JAPAN LESSONS-LEARNED PROJECT DIRECTORATE

JLD-ISG-2012-05

Guidance for Performing the Integrated Assessment for Flooding

DRAFT Interim Staff Guidance

Revision 0
(Draft Issue for Public Comment)

September 20, 2012 ML12235A319

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

<u>JAPAN LESSONS-LEARNED PROJECT DIRECTORATE</u>

JLD-ISG-2012-05

Guidance for Performing the Integrated Assessment for Flooding

DRAFT Interim Staff Guidance

Revision 0
(Draft Issue for Public Comment)

September 20, 2012 ML12235A319

DRAFT
INTERIM STAFF GUIDANCE
JAPAN LESSONS-LEARNED PROJECT DIRECTORATE
GUIDANCE FOR PERFORMING THE INTEGRATED ASSESSMENT FOR EXTERNAL FLOODING
JLD-ISG-12-05

PURPOSE

This interim staff guidance is being issued to describe to stakeholders methods acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for performing the Integrated Assessment for external flooding as described in NRC's March 12, 2012 request for information (Ref. (1)) issued pursuant to "Title 10, Code of Federal Regulations, Part 50, Section 54 (10 CFR 50.54)" regarding Recommendation 2.1 of the enclosure to SECY-11-0093, "Recommendations for Enhancing Reactor Safety in the 21st Century, the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (Ref. (2)). Among other actions, the March 12, 2012 letter requests that respondents reevaluate flood hazards at each site and compare the reevaluated hazard to the current design basis at the site for each flood mechanism. Addressees are requested to perform an Integrated Assessment if the current design basis flood hazard does not bound the reevaluated flood hazard for all mechanisms. This ISG will assist operating power reactor respondents and holders of construction permits under 10 CFR Part 50 with performance of the Integrated Assessment. It should be noted that the guidance provided in this ISG is not intended to describe methods for use in regulatory activities beyond the scope of the March 12, 2012, 50.54(f) letter.

BACKGROUND

Following the events at the Fukushima Dai-ichi nuclear power plant, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF conducted a systematic and methodical review of the NRC regulations and processes and determined if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in the enclosure to SECY-11-0093 (Ref. (2)). These recommendations were enhanced by the NRC staff following interactions with stakeholders. Documentation of the NRC staff's efforts is contained in SECY-11-0124, "Recommended Actions to Be Taken without Delay from the Near-Term Task Force Report," dated September 9, 2011 (Ref.(3)), and SECY-11-0137, "Prioritization of Recommended Actions To Be Taken in Response to Fukushima Lessons Learned," dated October 3, 2011(Ref. (4)).

As directed by the staff requirements memorandum for the enclosure to SECY-11-0093 (Ref. (2)), the NRC staff reviewed the NTTF recommendations within the context of the NRC's existing regulatory framework and considered the various regulatory vehicles available to the NRC to implement the recommendations. SECY-11-0124 and SECY-11-0137 established the staff's prioritization of the recommendations based upon the potential safety enhancements.

As part of the staff requirements memorandum for SECY-11-0124, dated October 18, 2011 (Ref.(3)), the Commission approved the staff's proposed actions, including the development of three information requests under 10 CFR 50.54(f). The information collected would be used to support the NRC staff's evaluation of whether further regulatory action should be pursued in the areas of seismic and flooding design, and emergency preparedness.

In addition to Commission direction, the Consolidated Appropriations Act, Public Law 112-074, was signed into law on December 23, 2011. Section 402 of the law requires a reevaluation of licensees' design basis for external hazards.

In response to the aforementioned Commission and Congressional direction, the NRC issued a request for information to all power reactor licensees and holders of construction permits under 10 CFR Part 50 on March 12, 2012 (Ref.(1)). The March 12, 2012 50.54(f) letter includes a request that respondents reevaluate flooding hazards at nuclear power plant sites using updated flooding hazard information and present-day regulatory guidance and methodologies. The letter also requests the comparison of the reevaluated hazard to the current design basis at the site for each potential flood mechanism. If the reevaluated flood hazard at a site is not bounded by the current design basis, respondents are requested to perform an Integrated Assessment. The Integrated Assessment will evaluate the total plant response to the flood hazard, considering multiple and diverse capabilities such as physical barriers, temporary protective measures, and operational procedures. The NRC staff will review the responses to this request for information and determine whether regulatory actions are necessary to provide additional protection against flooding.

RATIONALE

On March 12, 2012, NRC issued a request for information to all power reactor licensees and holders of construction permits under 10 CFR Part 50. The request was issued in accordance with the provisions of Sections 161.c, 103.b, and 182.a of the Atomic Energy Act of 1954, as amended (the Act), and NRC regulation in Title 10 of the *Code of Federal Regulations*, Part 50, Paragraph 50.54(f). Pursuant to these provisions of the Act or this regulation, respondents were required to provide information to enable the staff to determine whether a nuclear plant license should be modified, suspended, or revoked.

The information request directed respondents to submit an approach for developing an Integrated Assessment Report including criteria for identifying vulnerabilities. This ISG describes an approach for developing the Integrated Assessment Report that is acceptable to the staff.

APPLICABILITY

This ISG shall be implemented on the day following its approval. It shall remain in effect until it has been superseded or withdrawn.

PROPOSED GUIDANCE

This ISG is applicable to holders of operating power reactor licensees and construction permits under 10 CFR Part 50 from whom an Integrated Assessment is requested (i.e., sites for which the current design basis flood hazard does not bound the reevaluated hazard for all potential flood mechanisms). For combined license holders under 10 CFR Part 52, the issues in NTTF Recommendation 2.1 and 2.3 regarding seismic and flooding reevaluations and walkdowns are resolved and thus this ISG is not applicable.

IMPLEMENTATION

Except in those cases in which a licensee or construction permit holder under 10 CFR Part 50 proposes an acceptable alternative method for performing the Integrated Assessment, the NRC staff will use the methods described in this ISG to evaluate the results of the Integrated Assessment.

BACKFITTING DISCUSSION

Licensees and construction permit holders under 10 CFR Part 50 may use the guidance in this document to perform the Integrated Assessment. Accordingly, the NRC staff issuance of this ISG is not considered backfitting, as defined in 10 CFR 50.109(a)(1), nor is it deemed to be in conflict with any of the issue finality provisions in 10 CFR Part 52.

FINAL RESOLUTION

The contents of this ISG, or a portion thereof, may subsequently be incorporated into other guidance documents, as appropriate.

ENCLOSURE

1. Guidance for Performance of Integrated Assessment

REFERENCES

1. U.S. Nuclear Regulatory Commission. Request for information pursuant to Title 10 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident. March 12, 2012. ADAMS Accession No. ML12053A340.

2. —. "Recommendations for Enhancing Reactor Safety in the 21st Century, The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," Enclosure to SECY-11-0093. July 12, 2011. ADAMS Accession No. ML111861807.

3. —. "Recommended Actions To Be Taken Without Delay From the Near Term Task Force Report," SECY-11-0124. September 9, 2011. ADAMS Accession No. ML11245A158.

4. —. "Prioritization of Recommended Actions to Be Taken in Response to Fukushima Lessons Learned," SECY-11-0137. October 2011. ADAMS Accession No. ML11272A111.

GUIDANCE FOR PERFORMANCE OF INTEGRATED ASSESSMENT

1. Introduction

The objective of this document is to provide guidance for performance of the Integrated Assessment. The Integrated Assessment evaluates the total plant response to external flood hazards, considering both the protection and mitigation capabilities of the plant. The purpose of the Integrated Assessment is to: (1) evaluate the effectiveness of the current licensing basis, (2) identify plant-specific vulnerabilities, and (3) assess the effectiveness of existing or planned plant systems and procedures in protecting against flood conditions and mitigating consequences for the entire duration of a flooding event.

In general, the types and attributes of flood protection features used at nuclear power plants are diverse due to differences in factors such as: hazard characteristics (e.g., flood mechanisms, flood durations, and debris quantity), site topography and surrounding environment, and other site-specific considerations (e.g., available warning time). As a result, this guidance must be capable of accommodating the unique environments and characteristics of nuclear power plant sites while ensuring that the information gathered as part of the NRC's March 12, 2012 50.54(f) letter provides a sufficient technical basis to determine if any additional regulatory actions are necessary to protect against external flood hazards.

Recommendation 2.1 of the NTTF is being implemented in two phases. In Phase 1 licensees and construction permit holders will reevaluate the flooding hazard at each site using present-day regulatory guidance and methodologies. If the reevaluated hazard is not bounded by the design basis flood at the site, licensees and construction permit holders are also requested to perform an Integrated Assessment for external flooding. Phase 2 uses the Phase 1 results to determine whether additional regulatory actions are necessary (e.g., update the licensing basis and SSCs important to safety).

1.1 Integrated Assessment concept

Figure 1 provides a conceptual illustration of the Integrated Assessment process. The outcomes of the hazard reviews performed under the Near-Term Task Force (NTTF) Recommendation 2.1 flood hazard reevaluations[1] provide input into the Integrated Assessment Process. Upon entry into the Integrated Assessment process, licensees should evaluate the capability of flood protection systems to meet their intended safety functions under the reevaluated hazard.

If the site flood protection can be shown to be reliable and have margin, the licensee should proceed to documentation and justification of results. If site flood protection cannot be shown to be reliable and have margin, licensees should evaluate the plant's ability to maintain key safety functions during a flood in the event that one or more flood protection systems are compromised and unable to perform their intended functions. In the Integrated Assessment, this step of the process is referred to as an evaluation of mitigation capability and strategies. Upon evaluation of the mitigation capability of the plant, the process proceeds to documentation and justification of results.

---

[1] See Section 2.3 for additional details on the NTTF Recommendation 2.1 hazard reevaluations and the relationship to the Integrated Assessment.

In lieu of flood protection, some sites may allow water to enter buildings (or other areas housing structures, systems, or components that are important to safety) by procedure or design. If the presence of water in these locations may adversely affect structures, systems, or components that are important to safety, then the Integrated Assessment process should proceed directly into the evaluation of the mitigation capability of the plant. This is represented by the large arrow on the rightmost side of Figure 1.

Additional details on the Integrated Assessment process are provided in subsequent sections of this document.

1.2 Scope of Integrated Assessment

In accordance with the March 12, 2012 letter, the scope of the Integrated Assessment includes full-power operations and other plant configurations that could be susceptible to damage due to the status of the flood protection features. The scope also includes flood-induced loss of an ultimate heat sink (UHS) water source (e.g., due to failure of a downstream dam) that could be caused by the flood conditions. (The loss of the UHS from causes other than flooding are not included.) The March 12, 2012 50.54(f) letter also requests that the Integrated Assessment address the entire duration of the flood conditions.

2. Background

2.1 Actions and information requested

For the sites where the reevaluated flood is not bounded by the current design basis for all flood-causing mechanisms, the March 12, 2012 letter requests that licensees and construction permit holders perform an Integrated Assessment of the plant to identify vulnerabilities and actions to address them. This ISG provides guidance on methods the NRC considers acceptable for performing the Integrated Assessment as requested by the March 12, 2012 50.54(f) letter.

Consistent with the March 12, 2012 letter (Enclosure 2, p. 8-9), licensees and construction permit holders are requested to provide the following as part of the Integrated Assessment report:

a) Description of the integrated procedure used to evaluate integrity of the plant for the entire duration of flood conditions at the site.
b) Results of the plant evaluations describing the controlling flood mechanisms and its effects, and how the available or planned measures will provide effective protection and mitigation. Discuss whether there is margin beyond the postulated scenarios.
c) Description of any additional protection and/or mitigation features that were installed or are planned, including those installed during course of reevaluating the hazard. The description should include the specific features and their functions.
d) Identify other actions that have been taken or are planned to address plant-specific vulnerabilities.

This ISG provides guidance on methods considered acceptable to NRC for performing the Integrated Assessment as requested by the March 12, 2012 50.54(f) letter.

2.2 NTTF Recommendation 2.3 flood walkdowns

As part of the 50.54(f) letter issued by the NRC on March 12, 2012, licensees were requested to perform flood protection walkdowns to verify that plant features credited in the current licensing basis for protection and mitigation from external flood events are available, functional, and properly maintained. These walkdowns are interim actions to be performed while the longer-term hazard reevaluations and Integrated Assessments are performed. NRC and NEI worked collaboratively to develop guidelines for performing the walkdowns, resulting in NEI 12-07, “Guidelines for Performing Verification Walkdowns of Plant Flood Protection Features” (Ref. (1)), which NRC endorsed on May 31, 2012 (Ref. (2)).

As part of the walkdowns, licensees and construction permit holders will verify that permanent structures, systems, and components (SSC) as well as temporary or portable flood protection and mitigation equipment will perform their intended safety functions as credited in the current licensing basis. Verification activities will ensure that changes to the plant (e.g., security barrier installations and topography changes) do not adversely affect flood protection and mitigation equipment. In addition, the walkdown will verify that procedures needed to install and operate equipment needed for flood protection or mitigation can be performed as credited in the current licensing basis. The walkdown will also verify that the execution of procedures will not be impeded by adverse weather conditions that could be reasonably expected to simultaneously occur with a flood event. As part of the walkdowns, observations of potential deficiencies, as well as observations of flood protection features with small margin and potentially significant safety consequences if lost, will be entered into the licensee's corrective action program.

It is anticipated that the walkdowns will be a valuable source of information that will be useful during the performance of the Integrated Assessment. In particular, the walkdowns will provide information on available physical margin (APM) under the current design basis hazard, the condition of flood protection features, the feasibility of procedures, SSCs that are subjected to flooding, and the potential availability of systems to mitigate flood events. However, it is emphasized that the walkdowns are performed to the current licensing basis. The reevaluated flood hazards performed under Recommendation 2.1 (see Section 2.3) may be associated with higher water surface elevations and different associated effects when compared to the current licensing basis. Therefore, some of the information from the walkdowns may not be directly applicable as part of the Integrated Assessment. It is expected that any additional information related to the impact of the flooding hazard reassessment will be considered as part of the Integrated Assessment, and that this information would be available to effectively consider the flood protection capabilities in light of potential additional flooding impacts to the site (i.e., higher elevations, accessibility issues) that may not have been fully considered during the implementation of Recommendation 2.3 walkdown.

2.3 NTTF Recommendation 2.1 flood hazard reevaluations

NRC's March 12, 2012 50.54(f) letter requests that licensees and construction permit holders reevaluate all appropriate external flooding sources, including the effects from local intense precipitation on the site, probable maximum flood (PMF) on stream and rivers, storm surges, seiche, tsunami, and dam failures. It is requested that the reevaluation apply present-day regulatory guidance and methodologies used for early site permit (ESP) and combined license (COL) reviews including current techniques, software, and methods used in present-day standard engineering practice.

For the sites where the reevaluated flood is *not* bounded by the current design basis hazard for all flood mechanisms applicable to the site, licensees and construction permit holders are requested to submit an interim action plan with the hazard report that documents actions planned or taken to address the reevaluated hazard. Subsequently, licensees and construction permit holders are also asked to perform an Integrated Assessment. In light of the reevaluated hazard, the Integrated Assessment will evaluate the effectiveness of the current licensing basis (i.e., flood protection and mitigation systems), identify plant-specific vulnerabilities, and assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating the effects of the reevaluated hazard for the entire duration of the flood event.

3. Framework of Integrated Assessment

3.1 Integrated Assessment process

The Integrated Assessment is intended to identify site-specific vulnerabilities and provide other important insights.[2] As described above, the Integrated Assessment is based on a graded approach to ensure the assessment performed is appropriate for the unique characteristics of a given site. Depending on site characteristics, the graded approach supports assessments ranging from engineering evaluations of individual flood protection features to evaluations based on PRA-techniques[3] (e.g., system logic models and risk-insights). The Integrated Assessment process consists of up to five possible steps, depending on site characteristics:

1. definition of peer review scope and assembly of a peer review team
2. determination of controlling flood parameters
3. evaluation of flood protection systems (if applicable[4])
4. evaluation of mitigation capability (if appropriate)
5. documentation of results

The Integrated Assessment process is illustrated by the flowchart in Figure 2 and described below.

The first step of the Integrated Assessment process involves assembly of a participatory peer review team. Section 4 and Appendix B provide additional details on the peer review and composition of the peer review team.

The second step in the Integrated Assessment process involves determination of the flood scenario parameters that should be considered based on the results produced as part of the NTTF Recommendation 2.1 flood hazard reevaluations (represented by box 2 in Figure 2). Section 5 provides additional guidance on determining the flood scenario parameters that should be considered as part of the Integrated Assessment.

Box 3 of Figure 2 represents a decision point. If a site has flood protection to prevent the entry of water into buildings or other areas containing SSCs that are important to safety, the process proceeds to Step 3, which involves an evaluation of the effectiveness of the flood protection system at the site. Section 6 provides additional guidance on the evaluation of flood protection. Conversely, if a site allows water to enter buildings or other areas with SSCs that are important to safety (by procedure or design) with potential effects on those SSCs, the Integrated Assessment process skips Step 3 and proceeds directly to Step 4. Step 4 involves the evaluation of the capability of the plant to maintain key safety functions[5] during a flood event.

---

[2] It is expected that the Integrated Assessment will yield insights related to available margin, defense-in-depth, and cliff-edge effects.
[3] This guide describes the use of PRA-techniques, however the approaches described in this document are not intended to be compliant with guidance provided in Ref. (8).
[4] Some sites may have little or no flood protection, in which case a flood protection evaluation would not be applicable.
[5] See Section 8 for definition of key safety functions.

Following the performance of the flood protection evaluation (Step 3), there is another decision point, as shown by Box 5 of Figure 2. If the on-site flood protection is reliable and has margin, the Integrated Assessment process proceeds directly to Step 5 (documentation of results). However, if the on-site flood protection cannot be shown to be reliable and have margin, the process proceeds to Step 4 and the capability of the plant to mitigate a loss of one or more flood protection systems by maintaining key safety functions is evaluated (represented by box 6 in Figure 2). Section 7 provides additional information on evaluating the capability of a plant to mitigate the loss of one more flood protection systems. Section 8 provides guidance on documentation of results.

3.2 Key assumptions

The following subsections provide information on key assumptions applicable to the Integrated Assessment.

3.2.1 Use of available resources for protection and mitigation

The Integrated Assessment evaluates the current licensing basis protection and mitigation capability of plants in response to the reevaluated flood hazards as well as additional in-place or planned resources. In assessing the protection and mitigation capability of a plant, credit can be taken for all available resources (onsite and offsite) as well as the use of systems, equipment, and personnel in nontraditional ways. Temporary protection and mitigation measures as well as non-safety related SSCs can also be credited with sufficient technical bases. In crediting use of systems, equipment, and personnel in non-traditional ways, non-safety related SSCs, temporary mitigation and protection features, or similar resources, the Integrated Assessment should account for the potentially reduced reliability of such resources relative to permanent, safety-related equipment (Ref.(3)). Moreover, if credit is taken for these resources, the licensee or construction permit holder should justify that the resources will be available and functional when required for the flood event duration.[6] Justification should consider the time required to acquire these resources and place them in service. Sections 6 and 7 provide guidance on evaluation of flood protection and mitigation capability.

3.2.2 Modes of operation and concurrent conditions

As described in Section 1.2, the scope of the Integrated Assessment includes full power operations and other plant configurations that could be susceptible due to the status of the flood protection features. The Integrated Assessment should evaluate the effectiveness of flood protection and mitigation capability of the plant for the mode(s) of operation that the plant will be in for the entire flood event duration. In addition, the Integrated Assessment should describe the expected total plant response under other modes of operation, including a discussion of controls that are in place in the event that a flood occurs during any of these modes (e.g., during refueling). The Integrated Assessment should also consider whether specific vulnerabilities may arise during modes of operation other than full-power (e.g., conditions where flood protection features may be bypassed or defeated for maintenance or refueling activities).

---

[6] See Section 8 for definition of flood event duration and Figure 3 for an illustration of flood event duration.

Finally, the Integrated Assessment should consider concurrent plant conditions, including adverse weather that could reasonably be expected to simultaneously occur with an external flood event[7] as well as equipment that may be directly affected by the flood event (e.g., loss of the switchyard due to inundation).

3.2.3 Flood frequencies

For most flood mechanisms, widely accepted and well-established methodologies are not available to assign initiating event frequencies to severe floods using probabilistic flood hazard assessment (Ref. (4)). For this reason, the Integrated Assessment does not require the computation of initiating flood-hazard frequencies. It is not acceptable to use initiating event frequencies to screen out flood events in lieu of evaluation of flood protection features at the site. However, if desired and given appropriate justification, the use of flood event frequency is deemed acceptable for use as part of a PRA.

[7] Ref. (28) provides guidance on combined events that should be considered as part of the Integrated Assessment. As part of the Recommendation 2.1 hazard reevaluations (see Section 2.3), Ref. (28) should have been used in establishing the combined events applicable to a site.

4. Peer review

An independent peer review is an important element of ensuring technical adequacy. The technical adequacy of the Integrated Assessment is measured in terms of the appropriateness with respect to scope, level of detail, methodologies employed, and plant representation, which should be consistent with this guidance and commensurate with the site-specific hazard and inherent flood protection reliability. The licensee's Integrated Assessment submittal should discuss measures used to ensure technical adequacy, including documentation of peer review. Appendix B provides additional details on peer review for the Integrated Assessment.

5. Hazard definition

5.1 Identification of applicable flood mechanisms and plant conditions

The hazard reevaluations performed under Recommendation 2.1 (see Section 2.3) identify the external flood mechanisms applicable to a site. Prior to performing the Integrated Assessment, the flood height and associated effects[8] for all applicable flood mechanisms from the hazard review should be collected or reviewed for use in the Integrated Assessment.

In addition, for each flood mechanism, the following information should be collected for use in the Integrated Assessment:[9]

- the expected plant mode(s) during the flood event duration
- available instrumentation and communication mechanisms associated with each flood mechanism, if applicable (e.g. river forecasts, dam condition reports, river gauges)
- the availability of and access to onsite and offsite resources and consumables (e.g., fuel)
- accessibility considerations to/from and around the site that may impact protective and mitigating actions
- effect of flood conditions on the availability of the UHS

5.2 Identification of controlling flood parameters

The flood parameters considered as part of the Integrated Assessment for a plant are based on the Recommendation 2.1 hazard reevaluations (see Section 2.3). Flood hazards do not need to be considered individually as part of the Integrated Assessment. Instead, the Integrated Assessment should be performed for a set(s) of flood scenario parameters defined based on the results of the Recommendation 2.1 hazard reevaluations.

The flood scenario parameters that should be defined and considered as part of the Integrated Assessment include:

- flood height and associated effects[10]
- flood event duration, including warning time and intermediate water surface elevations that trigger actions by plant personnel
- plant mode(s) of operation during the flood event duration

In some cases, there is one controlling flood hazard for a site. In this case, the flood scenario parameters should be defined based on this controlling flood hazard. However, at some sites, due the diversity of flood hazards to which the site is exposed, it may be necessary to define multiple sets of flood scenario parameters to capture the different plant effects from the diverse flood parameters associated with applicable hazards. In addition, sites may utilize different flood protection systems to protect against or mitigate different

---

[8] See Section 8 for definition of flood height and associated effects.
[9] This information may be available, in part, from the Recommendation 2.3 walkdown report or licensee walkdown records (see Section 2)
[10] See definition of flood height and associated effects in Section 8.

flood hazards. In such instances, the Integrated Assessment should define multiple sets of flood scenario parameters.

If appropriate, instead of considering multiple sets of flood scenario parameters as part of the Integrated Assessment, it is acceptable to develop an enveloping scenario (e.g., the maximum water surface elevation and inundation duration with the minimum warning time generated from different hazard scenarios). For simplicity, these flood parameters may be combined to generate a single bounding set of flood scenario parameters for use in the Integrated Assessment.

5.3 Collection of critical plant elevations and protection of equipment

To facilitate the performance of the Integrated Assessment the following information should be collected or otherwise understood:

- the critical elevations[11] of plant equipment that is important to safety and the safety functions affected when the critical elevation of the equipment is reached
- the flood protection features or systems used to protect each piece or group of critical plant equipment (e.g., a site levee, a category 1 wall and flood doors, or a sandbag barrier) and any procedures required to install, construct, or otherwise implement the flood protection
- the manner by which the equipment could be subjected to flooding (e.g., site inundation, building leakage)
- potential pathways for ingress of water (e.g., through conduits or ducts)

[11] See Section 8 for definition of critical elevations.

6. Evaluation of effectiveness of flood protection

As part of the Integrated Assessment, an evaluation should be performed of the capability of the site flood protection to protect SSCs important to safety from flood height and associated effects for each set of flood scenario parameters.

There are vast differences from plant to plant with regard to the flood protection features used. Site flood protection may include incorporated, exterior, and temporary features with passive and active functions credited to protect against the effects of external floods. In addition to physical barriers, flood protection at nuclear power plants may involve a variety of operator manual actions. These operator manual actions may be associated with installation of features (e.g., floodgates, portable panels, placement of portable pumps in service), construction of barriers (e.g., sandbag barriers), and other actions.

6.1 Procedure overview

An acceptable procedure to evaluate flood protection is illustrated by the flowchart in Figure 4. The evaluation begins by selecting a set flood scenario parameters for evaluation. Next, a flood protection system[12] is selected for evaluation. An evaluation is then performed of the selected flood protection system under the flood scenario parameters. The type of methodology considered appropriate for evaluating a flood protection system is based on the types of flood protection features employed in the flood protection system. The flood protection evaluation should assess the performance of the flood protection at both the feature- and system-levels. Additional information on the evaluation of flood protection is provided in Sections 6.2 and 6.3 as well as Appendix A.

If it can be shown that the flood protection can reliably accommodate the flood scenario parameters with margin (Figure 4, box 4) based on available performance criteria (see Section 6.2) or quantification of flood protection reliability, then the integrity of the system is documented and justified (box 5) and the evaluation is repeated for the next flood protection system. Conversely, if the flood protection system is not able to reliably accommodate the flood scenario parameters with margin, and modifications will not be made (box 6), the credible failure modes and vulnerabilities should be documented along with the direct consequences (e.g., inundation of a room) of each failure mode and vulnerability. The analysis is then repeated for the next flood protection system. If modifications to the flood protection system are in-place or planned (box 6), the modified flood protection system should be defined (box 7) and the evaluation repeated for the modified flood protection system.

---

[12] Section 8 defines the term flood protection system. A site may have multiple and diverse flood protection systems. For example, a site may be protected by a levee around the entire site as well as incorporated barriers at the structure/environment interface for each individual building. The site levee would constitute one flood protection system while a set of barriers that protects an individual building, which can be isolated from other buildings (either through separation by location or flood protection features), would comprise a separate flood protection system.

6.2 Performance criteria

To provide confidence in the reliability and margin of flood protection, considering both qualitative and quantitative performance criteria, the flood protection evaluation should do the following:

- provide an understanding of potential failure modes of the flood protection system, including consideration of potential ingress pathways for floodwaters (e.g., through conduits or ducts)
- demonstrate the soundness of the individual features comprising the flood protection system under the loads (i.e., flood height and associated effects) due to the flood scenario parameters and confirm that the features are:
  - in satisfactory condition
  - higher than the reevaluated flood height
  - structurally adequate based on quantitative engineering evaluations
- compare the performance, characteristics, and configuration of the flood protection feature(s) against appropriate, present-day design codes and standards (including Standard Review Plan Sections 3.4.1 and 3.4.2, Refs. (5) and(6)) to determine that the feature(s) conforms to good practices and is sufficiently robust (e.g., demonstrates an appropriate factor of safety)
- perform qualitative assessment of operational requirements such as surveillance, inspection, design control, maintenance, procurement, and testing
- include sensitivity studies, if there is uncertainty about the construction or characteristics of a flood protection feature or system (e.g., uncertainty about the parameters of concrete used in construction of a concrete wall)
- ensure capacity of pumping or drainage systems is sufficient to handle any inflow through flood protection features for the entire flood event duration
- quantify the reliability of the active features, other than flood doors and hatches,[13] based on operating experience and other available data or information using traditional PRA or statistical techniques
- evaluate the feasibility and reliability of credited operator actions (including construction, installation, or other actions) through comparison against criteria described in Appendix C
- demonstrate necessary consumables are available for the entire flood event duration
- demonstrate temporary features can be moved to the location where needed and installed
- evaluate the flood protection system as a whole

Additional information on the evaluation of individual flood protection features (including feature-specific performance criteria) is provided in Section A.1 of Appendix A. Guidance on the evaluation of a flood protection system as a whole is provided in Section A.2 of Appendix A.

Probabilistic evaluation of the fragility of exterior and incorporated features under the flood scenario parameters is also acceptable, given adequate justification.

[13] Flood doors and hatches should be evaluated as described in Appendix A.

6.3 Justification of flood protection performance

If, based on the flood protection evaluation, a flood protection system is deemed capable of withstanding the flood height and associated effects for a set of flood scenario parameters, the Integrated Assessment should justify this conclusion. The Integrated Assessment should also demonstrate that the flood protection system integrity is reliably maintained with margin based on comparison against appropriate performance criteria or quantification of feature or system reliability. In addition, the limiting margin associated with the flood protection system as well as the margin associated with individual flood protection features should be identified.

Margin should be characterized with respect to physical barrier dimensions,[14] structural or other performance capacity, as well as time and staffing associated with performance of operator manual actions. Demonstration of the aforementioned items requires an understanding of the capability of flood protection systems for a range of flood heights and associated effects (including reasonable variation in warning time and flood event duration). Physical margin and structural capacity can be demonstrated by increasing the flood elevation (while accounting for associated effects) and showing the elevation beyond which the system is no longer capable of reliably performing its intended function.

The Integrated Assessment should identify any flood protection features or systems that are unable to reliably accommodate the flood height and associated effects for a set of flood scenario parameters with margin. Any flood protection feature or system determined not to be capable of performing its intended safety function under the reevaluated hazard should be documented as a vulnerability (see Section 8) for all susceptible plant configurations. In addition, if a flood protection feature or system is not able to accommodate the flood scenario parameters, the flood protection evaluation should determine at what flood height and under what associated effects, the flood protection feature or system is able to reliably accommodate a flood with margin. If modifications are proposed to address vulnerabilities, improve margin, or otherwise improve the effectiveness of site flood protection, the Integrated Assessment should justify that the modified flood protection is reliable and has margin through comparison against established performance criteria or quantification of reliability (as appropriate).

[14] Margin with respect to physical barrier dimensions is analogous to the concept of available physical margin (APM) defined under the NTTF Recommendation 2.3 flood walkdowns (see Ref. (1)). However, APM was computed as part of the NTTF Recommendation 2.3 flood walkdowns with respect to the current licensing basis flood protection height. In the context of the Integrated Assessment, margin with respect to physical barriers in defined with respect to the reevaluated hazard (including flood height and associated effects).

7. Evaluation of mitigation capability

Mitigation capability refers to the capability of the plant to maintain key safety functions[15] in the event that a flood protection system(s) fails or a site does not have flood protection under the flood scenario parameters.

An evaluation of mitigation capability is appropriate for sites that have not demonstrated that the flood protection systems are reliable and have margin. Mitigation capability should be evaluated for credible flood protection failure modes, including concurrent failures, identified based on the evaluation described in Section 6. For each scenario involving the compromise of flood protection under the flood scenario parameters, the mitigation capability of the plant should be evaluated for the entire flood event duration considering all available resources.

In addition, as described in Section 3.1, sites that allow water to enter buildings or other areas with SSCs important to safety by procedure or design (and resulting in the potential compromise of those SSCs) should evaluate mitigation capability.

7.1 Procedure Overview

The mitigation capability of a plant may be demonstrated using one of three potential methods, depending on site characteristics and information needed for decisions:

- scenario-based evaluation
- margins-type evaluation
- full PRA

A margins-type evaluation and full PRA are acceptable for evaluating mitigation capability at all sites. A scenario-based evaluation is generally appropriate for use at sites where: (1) plant systems affected by flood protection failure do not involve complex interactions or interdependencies; (2) there is sufficient time (consistent with guidance in Appendix C for being feasible and reliable) to perform credited operator actions, which must not be complex; and (3) the logic used to evaluate the scenario is simple.

7.2 Scenario-based evaluation of mitigation capability

The scenario-based evaluation is used to demonstrate that there is high confidence that key safety functions can be maintained using qualitative and quantitative information and insights. While the scenario-based evaluation does not require the use of complex logic diagrams or computation of risk-based metrics (conditional core damage probability and conditional large early release probability), it nonetheless should utilize a systematic and rigorous approach to demonstrate that key safety functions can be maintained with high confidence under the flood scenario parameters. While not required, use of a scenario-based evaluation does not preclude the use of system logic model tools such as event trees and fault trees.

[15] See Section 8 for definition of key safety functions.

Figure 5 provides a flowchart depicting the process for a scenario-based evaluation of mitigation capability. The evaluation begins by defining the scenario to be evaluated (boxes 1-4 of Figure 5), which consists of specifying:

- the flood scenario parameters
- the credible flood protection failure mode(s)[16]
- all direct consequences of flood protection failure (e.g., particular rooms inundated)
- the plant conditions (e.g., identification of whether onsite and offsite power are available) and all equipment affected by the consequences of flood protection failure

Typically, inundation of equipment will cause failure. However, associated flood effects (e.g., debris, dynamic loads) may also adversely affect equipment and should be considered. The scenario-based evaluation should concurrently consider all failures of flood protection features and equipment that could result from the flood scenario parameters.

Once the scenario has been defined the following steps should be performed:

- the key safety functions that must be maintained are defined (Figure 5, box 5)
- equipment available for use in maintaining key safety functions (Figure 5, box 6) is specified
- an evaluation of mitigation capability using available resources (Figure 5, box 7) should demonstrate whether there is high confidence that key safety functions can be maintained

In demonstrating that there is high confidence that key safety functions can be maintained, the evaluation should:

- demonstrate that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration, and can be deployed when necessary (see Section A.1.4 of Appendix A)
- quantitatively evaluate the reliability of active components based on operating experience, testing, and other available information using traditional PRA or statistical techniques[17]
- evaluate the feasibility and reliability of credited operator manual actions using Appendix C
- qualitatively assess of operational requirements such as surveillance, inspection, design control, maintenance, procurement, and testing (e.g., document whether a component is covered by the Maintenance Rule, 10 CFR 50.65(b))
- demonstrate sufficient consumables (e.g., fuel) on site

---

[16] Credible failure modes of flood protection systems for a given set of flood scenario parameters are identified as part of the evaluation of flood protection systems (see Section 6 and Appendix A). Concurrent failures of multiple flood protection systems (along with associated consequences) should be considered if the flood scenario parameters could adversely affect multiple flood protection systems.

[17] If the reliability of an active component cannot be quantified, the considerations in Section A.1.2 of Appendix A should be used to justify high confidence in the reliability of the active component. Moreover, if reliability cannot be quantified, the effect of excluding the component (i.e., not crediting the component as part of the evaluation of mitigation capability) should be understood and reported.

- consider other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited operator manual actions

If it can be demonstrated that there is high confidence that key safety functions can be maintained, the results must be documented and justified. If the evaluation cannot demonstrate with high confidence that key safety functions can be maintained, then a scenario-based evaluation is not sufficient and a margins-type evaluation or PRA is necessary or modifications should be made to the plant to improve mitigation capability such that there is high confidence that key safety functions can be maintained.

The evaluation should be repeated until all flood protection failure modes and sets of flood scenario parameters have been evaluated (as directed by boxes 11 and 12 of Figure 5).

7.3 Margins-type evaluation of mitigation capability

A margins-based evaluation is appropriate for all sites. Figure 6 illustrates the margins-based method for the evaluation of mitigation capability. Like the scenario-based mitigation evaluation, the margins-based mitigation evaluation begins by specifying:

- the flood scenario parameters
- the credible flood protection failure mode(s)[18]
- all direct consequences of flood protection failure (e.g., particular rooms inundated)
- the plant conditions (e.g., identification of whether onsite and offsite power are available) and all equipment affected by the consequences of flood protection failure

Typically, inundation of equipment will cause failure. However, associated flood effects (e.g., debris, dynamic loads) may also adversely affect equipment and should be considered.

Once the plant conditions have been specified along with equipment affected by the flood protection failure, plant system models[19] should be updated or developed to reflect the current plant state and available equipment. In updating system models, the evaluation should:

- consider equipment failures caused directly by the flood event as well as all random failures of remaining plant equipment (e.g., failure to start, failure to run)

---

[18] Credible failure modes of flood protection systems for a given set of flood scenario parameters are identified as part of the evaluation of flood protection systems (see Section 6). Concurrent failures of multiple flood protection systems (along with associated consequences) should be considered if the flood scenario parameters could adversely affect multiple flood protection systems.

[19] The internal events PRA model, with appropriate modifications, can be used to model plant systems. Basic failure events are added to the internal events PRA model for evaluating the mitigation capability of the plant during a flood event. Alternatively, it may be acceptable to develop a system models specifically intended to compute CCDP and CLERP under the flood scenario parameters and flood protection failure mode(s) being analyzed rather than adapting the existing internal events PRA model. If such a model is developed, it should be consistent with the internal events systems model with respect to plant response.

- quantitatively evaluate the reliability of active components based on operating experience, testing, and other available information using traditional PRA techniques[20]
- quantify the reliability of credited operator manual actions using human reliability concepts and approaches
  When it is not feasible to use HRA concepts and approaches, use the criteria described in Appendix C to demonstrate acceptability of the operator manual actions. In such cases, for quantification purposes in a margin analysis, use an initial failure probability of no less than 1×10^{-1} if the criteria in Appendix C are met. This value may be used as a basis for further refinement (e.g., through justifying performance shaping factors that exceed the requirements of Appendix C, modifying operator manual actions, or performing sensitivity studies).

In addition, for all credited resources and actions, the evaluation should:

- demonstrate that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration, and can be deployed when necessary (see Section A.1.4 of Appendix A)
- qualitatively assess operational requirements such as surveillance, inspection, design control, maintenance (e.g., document whether a component is covered by the Maintenance Rule, 10 CFR 50.65(b)), procurement, and testing
- demonstrate sufficient consumables (e.g., fuel) on site
- consider other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited operator manual actions

Given the updated system models, the CCDP and CLERP should be calculated using plant system models. The evaluation of mitigation capability should be repeated until all flood protection failure modes and sets of flood scenario parameters have been evaluated.

If modifications to the plant are proposed, the effectiveness of the modification on mitigation capability should be evaluated as described above.

7.4 Use of PRA to evaluate total plant response, including mitigation capability

If a PRA is used to assess total plant response, including the mitigation capability of a plant, the evaluation should be consistent with guidance contained in Section 8 of Ref. (7) as well as Ref. (8). However, it is noted that Section 8 of Ref. (7) establishes technical requirements when a reactor is at power. As part of the Integrated Assessment, it is necessary to consider mitigation capability during other modes of operation.

If modifications to the plant are proposed, the effectiveness of the modification on mitigation capability should be evaluated as described above.

[20] If the reliability of an active component cannot be quantified, CCDP and CLERP should be calculated without taking credit for the component. However, the component should be retained in the model. Qualitative arguments may be later used to provide justification for taking credit for the component.

8. Documentation

The Integrated Assessment submittal should provide the following (Ref. (9), Encl. 2, p. 8-9):

a) Description of the integrated procedure used to evaluate integrity of the plant for the entire duration of flood conditions at the site.

- Describe the methodologies used to demonstrate the effectiveness of:
  - flood protection features and systems
  - mitigation strategies
- Describe any plant system models, including modifications made to existing internal event model(s), for the evaluation of the plant's flood protection and mitigation capability

b) Results of the plant evaluations describing the controlling flood mechanisms and its effects, and how the available or planned measures will provide effective protection and mitigation. Discuss whether there is margin beyond the postulated scenarios.

Controlling Flood Mechanism(s)

- Discuss the applicable flood mechanism(s) and the flood scenario parameters, including flood height and associated effects, evaluated as part of the Integrated Assessment
- Discuss the site conditions during the entire flood event duration for each set of flood scenario parameters, including:
  - the plant mode(s), including the duration of time the plant is expected to remain in each mode
  - available water gauges, meteorological gauges, weather and tsunami forecasting tools, or similar instrumentation and communication mechanisms
  - the availability of and access to onsite and offsite resources and consumables (e.g., diesel fuel)
  - accessibility considerations to/from and around the site that may impact protective and mitigating actions (e.g., scaffolding)
  - the condition and access to the ultimate heat sink
  - availability of offsite power
  - structures and systems important to safety affected by the flood scenario parameters

Evaluation of Flood Protection

- Describe all site flood protection system(s), including all operator manual actions necessary for the implementation of flood protection
- Describe performance criteria used to evaluate flood protection, including any codes or standards used in the evaluation
- Provide technical justification for assumptions (including failure modes considered) used to demonstrate the effectiveness of flood protection features.
- For each set of flood scenario parameters and flood protection system, document the following:
  - credible flood protection modes identified and justification for any flood protection modes deemed not credible
  - the condition of flood protection features
  - results of quantitative engineering evaluations

  - results of comparisons against appropriate present-day codes and standards (including Standard Review Plan Sections 3.4.1 and 3.4.2, if applicable)
  - description of operational requirements applicable to flood protection features (surveillance, inspection, design control, maintenance, procurement, and testing)
  - the reliability of active features
  - expected leakage through barriers
  - justification of whether the capacity of pumping or drainage systems is sufficient to handle any inflow through flood protection features for the entire flood event duration
  - results of evaluations of operator manual actions against the criteria contained in Appendix C, including a detailed description justifying whether all criteria are met (see Section C.10)
  - whether necessary consumables are available for the entire flood event duration
  - results of sensitivity studies, if appropriate
  - results of system-level evaluations performed of flood protection systems, including justification
- Provide a discussion of any defense-in-depth considerations that are maintained under each set of flood scenario parameters
- Discuss any additional margin beyond the postulated scenarios for the flood protection system(s). Margin should be characterized with respect to physical barrier dimensions, structural and other performance capacity, and time and staffing associated with performance of operator manual actions.

Evaluation of Mitigation Capability

- Describe the equipment and operator manual actions, if applicable, associated with the mitigation capability of the plant
- Describe the performance criteria used to evaluate the mitigation capability of the plant
- Provide an evaluation (including sensitivity studies if appropriate) regarding the effectiveness of the total mitigation capability
- If a scenario-based evaluation of mitigation capability is used, document the following:
  - scenarios evaluated, including:
    - the flood scenario parameters
    - the flood protection failure modes considered
    - all direct consequences of flood protection failure
    - plant conditions and all equipment affected by the consequences of flood protection failure
    - key safety functions that must be maintained
  - demonstration that key safety functions can be maintained with high confidence under each scenario, including:
    - demonstration that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration, and can be deployed when necessary
    - the reliability of active components
    - results of evaluation of operator manual actions against the criteria contained in Appendix C, including a detailed description justifying whether all criteria are met (see Section C.10)

        - description of operational requirements applicable to mitigation equipment (surveillance, inspection, design control, maintenance, procurement, and testing)
        - demonstration of sufficient consumables on site
        - other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited operator manual actions
- If a margins-based evaluation of mitigation capability used, document the following:
    - scenarios evaluated, including:
        - the flood scenario parameters
        - the flood protection failure modes considered
        - all direct consequences of flood protection failure
        - plant conditions and all equipment affected by the consequences of flood protection failure
    - a summary of system models developed specifically for evaluation of mitigation capability or modifications made to existing PRA models
    - justification for equipment, actions, and resources credited for mitigation, including:
        - the reliability of active components
        - results of evaluation of operator manual actions against the criteria contained in Appendix C, including a detailed description justifying whether all criteria are met (see Section C.10)
        - demonstration that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration, and can be deployed when necessary
        - description of operational requirements applicable to mitigation equipment (surveillance, inspection, design control, maintenance, procurement, and testing)
        - demonstration of sufficient consumables on site
        - other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited operator manual actions
    - CCDP and CLERP calculated for each scenario
    - dominant sequences and contributors identified
- If a PRA is performed, the analysis and results should be documented as described in Ref. (7), with appropriate additional considerations to account for all modes of operation considered as part of the Integrated Assessment.
- Provide a discussion of any defense-in-depth considerations that are maintained under each set of flood scenario parameters
- Discuss any additional margin beyond the postulated scenarios for the mitigation capability of the plant. Margin should be characterized with respect to physical barrier dimensions, structural and other performance capacity, and time and staffing associated with performance of operator manual actions.

Peer Review

- Include the peer review documentation, as described in Section B.4 of Appendix B.

c) Description of any additional protection and/or mitigation features that were installed or are planned, including those installed during course of reevaluating the hazard. The description should include the specific features and their functions.

- Describe any flood protection or mitigation capabilities discussed in item (b) above that are credited in the plant's current licensing basis but were modified during the course of the hazard reevaluation or Integrated Assessment. The description should include specific features and their functions.
- Describe any flood protection or mitigation capabilities discussed in item (b) above that are not credited in the plant's current licensing basis. The description should include specific features and their functions.
- Describe any flood protection or mitigation capabilities discussed in item (b) above that are planned and have not yet been installed. The description should include specific features and their functions.
- Provide a timeline for completion of all planned actions credited as part of the Integrated Assessment.
- Describe any interim actions that are in place until planned actions are completed.

d) Identify other actions that have been taken or are planned to address plant-specific vulnerabilities.

- Describe any vulnerabilities (see definition in Section 9) identified during the review, including the key safety functions that may be affected
- Describe any actions that have been taken to address these plant-specific vulnerabilities.
- Separately, describe any actions that are planned to address these plant-specific vulnerabilities.

9. Terms and definitions

Active (flood protection) feature: Incorporated, exterior, or temporary flood protection features that require the change of state of a component in order to perform as intended. Examples include sump pumps, portable pumps, isolation and check valves, flood detection (e.g., level switches), and flood doors (e.g., watertight doors).

Available Physical Margin (APM): The term available physical margin describes the flood margin available for applicable flood protection features at a site (not all flood protection features have APMs). The APM for each applicable flood protection feature is the difference between licensing basis flood protection height and the flood height at which water could affect an SSC important to safety. Determination of APM for local intense precipitation may not be possible. Additional details are provided in Section 3.13 of the flooding design basis walkdown guidance, NEI 12-07, Ref. (2).

Cliff-edge effect: An elevation at which safety consequences of a flood event may increase sharply with a small increase in the flood height and associated effects.

Critical elevation: The elevation at which a piece or group of equipment will fail to function, or a transient will be induced, due to flood height and associated effects.

Current Licensing Basis (CLB): As defined by 10 CFR 54.3, the current licensing basis is the set of NRC requirements applicable to a specific plant, plus a licensee's docketed and currently effective written commitments for ensuring compliance with, and operation within, applicable NRC requirements and the plant-specific design basis, including all modifications and additions to such commitments over the life of the facility operating license. It also includes the plant-specific design basis information, defined by 10 CFR 50.2, as documented in the most recent UFSAR as required by 10 CFR 50.71. The set of NRC requirements applicable to a specified plant CLB includes:

- NRC regulations in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73 and 100 and appendices thereto
- Commission Orders
- License Conditions
- Exemptions
- Technical Specifications
- Plant-Specific design basis information defined in 10 CFR 50.2 and documented in the most recent UFSAR (as required by 10 CFR 50.71)
- Licensee Commitments remaining in effect that were made in docketed licensing correspondence (such as licensee responses to NRC bulletins, License Event Reports, Generic Letters and Enforcement Actions)
- Licensee Commitments documented in NRC safety evaluations (Ref. (1))

Design bases: As defined by 10 CFR 50.2, the design bases are information that identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals (Ref. (1)).

Event tree: A logic diagram that begins with an initiating event or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state (Ref. (7)).

Exterior (flood protection) feature: Engineered passive or active flood protection feature that is external to the immediate plant area and credited to protect safety-related SSCs from inundation and static/dynamic effects of external floods. Examples include levees, dikes, floodwalls, flap gates, sluice gates, duckbill valves and pump stations (Ref. (1)).

Failure modes and effects analysis (FMEA): A process for identifying failure modes of specific components and evaluating their effects on other components, subsystems, and systems (Ref. (7)).

Fault tree: A deductive logic diagram that depicts how a particular undesired event can occur as a logical combination of other undesired events (Ref. (7)).

Feasible action: An action that is analyzed and demonstrated as being able to be performed within an available time to avoid a defined undesirable outcome. As compared to a reliable action (see definition), an action is considered feasible if it is shown that it is possible to be performed within the available time (considering relevant uncertainties in estimating the time available); but it does not necessarily demonstrate that the action is reliable. For instance, performing an action successfully one time out of three attempts within the available time shows that the action is *feasible*, but not necessarily reliable (Ref. (10)).

Flood event duration: The length of time in which the flood event affects the site, beginning with notification of an impending flood (e.g., a flood forecast or notification of dam failure), including preparation for the flood and the period of inundation, and ending when water has receded from the site and the plant has reached a stable state that can be maintained indefinitely . Figure 3 provides an illustration of flood event duration.

Flood height and associated effects: Maximum stillwater surface elevation plus factors such as:

- wind waves and run-up effects
- hydrodynamic loading, including debris
- effects due to sediment deposition and erosion
- concurrent site conditions, including adverse weather conditions
- groundwater ingress
- other pertinent factors

Flood scenario parameters: A set(s) of flood parameters that should be considered as part of the Integrated Assessment. (see Section 5.2 for additional details).

Flood protection feature: An individual incorporated, exterior or temporary structure, system, component (e.g., barrier), or associated procedure that protects safety-related SSCs against the effects of external floods, including flood height and associated effects.

Flood protection system: In the context of the Integrated Assessment, a flood protection system is a set of flood protection features that are intended to protect a specific SSC or group of SSCs (e.g., features used to protect the intake structure) or the entire plant (e.g., a levee around an entire site) and that are primarily separate and independent from the flood protection features used to protect other SSCs.

Human reliability analysis (HRA): A structured approach used to identify potential human failure events and to systematically estimate the probability of those events using data, models, or expert judgment (Ref. (7)). In the context of the Integrated Assessment, HRA approaches and concepts are used to evaluate whether operator manual actions are feasible and reliable (see Appendix C).

Incorporated (flood protection) feature: Engineered passive or active flood protection feature that is permanently installed in the plant to protect safety-related SSCs from inundation and static/dynamic effects of external flooding. Examples include pumps, seals, valves, gates, etc. that are permanently incorporated into a plant structure (Ref. (1)).

Important to safety: In accordance with the Appendix A to Part 50, structures, systems, and components (SSCs) important to safety refers to SSCs that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.

Key safety functions: The minimum set of safety functions that must be maintained to prevent core damage and large early release. These include reactivity control, reactor pressure control, reactor coolant inventory control, decay heat removal, and containment integrity in appropriate combinations to prevent core damage and large early release. (Ref. (7)).

Mitigation capability: In the context of the Integrated Assessment, mitigation capability refers to the capability of the plant to maintain key safety functions in the event that a flood protection system(s) fails (or is otherwise not available).

Operator manual action (for flooding): Proceduralized activity carried out by plant personnel to prepare for or respond to an external flood event.

Passive (flood protection) feature: Incorporated, exterior, or temporary flood protection features that do *not* require the change of state of a component in order to perform as intended. Examples include dikes, berms, sumps, drains, basins, yard drainage systems, walls, removable wall and roof panels, floors, structures, penetration seals, temporary water tight barriers, barriers exterior to the immediate plant area that are under licensee control, and cork seals.

Performance criteria (for flood protection): In the context of the Integrated Assessment, performance criteria refer to criteria or standards that are used, in part, to demonstrate that a flood protection feature is reliable and has margin

Performance shaping factor (PSF): A factor that influences human performance and human error probabilities (definition adapted from Ref. (11)). In the context of the Integrated Assessment for flooding, the following performance shaping factors are considered:

- available time
- accessibility
- environmental/stress factors
- diagnostic complexity, indications or cues
- training
- procedures
- staffing
- communications
- human factor engineering

Plant-specific vulnerability: As defined in Ref. (9), plant-specific vulnerabilities are "those features important to safety that when subject to an increased demand due to the newly calculated hazard evaluation have not been shown to be capable of performing their intended safety functions."

Reasonable simulation: a walk-through of a procedure or activity to verify the procedure or activity can be executed as specified/written. This simulation requires verification that:

1) all resources needed to complete the actions will be available. (Note that staffing assumptions must be consistent with site access assumptions in emergency planning procedures.)
2) any credited time dependent activities can be completed in the time required considering the time required for detection, recognition and communication to initiate action for the applicable flood hazard.
3) specified equipment/tools are properly staged and in good working condition.
4) connection/installation points are accessible.
5) the execution of the activity will not be impeded by the event it is intended to mitigate or prevent (for example, access to the site and movement around it can be accomplished during the flood).
6) the execution of the activity will not be impeded by other adverse conditions that could reasonably be expected to simultaneously (Ref. (1))

Reliable action: A feasible action that is analyzed and demonstrated as being dependably repeatable within an available time, so as to avoid a defined adverse consequence, while considering varying conditions that could affect the available time and/or the time to perform the action. As compared to an action that is only feasible (see definition), an action is considered to be reliable as well if it is shown that it can be dependably and repeatably performed within the available time, by different crews, under somewhat varying conditions that typify uncertainties in the available time and the time to perform the action, with a high success rate. All reliable actions need to be feasible, but not all feasible actions will be reliable (Ref. (10)).

Temporary (flood protection) feature: Passive or active flood protection feature within the immediate plant area that protects safety-related SSCs from inundation and static/dynamic effects of external flooding and is temporary in nature (i.e., they must be installed prior to the advent of the design basis external flood). Examples include portable pumps, sandbags, plastic sheeting, and portable panels (Ref. (1)).

Total plant response: The total plant response is the capability of the plant to (1) protect against flood events (considering diverse flood protection features) and (2) mitigate consequences, if the flood protection system is compromised (or otherwise not available), by maintaining key safety functions using all credited resources.

Variety of site conditions: The site conditions considered in the Integrated Assessment should be all modes of operation (e.g., full power operations, startup, shutdown, and refueling) and adverse weather conditions that could reasonably be expected to occur concurrent with a flood event.

Vulnerability: See definition for *plant-specific vulnerability*.

10. Figures

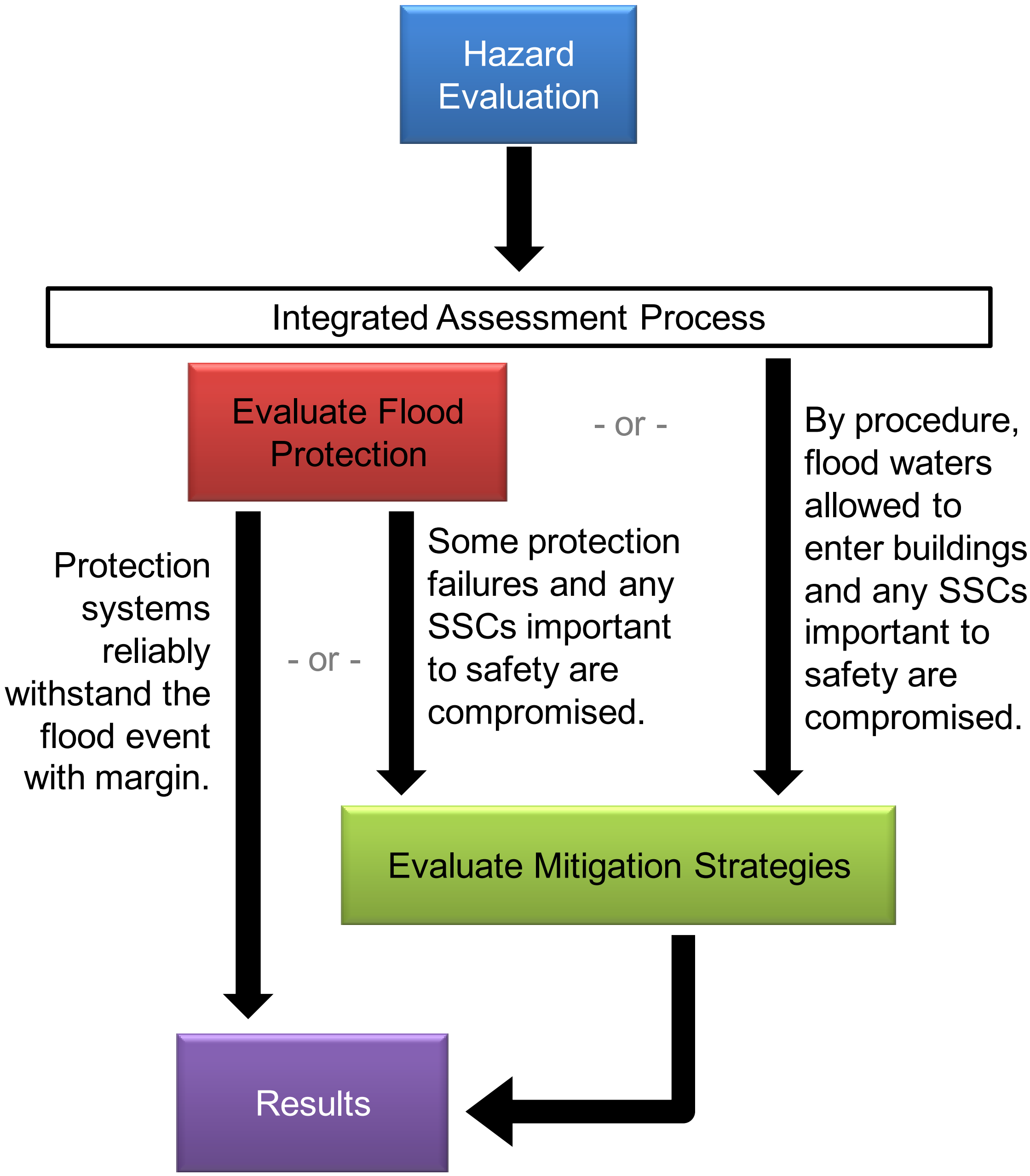

Figure 1: Conceptual illustration of Integrated Assessment process

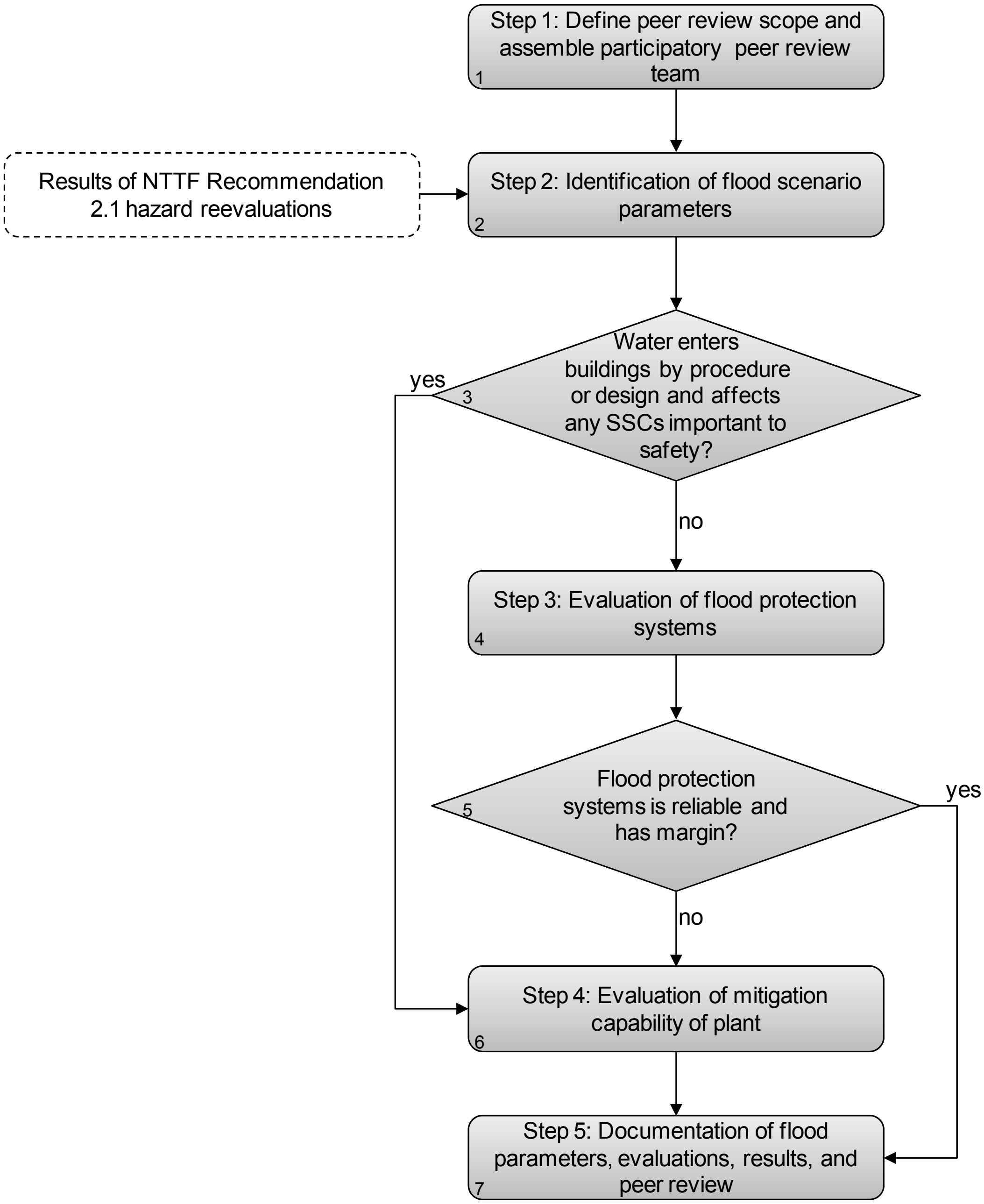

Figure 2: Integrated Assessment process flowchart

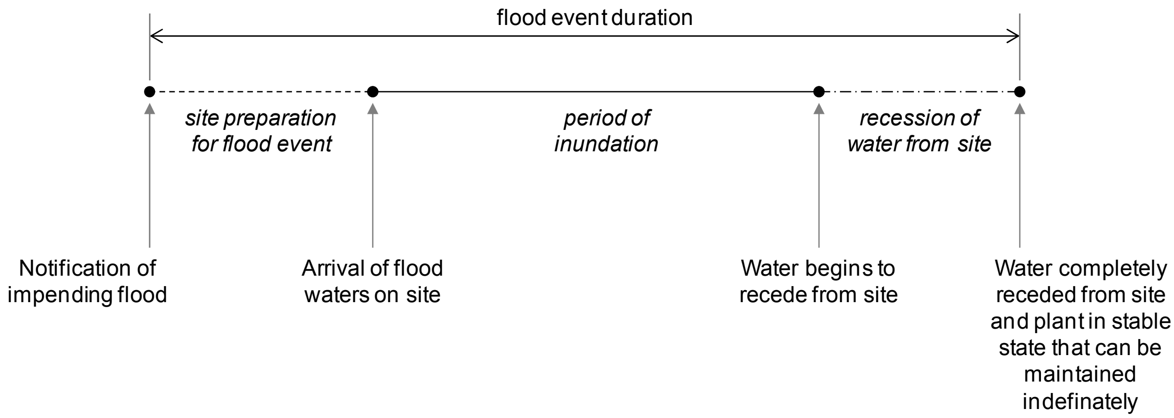

Figure 3: Illustration of flood event duration

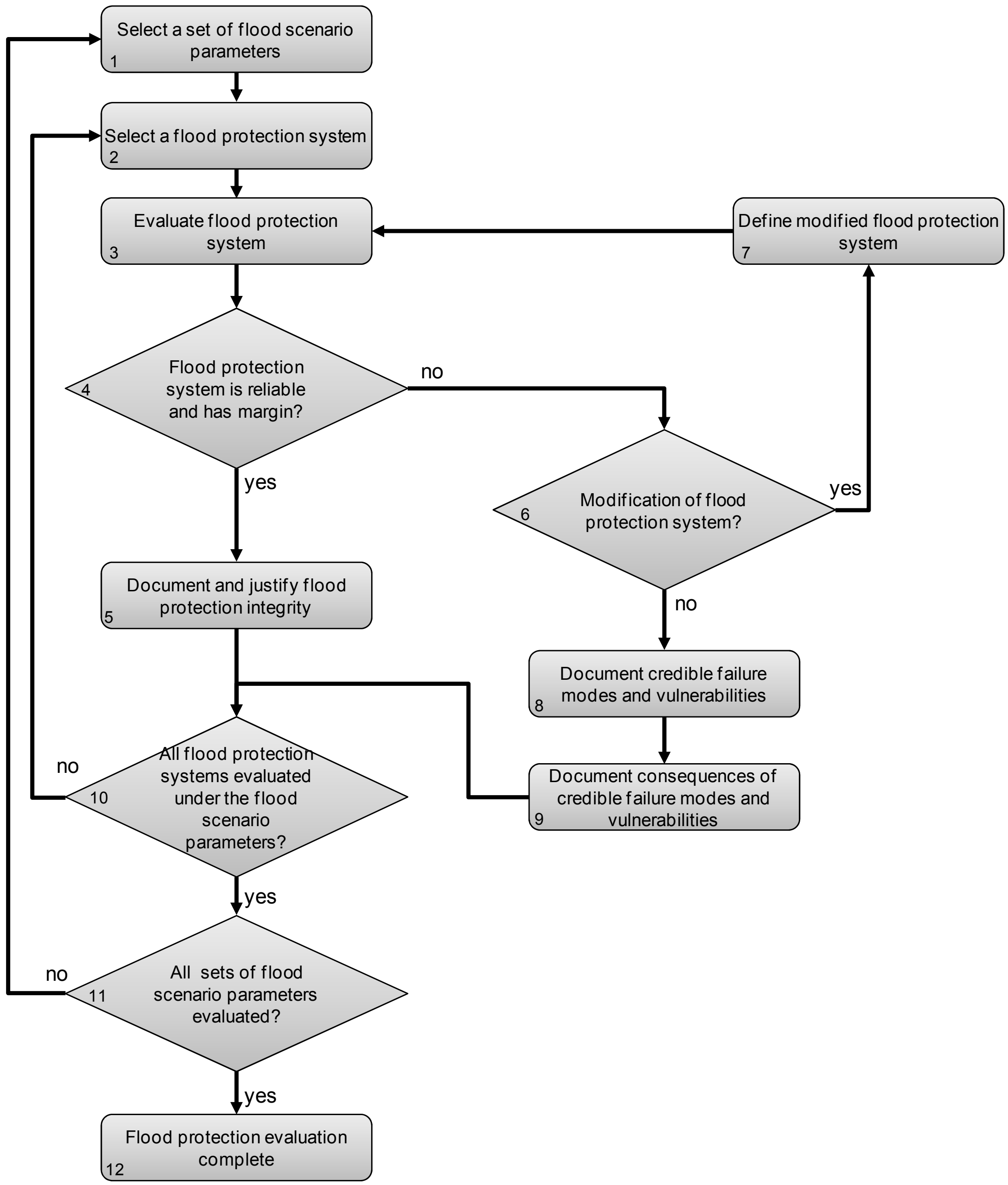

Figure 4: Flood protection evaluation procedure flowchart

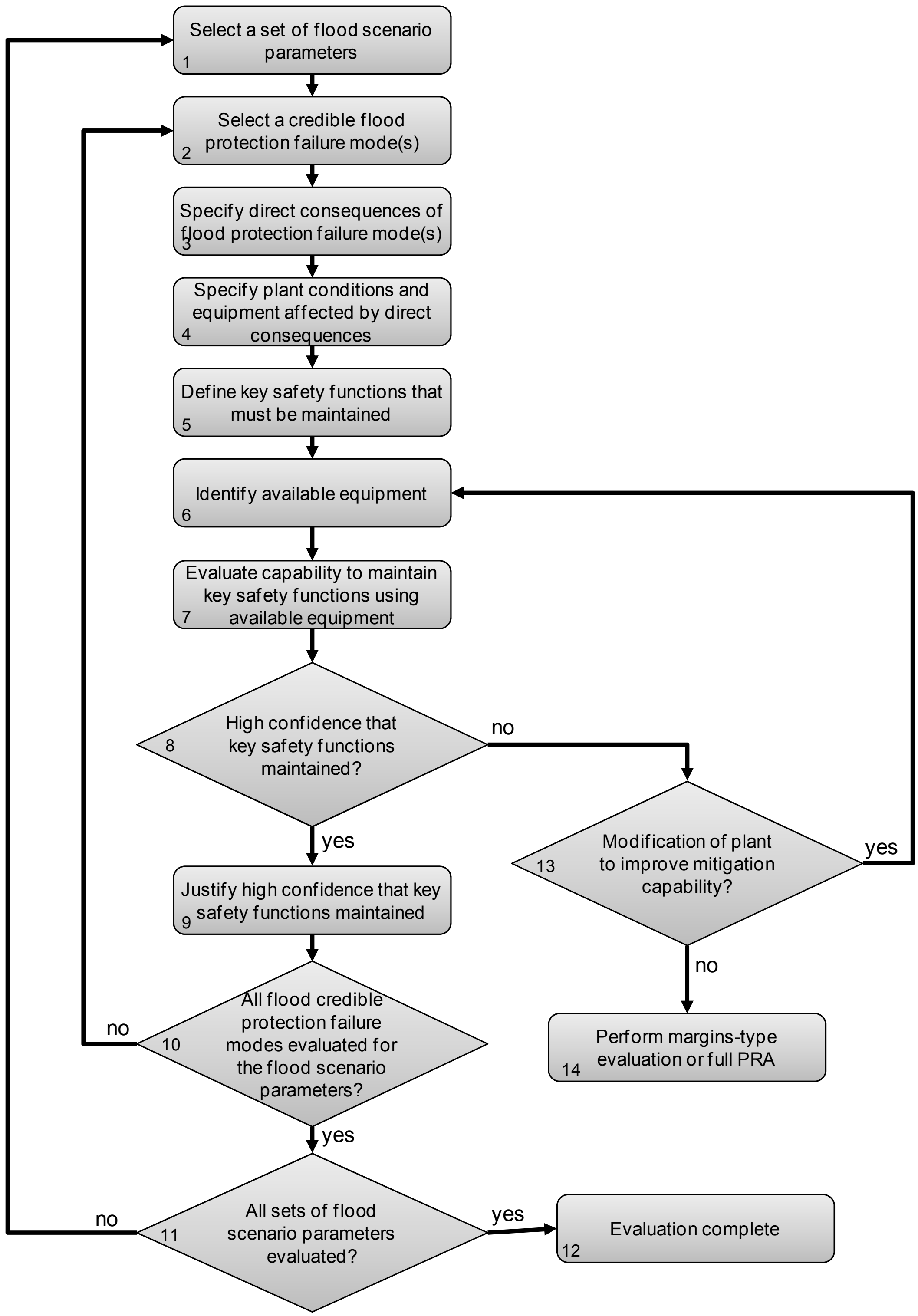

Figure 5: Scenario-based mitigation evaluation flowchart

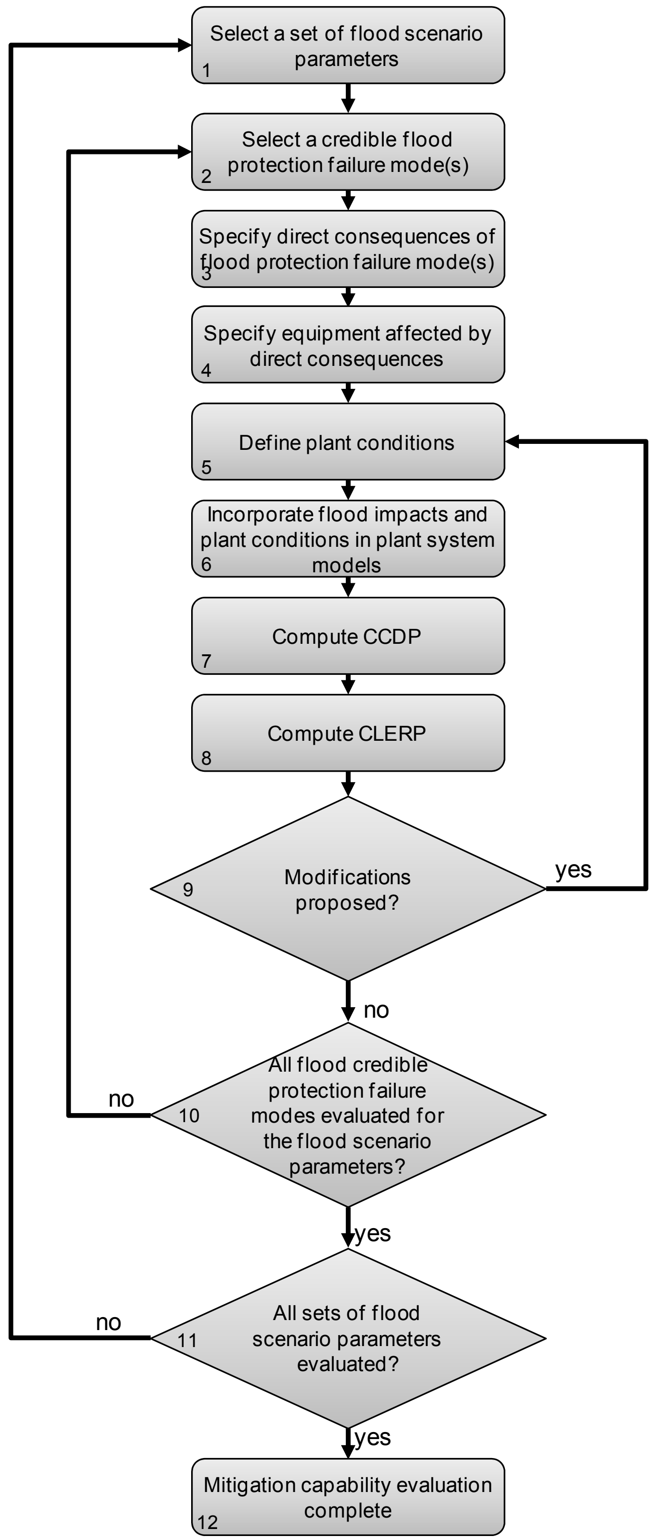

Figure 6: Margins-based mitigation evaluation flowchart

11. References

1. Nuclear Energy Institute. "Guidelines for Performing Verification Walkdowns of Plant Flood Protection Featuresk," NEI 12-07, Rev. 0-A. May 2012. ADAMS Accession No. ML12173A215.

2. U.S. Nuclear Regulatory Commission. Endorsement of Nuclear Energy Institute (NEI) 12-07, "Guidelines for Performing Verification Walkdowns of Plant Flood Protection Features". June 14, 2012. Agencywide Document Access and Management System (ADAMS) Accession No. ML12159A290.

3. —. "Proposed Orders and Requests For Information In Response To Lessons Learned From Japan's March 11, 2011, Great Tohoku Earthquake And Tsunami," SECY-12-0025. February 22, 2012. ADAMS Accession No. ML12039A103.

4. —. "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America," NUREG/CR-7046. November 2011. ADAMS Accession No. ML11321A195.

5. —. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, Section 3.4.1: Internal Flood Protection for Onsite Equipment Failures, Rev. 3. March 2007.

6. —. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, Section 3.4.2: Analysis Procedures, Rev. 3. March 2007.

7. The American Society of Mechanical Engineers. Addenda to ASME/ANS RA-S–2008, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications. 2009. ASME/ANS RA-Sa-2009.

8. U.S. Nuclear Regulatory Commission. "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," Regulatory Guide 1.200, Rev. 2. March 2009. ADAMS Accession No. ML090410014.

9. —. Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident. March 12, 2012. ADAMS Accession No. ML12053A340.

10. —. "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," NUREG-1852. October 2007.

11. —. "The SPAR-H Human Reliability Analysis Method," NUREG/CR 6883. August 2005.

12. —. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, Section 2.4.2: Floods, Rev. 4.

13. U.S. Army Corps of Engineers, St. Paul District. Flood-Fight Handbook - Preparing for a Flood. 2009.

http://www.mvp.usace.army.mil/docs/disaster_response/CEMVP_Flood-Fight_Handbook_2009.pdf.

14. U.S. Army Corps of Engineers. Sandbag Construction. http://www.mvp.usace.army.mil/docs/flood_fight2009/5Sandbag_Construction_2009_JRL.pdf.

15. —. Laboratory Testing of Flood Fighting Products. Coastal and Hydraulics Laboratory. [Online] [Cited: August 23, 2012.] http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=Projects;182.

16. U.S. Nuclear Regulatory Commission. "EPRI/NRC-RES Fire Human Reliability Analysis Guidelines," NUREG-1921. July 2012. ADAMS Accession No. ML12216A104.

17. —. "Good Practices for Implementing Human Reliability Analysis (HRA)," NUREG-1792. April 2005. ADAMS Accession No. ML051160213.

18. —. Fort Calhoun Station - NRC Followup Inspection - Inspection Report NRC 05000285/2010007; Preliminary Substantial Finding. July 15, 2010. ADAMS Accession No. ML101970547.

19. —. "Shutdown Decay Heat Removal Analysis of a Babcock and Wilcox Pressurized Water Reactor," NUREG/CR-4713. March 1987.

20. —. "Shutdown Decay Heat Removal Analysis of a Westinghouse 2-Loop Pressurized Water Reactor," NUREG/CR-4458. March 1987.

21. —. "Shutdown Decay Heat Removal Analysis of a General Electric BWR3/Mark I," NUREG/CR-4448. March 1987.

22. —. "Shutdown Decay Heat Removal Analysis of a Combustion Engineering 2-Loop Pressurized Water Reactor," NUREG/CR-4710. August 1987.

23. —. "Shutdown Decay Heat Removal Analysis of a Westinghouse 3-Loop Pressurized Water Reactor," NUREG/CR-4762. March 1987.

24. —. "Shutdown Decay Heat Removal Analysis of a General Electric BWR4/Mark I," NUREG/CR-4767. July 1987.

25. —. "Evaluation of External Hazards to Nuclear Power plants in the United States," NUREG/CR-5042. 1987.

26. —. "Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program," NUREG-1742. April 2002.

27. American Nuclear Society. "Determining Design Basis Flooding at Power Reactor Sites," ANS/ANSI 2.8-1992. La Grange Park, IL : s.n., 1992.

28. U.S. Nuclear Regulatory Commission. "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," NUREG/CR-1278. August 1983. ADAMS Accession No. ML071210299.

APPENDIX A: Evaluation of flood protection

The goal of this appendix is to provide guidance on the evaluation of flood protection. Section A.1 provides on guidance on evaluating individual features of a flood protection system. Section A.2 provides guidance on evaluating a complete flood protection system.

A.1 Evaluating individual features of flood protection systems

This section provides guidance on evaluating individual features comprising flood protection systems. Section A.1.1 of this Appendix provides guidance on the evaluation of exterior and incorporated flood protection features that are passive and permanent. Section A.1.2 provides guidance on the evaluation of active flood protection features. Section A.1.3 provides guidance on the evaluation of temporary protective measures. Section A.1.4 provides guidance on evaluation of operator manual actions.

A.1.1 Evaluation of exterior and incorporated flood protection features that are permanent and passive

Use of conventional engineering evaluations are generally considered acceptable for demonstrating the capability of exterior and incorporated features that are permanent and passive to perform their intended functions. The following steps should be considered in the flood protection assessment:

- analysis of potential failure modes
- evaluation of capacities
- comparison against present-day codes and standards
- evaluation of operational requirements
- sensitivity studies, as appropriate

It is appropriate to systematically consider the potential failure modes when evaluating a permanent, passive flood protection system.

Section 6.2 describes high-level performance criteria applicable to all types of flood protection, including exterior and incorporate flood protection features that are permanent and passive. The following sections provide points of consideration in evaluating soil structures (embankment, levees, and berms), concrete barriers, seals and plugs, and drainage systems. In evaluating these types of barriers, licensees should refer to the guidance below as well as appropriate codes and standards to assess whether in place or planned systems conform to good practices.

A.1.1.1 Soil embankments, levees, and berms

The foundation and subsurface design of an embankment, levee, or berm should be evaluated to determine whether the following factors were considered in its design:

- foundation stability
- positive control of seepage
- minimum adverse deformation via good contact between flood protection structure and foundation
- use of cut off walls and drainage systems to control seepage paths through foundation

The materials used in construction of the structure should be evaluated to determine whether the following factors were considered in its design:

- use of filter materials to preclude migration of soil materials through the embankment and foundation
- erosion control against surface runoff, wave action, hydrodynamic forces, and debris

The maintenance and inspection regime of the embankment, levee, or berm should be evaluated to assess whether:

- the embankment, levee, or berm is inspected at regular intervals
- written procedures are in place for proper maintenance
- personnel responsible for inspecting the structure have been trained in inspection techniques, implementing preventative and compensatory measures, and correcting or repairing deterioration
- suitable instrumentation is used to obtain information on the performance and condition of the structure

A.1.1.2 Concrete barriers

In assessing whether the concrete barrier can support flood loads, the foundation and subsurface design of the barrier should be evaluated to determine whether the following factors were considered in design of the structure:

- static loads from stillwater elevation
- hydrodynamic loading from wave effects and debris
- foundation design and treatment, including good contact between the flood protection structure and foundation
- removal of problem soils
- increasing seepage paths through the foundation by use of deep cut off walls, if necessary

The material properties of the concrete barrier should be evaluated (using available documentation and current condition) to assess whether:

- there was a competent investigation of material sources
- adequate testing was performed of materials in accordance with accepted standards
- proper proportioning of concrete was performed to improve strength and durability

The design of the concrete barrier should be evaluated to ensure it is safe against overturning and sliding without exceeding the allowable stress of the foundation and concrete for the loading conditions imposed by the flood and all associated flood effects

The maintenance and inspection regime of the concrete barrier should be evaluated to assess whether:

- the barrier is inspected at regular intervals
- written procedures are in place for proper maintenance
- personnel responsible for inspecting flood control structures have been trained in inspection techniques, implementing preventative and compensatory measures, and correcting or repairing deterioration

- suitable instrumentation is being used to obtain information on the performance and condition of the structure

A.1.1.3 Plugs and penetration seals

In assessing whether plugs and penetration seals are watertight and support applied loads the evaluation should demonstrate the following:

- able to withstand the flood height and associated effects (including static and dynamic loads) associated with the flood scenario parameters, including the following considerations:
  - all sizes have been tested to withstand hydrostatic seal pressures for the anticipated water pressures
  - adequately designed for the effects of hydrodynamic and debris loading from floods
- restrict leakage to amount within the capacity of drainage or pumping systems
- in satisfactory condition
- able to withstand anticipated temperatures
- suitable for applications in water - above ground and direct burial- and will provide the electrical insulation where cathodic protection is required
- adequately resistive to fires, corrosive fluids, UV and radiation
- qualitative evaluation of operational requirements such as surveillance, inspection, design control, maintenance, and testing is appropriate to provide confidence in the reliability of plugs and penetration seals.

A.1.1.4 Storm drainage systems

Storm drainage systems should be evaluated to demonstrate they are capable of passing sufficient flow to accommodate the reevaluated flood flow rate while maintaining the flood height not greater than the allowable value.[21] All effects associated with the flood (e.g., scour) should be considered in the evaluation. Performance should be compared against appropriate present-day codes and standards, including Standard Review Plan Section 2.4.2 (Ref. (12)). Storm drainage systems should also be evaluated to demonstrate they are in satisfactory condition. Qualitative evaluation of operational requirements such as surveillance, inspection, design control, maintenance, and testing is appropriate (e.g., a walkdown procedure should be provided for verifying that the system is clear of debris and objects that could impede flow). If drainage systems are associated with active components, they should be evaluated using considerations described in Section A.1.2.

A.1.2 Evaluation of equipment and active features

The reliability of active components, other than flood doors and hatches, should be quantified based on operating experience and other data or information using traditional PRA or statistical techniques. In special cases, this information may not be available, in which case, tests or analyses may be required to support quantification of reliability. If tests or analyses are not feasible, the attributes in Table A 1 may be used to justify the reliability of flood protection equipment; in addition, justification should be provided for the inability to quantify the reliability of active features.

---

[21] If storm drainage is not capable of handling the reevaluated flood, flood protection should be provided and evaluated.

A.1.2.1 Flood doors and hatches

In assessing whether water tight doors perform their intended functions, the following factors should be considered:

- Flood barriers shall conform to the criteria for resisting lateral forces due to hydrostatic pressure from freestanding water.
- Hydrodynamic force resistance – flood barriers shall conform to the criteria for resisting lateral forces due to moving flood waters.
- Debris impact force resistance – flood barriers shall conform to the criteria for resisting debris objects at stated velocities.

A.1.3 Evaluation of temporary barriers

In addition to the performance criteria described in Section 6.2, standards, codes, and guidance documents (e.g., Ref. (13) and (14)) should be consulted to determine whether the configuration of the temporary barrier (e.g., configuration of a sandbag wall) conforms to good practices. Operator manual actions associated with construction or installation of temporary protective measures should be evaluated using Appendix C. Justification of feature reliability may require laboratory or field testing (e.g., Ref. (15)), analytical modeling, or demonstrations.

A.1.4 Evaluation of operator manual actions and availability of necessary equipment

Operator manual actions associated with flood protection features should be evaluated as described in Appendix C.

Equipment necessary to facilitate performance of manual actions should be functional, available, and accessible when required. The availability of special equipment required for the performance of protective or mitigating actions should be considered. In crediting the availability of equipment for use by operators, the following criteria should be considered:

- Equipment should not be damaged or otherwise adversely effected by the flood event (e.g., due to direct inundation, humidity, hydrodynamic forces, or debris) or adverse environmental conditions.
- Equipment should not be located in an area exposed to the flood (including any associated effects), unless there is strong justification for the continued functionality of the equipment.
- All "needs" of the equipment should be met, including supporting electrical power, cooling, and ventilation, etc.
- Equipment should be easily located and all operator aids should be readily available.
- Physical access and manipulation constraints should be considered in evaluating whether equipment is available for use.

The operators should be able to find and reach the equipment and should be able to perform the required actions using the equipment. Credit should not be given if the equipment is not functional, available, and accessible to operators. Therefore, if any of the above criteria are not met, the operation of the equipment should be considered infeasible.

Consideration should be given to special and portable equipment that may be required to facilitate performance of required actions. Special equipment may include keys to open locked doors (doors may "fail closed" in the event of a loss of power), ladders, and special purpose tools (e.g., equipment required to fill sandbags, portable generators, tools to manipulate equipment manually) and equipment necessary to cope with environmental conditions (e.g., flashlights and protective equipment such as personal floatation devices). Equipment should be easily located and readily available so as not to impede or delay the performance of required actions. Equipment should be controlled and routinely verified. Personnel should be trained to locate and use the required equipment. Any delays associated with acquisition and use of portable equipment should be considered.

A.2 Evaluating flood protection systems

This section describes the evaluation of flood protection systems as a whole as directed by Section 6.2. System evaluation should begin with the definition of the flood scenario parameter to which the system is subjected. Next, criteria defining failure of the flood protection system should be identified. In the context of the Integrated Assessment, failure may be defined as loss of barrier integrity, a leakage rate into a room exceeding a specified threshold, or other effects. Failure modes and effects analysis (FMEA) is a common tool for systematically identifying possible failure modes of a SSC and evaluating the effects of the failure on other SSCs and is applicable to the Integrated Assessment. Once failure criteria have been defined, individual flood protection barriers within the flood protection system should be evaluated at the component level under the loads resulting from the flood scenario parameters. Finally, the flood protection system should be evaluated, accounting for interactions and dependencies between components.

Following the above steps, the system evaluation should progress though the sequence of subsequent events that can ultimately lead to end states corresponding to failure (or damage) of the flood protection system and subsequent adverse consequences (e.g., leakage of water past a barrier or inundation of a room). Logic structures, such as event trees, provide a way to represent the various outcomes that can occur as a result of the flood scenario parameters. An event tree starts with the specification of the flood scenario parameters and develops sequences based on whether a feature (including an operator manual action) succeed or fail in performing the intended functions. The system level evaluation should account for factors such as:

- the duration of the flood event[22]
- the reliability of active components (e.g., pumps that are required to remove water that bypasses flood barriers)
- the effect of flood height and associated flood effects on the performance of barriers
- the robustness of barriers, particularly temporary barriers
- the feasibility and reliability of operator manual actions that must be performed to install or construct barriers (e.g., flood gates, sandbag walls), including factors that can influence operator performance, as described in Appendix C

[22] For some hazards, flood conditions could persist for a significant amount of time. Extended inundation on or near the site could present concerns such as site and building access, travel around the site, equipment operating times, and supplies of consumables (Ref. (1)). Flood protection feature limitations based on flood duration should be evaluated. For example, if the duration of the design basis flood is 72 hours and a diesel driven pump is credited with removing water from an area, the total amount of fuel available for the pump and the operating time it represents should be determined and included in the assessment.

- the time available to carry out procedures and perform required actions, including consideration of the reliability of communication mechanisms and instrumentation that trigger actions by plant personnel
- potential hindrances to movement of personnel and equipment around the site

The final two factors in the above list primarily affect the feasibility and reliability of the identified operator manual action factor in the above list. To avoid double counting the affects of the last two factors, it is suggested that they only be taken into consideration in the evaluation of operator manual actions performed by Appendix C.

Table A 1: Criteria for evaluating active components when reliability cannot be quantified

Functional characteristics:	1. There is an engineering basis for the functional requirements for the equipment which: a. is auditable and inspectable b. is consistent with generally accepted engineering principles c. defines incorporated functional margin d. is controlled within the configuration document control system 2. Functionality of the equipment may be outside the manufacturer's specifications if a documented engineering evaluation justifies the equipment will be functional when needed during the flood event duration. 3. Equipment redundancy shall be provided for equipment that may be required to operate in an active manner at any time during the flood event duration
Operational characteristics	1. Testing (including surveillances) a. Equipment should be initially tested to verify performance conforms to the limiting performance requirements. b. Periodic tests and test frequency should be determined by an engineering evaluation based upon equipment type and expected use. c. The testing basis shall be documented. d. Periodic testing should address storage and standby conditions as well as in-service conditions (if applicable). e. Testing records shall be retained. f. Equipment issues identified through testing shall be incorporated into the corrective action program. 2. Preventive maintenance (including inspections) a. Preventive maintenance tasks and task intervals should be determined by an engineering evaluation based upon equipment type, expected use, as well as NRC and industry guidance. b. The preventive maintenance basis shall be documented. c. Preventive maintenance should address both storage / standby conditions and in-service conditions. d. Preventive maintenance records shall be retained. e. Equipment issues identified through preventive maintenance shall be incorporated into the corrective action program. 3. Corrective and elective maintenance a. Corrective and elective maintenance records shall be retained including the reasons for the corrective or elective maintenance performed.

	b. Equipment issues identified through corrective or elective maintenance shall be incorporated into the corrective action program.
Unavailability characteristics	1. The unavailability of equipment should be managed such that loss of capability is minimized. A temporary replacement should be procured for equipment that is expected to be unavailable for more than 30 days or when a flood event is forecasted. 2. A spare parts strategy should be developed to support availability considerations.
Equipment storage characteristics	1. Portable equipment should be stored and maintained as to assure that it does not degrade while being stored and that it is accessible for periodic maintenance and testing. 2. Credited active equipment should be protected from flooding while stored. It should be accessible during a flooding event. Alternatively, credited active equipment may be stored in locations that are neither protected from flooding nor accessible during a flood if adequate warning of an impending flood is available and equipment can be relocated prior to inundation. Operator manual actions associated with relocation of equipment should be evaluated using Appendix C. 3. If B.5.b equipment is credited, it must meet the above storage requirements.

APPENDIX B: Peer Review

A participatory peer review is an important element of the Integrated Assessment. The peer review increases confidence in the results of the Integrated Assessment and provides assurance that they form a sound basis for regulatory decisions. Expertise needed on the peer review team, attributes of an acceptable review, process considerations, and required documentation are described below.

B.1 Peer review team

The peer review team should be assembled based on the following considerations:

- Peer reviewers should be independent of those who are performing the Integrated Assessment. The independence of any reviewer chosen from the licensee's organization should be justified. At least one reviewer should be from an organization external to the licensee's, unless justification is provided to demonstrate the independence of reviewers assembled from inside the licensee's organization.
- The peer review team should have expertise in all areas of importance to the Integrated Assessment. The peer review team members should have combined experience in the following areas (as applicable): systems engineering, flood hazard assessment, flood protection engineering (e.g., structural and geotechnical engineering), human reliability analysis, and application of PRA methodologies.
- Reviewers focusing on the evaluation of flood protection features should have demonstrated experience consistent with the types of flood protection utilized at the site.
- Individuals with experience assessing operator manual actions (e.g., for fire) should be included in the peer review team at sites relying on operator manual actions to protect against or mitigate a flood event.
- One of the peer reviewers should be designated as the team leader. The peer review team leader is responsible for the entire peer review process, including completion of the final peer review documentation. The team leader is expected to provide oversight related to both the process and technical aspects of the peer review. The team leader should coordinate activities that require interface with plant personnel or the Integrated Assessment Team.
- If the Integrated Assessment only involves the evaluation of permanent flood protection features using conventional engineering methods with no reliance on operator manual actions, the peer review team may consist of a single reviewer (the peer review team leader).
- A larger peer review team with broader expertise is required if flood protection involves temporary protective measures, active components, or operator manual actions. The same is true if the Integrated Assessment includes evaluation of mitigation strategies. In these cases, the peer review team should consist of a minimum of two people, but should include as many people as necessary for review of all important aspects of the Integrated Assessment by people with appropriate expertise.

B.2 Peer review attributes

- The peer review should be a participatory peer review. In other words, it should be contemporaneous with the Integrated Assessment and observations made by the peer review team should be transmitted to the Integrated Assessment team as soon as possible.

- The peer review should evaluate each of the following if they formed a part of the Integrated Assessment and assess the rationale if they did not:
  - methodologies used to evaluate capabilities for flood protection and mitigation
  - assumptions made and methods used to validate them
  - performance criteria applied
  - evaluations of the reliability of flood protection features and systems for which generally accepted codes and standards are either unavailable or inapplicable
  - evaluations of the feasibility and reliability of operator manual actions
  - judgments made regarding the mitigation capability of credited systems (applies to both margins-type and full PRA methods)
  - judgments made that there is high confidence that key safety functions will be maintained (applies to scenario-based evaluation methods)
- The peer review team should pay particular attention to the following:
  - assumptions, particularly those that are not thoroughly documented
  - justification for the use of novel models or methods, especially if those models or methods are inconsistent with current practice
  - technical judgments, especially those that are not supported by explicit calculation
  - judgments made regarding the reliability of protection or mitigation actions involving the use of equipment, personnel, or other resources in non-traditional ways
- The peer review team should evaluate the completeness and accuracy of the final Integrated Assessment report

B.3 Peer review process

- The peer review should begin with the designation of a peer review team leader, who will establish the initial scope of the peer review and assemble an appropriate peer review team. The peer review team leader should have sufficient knowledge and experience to determine what kind of peer review is necessary based on the above considerations. Throughout the Integrated Assessment, the peer review team leader should expand the scope of peer review and add members to the team if necessary to ensure all areas of review are appropriately covered.
- Flood protection evaluations and design considerations based on generally recognized codes and standards need not be a focus of the peer review.
- Peer reviewers should have the opportunity to interact with one another when performing the reviews, irrespective of the specific areas of review to which they were assigned.
- The peer review should be conducted as an assembled team for critical items, including evaluation of the following (if credited): (1) operator manual actions, (2) temporary protective measures, and (3) non-safety-related equipment used for event mitigation.

B.4 Peer review documentation

The peer review process should be clearly documented in the Integrated Assessment report. Documentation of the peer review should be contained in a separate report as part of the in the licensee's Integrated Assessment submittal and should include the following:

- a description of the peer review process
- the names and qualifications of the peer review team members, as well as the areas reviewed by each participant.
- a discussion of the key findings and a discussion as to how the findings were addressed
- an assessment of the disposition of comments made by peer reviewers
- a review of the final Integrated Assessment report
- the conclusions of the peer review team

APPENDIX C: Evaluation of operator manual actions

This appendix provides guidance on evaluating operator manual actions associated with flooding based on concepts and approaches used in human reliability analysis (HRA). This appendix is not intended to provide prescriptive guidance on the performance of HRA. Instead, this appendix is intended to provide qualitative "points of consideration" and guidance on using existing HRA concepts and approaches in the context of flooding to evaluate whether operator manual actions are feasible and reliable.[23] Much of this appendix is adapted from existing guidance (Ref.(11)), including guidance related to evaluations of operator manual actions for fire (Refs. (10) and (16)). Thus, in addition to the primarily qualitative considerations described in this Appendix, additional guidance documents related to the evaluation of operator manual actions provide a valuable resource when evaluating operator manual actions as part of the Integrated Assessment. For example, while Ref. (17) is developed for HRAs associated with full-power and internal events applications, the document states that "most of the guidance should be useful for other applications (e.g., external events and other operating modes)" (Ref. (17), p. 2-1).

C.1 Overview

When a flood protection or mitigation action requires operator manual actions, the Integrated Assessment should evaluate whether operator[24] manual actions are feasible and reliable. Consistent with the definitions provided in Ref. (10), an action is considered feasible if it is analyzed and demonstrated as being able to be performed within an available time so as to avoid a defined undesirable outcome. Reasonable simulation[25] performed as part of the NTTF Recommendation 2.3 walkdowns (see Section 2.2) may provide useful information for assessing whether an action is feasible. A feasible action that is analyzed and demonstrated as being dependably repeatable within an available time (while considering varying conditions that could affect the available time and/or the time required to perform the action) is considered reliable. All reliable actions need to be feasible, but not all feasible actions will be reliable (Ref. (10)).

Consistent with common HRA practice, this Appendix differentiates between diagnosis and action tasks. Diagnosis tasks use procedures, knowledge and experience to interpret cues and then determine appropriate courses of action and finally plan and prioritize activities. Action tasks correspond to the response to available information. While it is often possible to distinguish between diagnosis and action tasks, sometimes the two types are intertwined and not easily discernible (Ref. (11)).

Determination of whether an operator manual action is feasible and reliable should account for the following performance shaping factors (PSFs):

- available time
- accessibility

[23] See Section 9 for definitions of feasible and reliable actions.
[24] This appendix refers to operators and operator manual actions. It is recognized that, due to the nature of flood events, actions may be performed by maintenance personnel or other plant staff. Thus, within the context of this appendix, the term operator is used inclusive to all plant staff. Requirements associated with experience and training apply to all plant personnel performing activities associated with protection and mitigation actions.
[25] See definition in Section 9.

- environmental/stress factors
- diagnostic complexity, indications or cues
- training
- procedures
- staffing
- communications
- human factor engineering

This appendix includes a section corresponding to each PSF described above. Each section includes a general discussion of the PSF as well as criteria for specifying whether a diagnosis and action task is feasible and reliable based on the categorization of the PSF associated with the task. An operator manual action is considered to be feasible and reliable if both of the following criteria are met:

1) the PSF for environmental/stress is categorized as “high” or “nominal”
2) all other PSFs are categorized as “nominal” or better

Table C1 and Table C2 facilitate documentation of the qualitative assessment of individual operator manual actions against each of the PSFs in this appendix for both diagnosis and action tasks.

C.2 Available time

An important component of establishing whether an operator manual action is feasible involves determination of whether the time available to complete the action exceeds the time required to perform the action. For each operator manual action, the analysis should show that there is adequate time to diagnose, perform, and confirm actions before an undesired consequence occurs. This evaluation includes three key elements:

1) estimation of the time available to perform the manual action
2) estimation of the time required to diagnose the need for action and to implement the action
3) comparison of the times in (1) and (2) above along with appropriate justification for any conclusions

If an action requires more time to diagnose and perform than is available, the time available is considered inadequate and therefore, the action is not feasible..

To establish whether an action is reliable, it is also necessary to consider the uncertainties associated with the time available and the time required to diagnose and execute the required action. Uncertainties are particularly important when there is a small difference between the time available and time required to perform actions. In the context of flooding, potential uncertainties include:

- variations in plant state and concurrent environmental conditions (e.g., adverse weather, hazards to operators)
- unexpected difficulties encountered by operators (e.g., inundated rooms, locked doors, loss of lighting, communication failures, and underwater hazards)
- factors that cannot be re-created as part of a demonstration (e.g., reasonable simulation performed as part of the NTTF Recommendation 2.3 walkdowns, see Section 2.2) such as the presence of floodwater on site and stress placed on

operators due to the site conditions or concurrent offsite events (e.g., effect of a large flood event on the homes and families of operators)

- obstructions to movement of operators or resources on site due to floodwaters and associated effects (including adverse weather)
- actions the cannot be “practiced” or demonstrated due to normal plant status, physical limitations (e.g., it is not possible to simulate actual flood waters on site), or other safety considerations
- variations between individuals and crews, including differences in size and strength, cognitive differences, different emotional responses to water or adverse weather conditions, differences in performance “under pressure,” and differences in crew characteristics or dynamics
- failure of communication mechanisms (e.g., failure to receive timely notification of an imminent dam failure)

Based on the considerations described above, the PSFs for available time should be categorized for diagnosis and action tasks using the following categorization schemes:

Diagnosis tasks

- Inadequate time (failure)—if the operator cannot diagnose the problem in the amount of time available, no matter what s/he does, then failure is certain.
- Nominal time—on average, there is sufficient time to diagnose the problem.
- Extra time—time available is between one to two times greater than the time required, and is also greater than 30 minutes.
- Expansive time—time available is greater than two times the nominal time required and is also greater than a minimum time of 30 minutes; there is an inordinate amount of time (a day or more) to diagnose the problem.

Action tasks

- Inadequate time (failure)—if the operator cannot execute the appropriate action in the amount of time available, no matter what s/he does, than failure is certain.
- Nominal time—there is some extra time above what is minimally required to execute the appropriate action.
- Extra time—there is an extra amount of time to execute the appropriate action (i.e., the approximate rate of at least 5:1).
- Expansive time—there is an expansive amount of time to execute the appropriate action (i.e., the approximate ratio of at least 50:1).

C.3 Accessibility

Actions that must be performed in inundated areas or requiring operators and/or equipment to travel through inundated areas, should be considered infeasible unless it can be shown that elevated pathways or other means are available to enable movement through the inundated areas and significant hazards to operators (e.g., electrical hazards due to presence of water, low temperatures, etc.) are not present. This criterion is particularly important when evaluating protection or mitigation actions that must be performed after the onset of flood conditions and throughout flood event duration. The evaluation of accessibility requires the consideration of the travel path required for local manual actions given the location of the flood waters and associated effects and how such accessibility might be compromised by the flood. Other accessibility issues include obstructions (e.g., charge fire hoses) and locked doors. In particular, the flood may cause electric security systems to fail locked. In this case, the operators will need to obtain keys for access. Doors that are normally locked should also be considered.

Based on the considerations described above, the PSFs for accessibility should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks:

- Inaccessible—if any of the required tasks is in a location that the operators will not be able to reach because of the flood.
- Nominal—the location(s) is reachable and conditions are such that the actions can be performed.

C.4 Environmental/stress

Environmental conditions may affect an operator's physical or mental performance, i.e., his/her stress level. As a result, the capability of the operator to perform the required actions may be degraded or precluded. Environmental conditions associated with flood events that could increase stress include:

- adverse weather (e.g., lightning, hail, wind, precipitation)
- temperatures (e.g., air and water temperatures, particularly if operators must enter water)
- conditions hazardous to the health and safety of operators (e.g., electrical hazards, hazards beneath the water surface, drowning)
- lighting
- humidity
- radiation
- noise

Based on the considerations described above, the PSFs for environmental/stress should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks

- Extreme—a level of disruptive stress in which the performance of most people will deteriorate drastically. This is likely to occur when the onset of the stressor is sudden and the stressing situation persists for long periods. This level is also associated with the feeling of threat to one's physical well-being or to one's self-esteem or professional status, and is considered to be qualitatively different from lesser degrees of high stress (e.g., catastrophic failures can result in extreme stress for operators because of the potential for radioactive release). For this qualitative evaluation if there is extreme stress, the human action is assumed to fail.
- High—a level of stress higher than the nominal level (e.g., multiple instruments and annunciators alarm unexpectedly and at the same time; loud, continuous noise impacts ability to focus attention on the task, weather, lighting and/or humidity conditions that impair the operators ability to obtain required information or perform required actions, elevated but not life threatening radiation levels; the consequences of the task represent a threat to plant safety).
- Nominal—the level of stress is conducive to good performance.

C.5 Diagnostic complexity, indications and cues

Diagnostic indications or cues provide the following functions:

1) enable operators to determine that manual actions are required or appropriate
2) direct or guide operators performing actions
3) provide feedback to operators

In the context of flooding, indications should be available to provide notification that a flood event is imminent if operator actions are required to provide protection against the flood event. Examples of indications include river forecasts, dam condition reports, and river gauges. Durable agreements should be in place if indications rely on offsite entities to provide notification of an impending flood event. If durable agreements are not in place to ensure communication from offsite entities and the plant does not have an independent capability to obtain the same information onsite, any operator manual action initiated by the indication should be considered infeasible. In assessing the reliability of operator manual actions, consideration should be given to the quality of the agreements in place between offsite entities and operators at the nuclear power plant site as well as the potential for the communication mechanisms to fail.

In the context of mitigation actions, indications should be available to alert operators to the failure of flood protection features and presence of water in locations that are intended to be kept dry or otherwise protected from flood effects. For cases in which indications are not available, the evaluation can consider compensatory measures (e.g., local operator observations). Evaluations of adequacy of time should account for the frequency of manual checks in the absence of continuous monitoring. If cues or indications are not available to operators, the mitigation actions should be considered infeasible.

Based on the considerations described above, the PSFs for diagnostic complexity, indications, and cues should be categorized for diagnosis and action tasks using the following categorization schemes:

Diagnosis tasks

- Highly complex—very difficult to perform. There is much ambiguity in what needs to be diagnosed. Many variables are involved, with concurrent diagnoses (i.e., unfamiliar maintenance task requiring high skill).
- Moderately complex—somewhat difficult to perform. There is some ambiguity in what needs to be diagnosed. Several variables are involved, perhaps with some concurrent diagnoses (i.e., evolution performed periodically with many steps).
- Nominal—not difficult to perform. There is little ambiguity. Single or few variables are involved.
- Obvious diagnosis—diagnosis becomes greatly simplified. There are times when a problem becomes so obvious that it would be difficult for an operator to misdiagnose it. The most common and usual reason for this is that validating and/or convergent information becomes available to the operator. Such information can include automatic actuation indicators or additional sensory information, such as smells, sounds, or vibrations. When such a compelling cue is received, the complexity of the diagnosis for the operator is reduced. For example, a radiation alarm in the secondary system, pressurized heaters, or a failure of coolant flow to the affected steam generator are compelling cues. They indicate a steam generator tube rupture. Diagnosis is not complex at this point; it is obvious to trained operators.

Action tasks

- Highly complex—very difficult to perform. There is much ambiguity in what needs to be executed. Many variables are involved, with concurrent actions (i.e., unfamiliar maintenance task requiring high skill).
- Moderately complex—somewhat difficult to perform. There is some ambiguity in what needs to be executed. Several variables are involved, perhaps with some concurrent actions (i.e., evolution performed periodically with many steps).
- Nominal—not difficult to perform. There is little ambiguity. Single or few variables are involved.
- Experience/Training

If credit is taken for operator manual actions, operators performing required actions should have been trained in their individual responsibilities. In evaluating the effectiveness of training on improving the reliability of operator manual actions, the following factors should be considered:

- Operator training should establish familiarity with procedures and required actions including operation of equipment (including special purpose equipment).
- Training should engender operator familiarity with potential adverse conditions arising from a flood event (e.g., dangerous weather).
- Training should prepare operators to handle departure from the expected sequence of events
- Training should provide the opportunity to practice operator response (e.g., construction of barriers using special equipment).

Based on the considerations described above, the PSFs for training should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks

- Low—less than 6 months experience and/or training. This level of experience/training does not provide the level of knowledge and deep understanding required to adequately perform the required tasks; does not provide adequate practice in those tasks; or does not expose individuals to various abnormal conditions.
- Nominal—more than 6 months experience and/or training. This level of experience/training provides an adequate amount of formal schooling and instruction to ensure that individuals are proficient in day-to-day operations and have been exposed to abnormal conditions.
- High—extensive experience; a demonstrated master. This level of experience/training provides operators with extensive knowledge and practice in a wide range of potential scenarios. Good training makes operators well prepared for possible situations.

C.6 Procedures

In evaluating the feasibility of an operator manual action, the quality of procedures should be assessed based on its ability to accomplish the following objectives:

- Assist operators in correctly diagnosing an impending flood event (i.e., flood height and associated effects) or the compromise of a flood protection feature

- Identifying the appropriate preventative (or mitigation) actions
- Account for prevailing current conditions, if applicable (e.g., high wind or lightning that makes it difficult for operators to work outdoors)

Except under special circumstances involving skill-of-the-craft,[26] operator manual actions that are not associated with procedures should be considered infeasible. Written and maintained plant procedures must be available to cover all credited manual actions. Even if procedures are available, actions should be considered infeasible if the associated procedures do not meet the above objectives.

Based on the considerations described above, the PSFs for procedures should be categorized for diagnosis and action tasks using the following categorization schemes:

Diagnosis tasks

- Not available—the procedure needed for a particular task or tasks in the event is not available.
- Incomplete—information is needed that is not contained in the procedure or procedure sections; sections or task instructions (or other needed information) are absent.
- Available, but poor—a procedure is available but it is difficult to use because of factors such as formatting problems, ambiguity, or such a lack in consistency that it impedes performance.
- Nominal—procedures are available and enhance performance.
- Diagnostic/symptom oriented—diagnostic procedures assist the operator/crew in correctly diagnosing the event. Symptom-oriented procedures (sometimes called function-oriented procedures) provide the means to maintain critical safety functions. These procedures allow operators to maintain the plant in a safe condition, without the need to diagnose exactly what the event is, and what needs to be done to mitigate the event. There will be no catastrophic result (i.e., fuel damage) if critical safety functions are maintained. Therefore, if either diagnostic procedures (which assist in determining probable cause) or symptom-oriented procedures (which maintain critical safety functions) are used, there is less probability that human error will lead to a negative consequence. This being said, if the symptom-based procedure is found to be inaccurate or awkwardly constructed, then the procedures PSF should be negatively rated.

Action tasks

- Not available—the procedure needed for a particular task or tasks in the event is not available.
- Incomplete—information is needed that is not contained in the procedure; sections or task instructions (or other needed information) are absent.
- Available, but poor—a procedure is available, but it contains wrong, inadequate, ambiguous, or other poor information. An example is a procedure that is so difficult to use, because of factors such as formatting, that it degrades performance.

---

[26] A term describing those tasks in which it is assumed that the workers know certain aspects of the job and need no written instructions, e.g., a plumber replacing a washer in a faucet. (Ref. (29))

- Nominal—procedures are available and enhance performance.

C.7 Staffing

In assessing the feasibility and reliability of an operator manual action, the persons involved in performing the operator manual action should be qualified. The feasibility assessment should consider the availability of a sufficient number of trained operators without collateral duties during a flood event such that the required operator action can be completed as needed. Required operators may be normally onsite or available from offsite, if sufficient warning time is available and the flood event does not inhibit access to the site. Consideration should to given to whether task assignments (or task loads) subject one or more operators to excessive physical or mental stress or if concurrent tasks challenge the ability of the person to perform as required. If there are insufficient qualified operators to complete the required actions (considering actions that must be performed concurrently), the action should be considered infeasible. In evaluating the reliability of an operator manual action, uncertainties in the number of operators onsite (or that can be “brought in” from offsite) should be considered.

Based on the considerations described above, the PSFs for staffing should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks

- Insufficient staffing—insufficient qualified operators are available to perform required activity.
- Nominal staffing—sufficient qualified operators are either 1) onsite, or 2) available offsite with sufficient warning time to arrive onsite and site access is not inhibited by the event, to perform the required activities. Also taken into account is the availability of qualified operators to perform all concurrent (simultaneously) required activities.

C.8 Communications

Equipment (e.g., two-way radios) may be required to support communication between operators to ensure the proper performance of manual actions (e.g., to support the performance of sequential actions and to verify procedural steps). Also because of the long durations of many flooding scenarios and because of the possible need of offsite support, communication with corporate and governmental organizations is important. Therefore, consideration of the causes of the floods impact on offsite communications must be considered. Due to the substantial amount of warning that may be present for some flood mechanisms, efficient communication may be less important when evaluating the feasibility and reliability of operator manual actions associated with preemptive protective measures. However, mitigation may require actions for which the time available to diagnose, perform, and confirm actions is short. Communications methods should be checked to ensure prevailing conditions do not challenge their effectiveness. Consideration should be given to whether operators are trained to ensure effective communication and coordination during a flood event.

Based on the considerations described above, the PSFs for communications should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks

- Poor—performance is negatively affected by the communication process/equipment (both onsite and offsite).
- Nominal—communications (both onsite and offsite) is not significantly affected by the flooding event.

C.9 Human factors engineering

Human factors engineering refers to the equipment, displays and controls, layout, quality, and quantity of information available from instrumentation, and the interaction of the operator/crew with the equipment to carry out tasks.[27] Many of the human actions anticipated for dealing with floods will be external to the main control room. As such, it is not the layout and design of the controls and annunciators in the control room that are of primary concern but instead those external to the control room. For example, controls and annunciators that are external to the control room may not be permanently installed (i.e., may be temporary and/or movable). This appendix addresses flood-specific operator manual actions carried out external to the control room; any actions carried out in the control room should be evaluated using well-established HRA methods.

When considering panel design layout, event investigations at U.S. commercial nuclear facilities have shown that when necessary plant indications are not located in one designated place, it is difficult for an operator to monitor all necessary indications to properly control the plant.[28] If there is evidence that this is the case, a negative PSF value is assigned.

Based on the considerations described above, the PSF for human factors engineering should be categorized for diagnosis and action tasks using the following categorization scheme:

Diagnosis and action tasks

- Missing/Misleading—the required instrumentation fails to support diagnosis or post diagnosis behavior, or the instrumentation is inaccurate (i.e., misleading). Required information is not available from any source (e.g., instrumentation is so unreliable that operators ignore the instrument, even if it is registering correctly at the time).
- Poor—the design of the plant negatively impacts task performance (e.g., poor labeling, needed instrumentation cannot be seen from a work station where control inputs are made, or poor computer interfaces).

---

[27] Aspects of human machine interface and the adequacy or inadequacy of computer software are also included in this PSF. Job performance aids can also be considered a special case of human factors engineering. However, if the job performance deficiency is related to a procedure, then the preferred means of evaluating the situation is to apply this information to the procedures PSF, as opposed to the human factors engineering PSF. For example, if the procedure does not match the equipment to be used, then the equipment procedure deficiency should be noted in the procedures, not the human factors engineering PSF.

[28] Examples of poor annunciators designs have been found where only a single acknowledge circuit for all alarms is available, which increases the probability that an alarm may not be recognized before it is cleared. Another problem exists where annunciators have set points for alarms that are set too near to the affected parameter for an operator or crew to react and perform a mitigating action. Examples of poor labeling include instances where labels are temporary, informal, or illegible. In addition, multiple names may be given to the same piece of equipment.

- Nominal—the design of the plant supports correct performance, but does not enhance performance or make tasks easier to carry out than typically expected (e.g., operators are provided useful labels; the computer interface is adequate and learnable, although not easy to use).
- Good—the design of the plant positively impacts task performance, providing needed information and the ability to carry out tasks in such a way that lessens the opportunities for error (e.g., easy to see, use, and understand computer interfaces; instrumentation is readable from workstation location, with measurements provided in the appropriate units of measure).

C.10 Documentation

Table C1 provides a documentation format for the PSFs for diagnosis tasks. Table C2 provides a documentation format for the PSFs for action tasks. As described above, an operator manual action is considered to be feasible and reliable if (1) the PSF for environmental/stress is categorized as “high” or “nominal,” and (2) all other PSFs are categorized as “nominal” or better. For each PSF, the category meeting the above criteria are identified by shaded cells in Table C1 and Table C2.

Table C1: Documentation of performance shaping factors for diagnosis

PSFs	PSF Levels	Applicable PSF Level	Specific reasons for PSF level selection.
Available Time	Inadequate time		
	Nominal time		
	Extra time (between 1 and 2 times nominal and greater than 30 minutes)		
	Expansive time (greater than 2 times nominal and greater than 30 minutes)		
Accessibility	Inaccessible		
	Nominal		
Environmental/ Stress	Extreme		
	High		
	Nominal		
Diagnostic Complexity, Indications and Cues	Highly complex		
	Moderately complex		
	Nominal		
	Obvious diagnosis		
Experience/ Training	Low		
	Nominal		
	High		
Procedures	Not available		
	Incomplete		
	Available, but poor		
	Nominal		
	Diagnostic/symptom oriented		
Staffing	Insufficient		
	Nominal		
Communications	Poor		
	Nominal		
Human factors engineering	Missing/misleading		
	Poor		
	Nominal		
	Good		
Shaded cells in the above table indicate PSF levels meeting the following criteria: (1) the PSF for environmental/stress is categorized as “high” or “nominal,” and (2) all other PSFs are categorized as “nominal” or better.			

Table C2: Documentation of performance shaping factors for action

PSFs	PSF Levels	Applicable PSF Level	Specific reasons for PSF level selection.
Available Time	Inadequate time		
	Nominal time		
	Extra time (greater than or equal to 5 times the time required)		
	Expansive time (greater than or equal to 50 times the time required)		
Accessibility	Inaccessible		
	Nominal		
Environmental/ Stress	Extreme		
	High		
	Nominal		
Complexity	Highly complex		
	Moderately complex		
	Nominal		
Experience/ Training	Low		
	Nominal		
	High		
Procedures	Not available		
	Incomplete		
	Available, but poor		
	Nominal		
Staffing	Insufficient		
	Nominal		
Communications	Poor		
	Nominal		
Human factors engineering	Missing/misleading		
	Poor		
	Nominal		
	Good		
Shaded cells in the above table indicate PSF levels meeting the following criteria: (1) the PSF for environmental/stress is categorized as “high” or “nominal,” and (2) all other PSFs are categorized as “nominal” or better.			

APPENDIX D: Existing resources and examples

The goal is this Appendix is to provide references to existing assessment of external flood risk at nuclear power plants. These references may provide useful resources and insights for performance of certain aspects of the Integrated Assessment. However, this Appendix does not necessarily endorse the methodologies used in the external flood risk studies referenced here and these references do not supersede the guidance contained in this ISG.

D.1 Evaluations performed under the NRC Significance Determination Process

In June 2010, NRC inspectors identified an apparent violation of Technical Specification 5.8.1.a, "Procedures," at Fort Calhoun Station for failure to establish and maintain procedures that protect the intake structure and auxiliary building during external flooding events. An NRC senior reactor analyst performed a Phase 3 significance determination process (SDP) analysis, which is documented in Ref (18). The analysis described in Ref. (18) was performed to represent a best-estimate risk evaluation of a specific performance deficiency related to flood protection. As such, the analysis has a different purpose and smaller scope that evaluations performed as part of the Integrated Assessment. Nonetheless, the analysis contained in Ref. (18) provides insights on how flood risks have been considered in other applications. In particular, Section 2 of Attachment 2 in Ref. (18) demonstrates the calculation of conditional core damage probability (CCDP), given flood elevations in varying ranges and the equipment compromised at those elevations (with and without the availability of flood protection). This portion of the assessment pertaining to the calculation of CCDP under the performance deficiency (i.e., given the failure of flood protection) is conceptually consistent with the type of evaluations required under a margins-type evaluation of mitigation capability. Section 2 of Attachment 2 in Ref. (18) also considers flood frequencies corresponding to a range of flood heights. This information is convolved with the estimates of CCDP given each flood range. This assessment is conceptually consistent with a PRA-based evaluation of mitigation capability. Moreover, the SDP discusses evaluations performed of additional methods for mitigating the event (e.g., alternate methods of refilling the essential feedwater tank and use of tabletop generated, non-proceduralized actions), including consideration of human failure probabilities based on application of SPAR-H (Ref. (11)). Under the SDP, the analysis was simplified to: (1) calculation of flooding frequencies, (2) computation of the gasoline powered pump system probability (estimated by fault tree as described in Ref. (18)), and (3) comparison of risk assuming flood protection failure to the baseline risk.

D.2 Evaluations performed under Task Action Plan A-45

The objectives of Task Action Plan (TAP) A-45 was initiated to evaluate the safety adequacy of decay heat removal systems in existing light water reactor nuclear power plants and to assess the value and impact of alternative measures for improving the overall reliability of the decay heat removal function. PRA and deterministic evaluations were used to evaluate decay heat removal systems and support systems required to achieve hot standby and cold shutdown. The following six plants were analyzed under the program:

- Arkansas Nuclear One-1 (Ref.(19))
- Point Beach (Ref. (20))
- Quad Cities (Ref. (21))
- St. Lucie (Ref.(22))
- Turkey Point (Ref.(23))
- Cooper (Ref. (24))

It was beyond the scope of TAP A-45 to perform an in-depth PRA. The objective was to conduct an analysis that quantified the significant threats to the plant. The authors indicate that the analysis performed “embodies the basic philosophy of a full scope probabilistic risk assessment.” As such, in many cases, the scope of the TAP A-45 evaluations maybe more limited than the evaluations required by the Integrated Assessment and all facets pertaining to the Integrated Assessment are not considered under TAP A-45.

To evaluate the frequency of plant damage due to external flooding, the following five tasks were performed:

- Plant familiarization
- Hazard analysis
- Fragility analysis
- Systems analysis
- Risk quantification

There are necessary differences in the specific methodologies and techniques used to evaluate external flood risk at each site. The summary provided here is intended to provide a general overview of what was done at the sites and not all parts may be explicitly used at a given site.

The purpose of plant familiarization (step 1) was to gather information on the occurrence of external hazards and the vulnerability of plant structures and equipment to flooding (e.g., plant location and flood hazard, plant design basis, and vulnerable structures and equipment). The hazard analysis (step 2) was performed in two steps: (1) screening, and (2) evaluation the frequency of occurrence. Due to the differences in flood hazard at each site, TAP A-25 uses site-specific approaches to assessing flood hazard. Fragility analysis (step 3) was performed for structures and equipment vulnerable to the effects of external flooding. A conservative approach was used in developing capacities of structures and equipment to resist external flood loads. An approach was used that is similar to that used in seismic applications. Fragility functions were typically computed with respect to hydrostatic loads and did not consider both flood height and associated effects, as required under the Integrated Assessment. Systems analysis (step 4) involved evaluation of response of the plant to safety system failures. The systems analysis describes the component and system failures due to external flooding and associated effect on plant functions. Simple functional event trees were used to model the plant response to external flooding. Risk is quantified (step 5) by determining core melt probability using system failure information and the functional event tree developed under step 4. The core melt frequency is determined by consideration of flood frequency and conditional core melt probability given an external flood event.

D.3 NUREG/CR-5042, Evaluation of External Hazards to Nuclear Power Plant in the United States

Ref. (25) investigates the effect of external hazards on nuclear power plants in the United States. The objective of the work was to gain an understanding of whether external initiators (internal fires, high winds and tornados, external flood and transportation accidents) are among the major potential accident initiators. Ref. (25) documents a review and evaluation of what was known (at the time) about the risk of core-damage accidents and potential for large radiological release as a result of external floods. The report uses two figures of merit as evaluation criteria: (1) mean core damage frequency less than 1×10^{-5}, and (2) frequency of large early release less than 1×10^{-6}. Ref. (25) provides a review of NRC's regulatory approach, General Design Criteria, Appendix A of 10 CFR 100, the Standard Review Plan, regulatory guides, papers and reports, selected plant specific documents, and PRA literature on flooding a nuclear power plants. Reviewed literature includes the following sources:

- Indian Point Probabilistic Safety Study, 1983
- Probabilistic Risk Assessment, Limerick Generating Station, 1981
- Severe Accident Risk Assessment, Limerick Generating Station, 1983
- Millstone Unit 2 Probabilistic Safety Study, 1983
- Oconee PRA, A Probabilistic Risk Assessment of Oconee Unit 3, 1984
- Zion Probabilistic Safety Study, 1982
- Studies performed under TAP A-45, 1987 (see Section D.2)

Ref. (25) provides a summary of the above references and offers conclusions based on available literature. The report also describes a proposed approach for plant evaluation of external flood risk. The approach involves evaluation of the frequency of large flood events and contingent likelihood of an accident scenario given a large flood. Bounding analysis is suggested as a mean to easily demonstrate the figures of merit are met. If a probabilistic bounding assessment cannot demonstrate risk is acceptably low (i.e., figures of merit are met) then a more extensive plant response analysis is required (e.g., through a full-scope PRA).

D.4 Individual Plant Examination of External Events (IPEEE) Program

External flooding was evaluated under the Individual Plant Examination of External Events (IPEEE) Program. Ref. (26) documents the perspectives gained as a result of the review of the IPEEE submittals. The report observes that under the IPEEE Program, twelve submittals reported the contribution of core damage frequency from external flooding. Typically, submittals treated external flooding as leading to a loss of offsite power (typically assumed unrecoverable) with additional random failures that could lead to core damage. Some submittals considered additional flood-induced damage (e.g., loss of intake structure, failures of diesel fuel oil transfer pumps, as well as failures of safety-related equipment in the diesel generator, auxiliary, and turbine buildings). The majority of sites used a qualitative screening rather than a PRA to evaluate external flooding under the IPEEE Program (Ref. (26)).