of the facility and initiate suitable protective measures provided that:

a. Sufficient warning time is shown to be available to curtail operations and implement adequate emergency procedures;

b. Those structures, systems, and components necessary for confinement of radioactivity during the emergency are designed with hardened protective features to remain functional while withstanding the entire range of flood conditions up to and including the worst site-related flood probable (e.g., PMF, seismically induced flood, hurricane, surge, seiche, heavy local precipitation), with coincident wind-generated wave action as discussed in Regulatory Position 1 above.

3. During the economic life of a nuclear facility, unanticipated changes to the site environs which may affect the flood-producing characteristics of the environs are possible. Examples include construction of a dam upstream or downstream of the nuclear facility, or comparably, construction of a highway or railroad bridge and embankment that obstructs the floodflow of a river, and construction of a harbor or deepening of an existing harbor near a coastal or lake site nuclear facility.

Significant changes in the runoff or other flood-producing characteristics of the site environs, as they affect the design basis flood, should be identified and used as the basis to develop or modify emergency operating procedures, if necessary, to mitigate the effects of the increased flood. The following should be reported.[8]

a. The type of investigation undertaken to identify changed or changing conditions in the site environs,

b. The changed or changing conditions noted during the investigation,

c. The hydrologic engineering bases for estimating the effects of the changed conditions on the design basis flood, and

d. Structures, systems, or components important to safety affected by the changed conditions in the design basis flood should be identified along with modifications to the nuclear facility necessary to afford protection during the increased flood conditions. If emergency operating procedures must be used to mitigate the effects of these new flood conditions, the emergency procedures developed or modifications to existing procedures should be provided.

4. Proper utilization of the data and procedures in Appendices B and C of Regulatory Guide 1.59 will result in PMF peak discharges and PMS peak still-water levels that will in many cases be approved by the NRC staff with no further verification. The staff will continue to accept for review detailed PMF and PMS analyses that result in less conservative estimates than those obtained by use of Appendices B and C of Regulatory Guide 1.59. In addition, previously reviewed and approved detailed PMF and PMS analyses will continue to be acceptable even though the data and procedures in Appendices B and C of Regulatory Guide 1.59 result in more conservative estimates.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes to use an acceptable alternative method for

[7] *Hardened protection* means structural provisions incorporated in the nuclear facility design that will protect safety-related structures, systems, and components from the static and dynamic effects of floods. In addition, each component of the protection must be passive and in place, as it is to be used for flood protection, during normal facility operation.

[8] Reporting should be by special report to the appropriate NRC Regional Office and to the Director of the Office of Inspection and Enforcement. Requirement for such reports should be included in the Technical Specifications or in applicable sections of the license application unless it can be demonstrated that such reports will not be necessary during the life of the nuclear facility.

complying with specific portions of the Commission's regulations, the methods described herein will be used in the evaluation of submittals for special nuclear material license or construction permit applications docketed after July 15, 1977. If an applicant wishes to use this regulatory guide in developing submittals for an application docketed prior to July 15, 1977, the pertinent portions of the application will be evaluated on the basis of this guide.

REFERENCES

1. U.S. Army Coastal Engineering Research Center, "Shore Protection Manual," 1973.
2. U.S. Weather Bureau (now U.S. Weather Service, NOAA), "Meteorological Characteristics of the Probable Maximum Hurricane, Atlantic and Gulf Coasts of the United States," Hurricane Research Interim Report, HUR 7-97 and HUR 7-97A, 1968.