From:	Miller, Ed
To:	RILEY, Jim
Subject:	FW: files from May 2 meeting
Date:	Monday, May 06, 2013 11:55:00 AM
Attachments:	Dam_Failure_ISG-Draft-Public-Meeting-2013-05-01-JFK.pptx Dam-Failure-ISG-Ind-Roll-up-Rev-4-NRC-Response-JFK-2013-04-15.docx

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From: Miller, Ed
Sent: Thursday, May 02, 2013 3:57 PM
To: Miller, Ed
Subject: files from May 2 meeting

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Sec. 1 / p. 1	1st paragraph, last sentence: "Therefore, in this ISG dam failure refers to flooding caused by any uncontrolled or controlled flow of water that threatens to impact structures, systems and components (SSCs) important to safety at the NPP site."	Definition of dam failure in the context of flooding usually refers to uncontrolled release of water from the reservoir. It is recognized that controlled releases from a reservoir may threaten SSCs at a site, and this potential should be investigated as part of the flood hazard reevaluation. However, flooding potential of controlled releases is never mentioned in the ISG except in this sentence. Also, the definition is imprecise in its wording because it refers to "any uncontrolled or controlled flow of water." Presumably, "flow of water" means reservoir releases, but the definition taken by itself could refer to any flooding mechanism.	The definition of dam failure should be revised to exclude controlled releases, or further discussion of the investigation of flooding potential of controlled releases should be added to the ISG (perhaps as a dedicated section). Also, suggest changing "flow of water" in the definition to "reservoir releases" to exclude other flooding mechanisms unrelated to dam failure.	Reword intro to discuss dam failure in the usual sense, as well as controlled releases. Add a section discussing controlled releases. - Gate discharge capacity - Check river op /dam procedures. - Communication w/ river/dam operator. Changed definition of dam failure back to conventional definition. Added paragraph on controlled releases to intro. Lumped operational failures and controlled releases together in background section 2.2.3 Added section 7, devoted to operations failures and controlled releases
Sec. 1 / p. 1	2nd paragraph, 4th sentence: "NPPs may also use some combination the protection outlined above."	Typographical/editing error, missing word, "of"	Suggest change to: "NPPs may also use some combination of the protection outlined above."	Typo fixed. Changed to "NPPs may also use some combination of the protection outlined above."
Sec. 1 / p. 1	"Failures of water-storage or water-control structures (such as onsite cooling or auxiliary water reservoirs and onsite levees) that are located at or above the grade of safety-related equipment are potential flooding mechanisms."	List should specifically exclude tanks		Better for licensee to provide justification for excluding tanks? Note: Will check with scope of 2.1 with respect to internal/external flooding.
Sec. 1.2 / p. 2	Last sentence of paragraph: "This ISG is applicable to Tier 1 sites that have been granted an extension."	Application of the ISG to sites that have been granted an extension and whose bounding flood hazard does not include dam failure may present an unreasonable burden.	Suggest excluding Tier 1 sites who have been granted an extension and whose bounding flood hazard does not include dam failure. Consideration should also be given to tier 1 sites that did not receive an extension long enough to allow use of this new guidance.	Will provide clarification to: Exclude sites w/ short extensions Can exclude Tier 1 sites that are clearly not impacted by dam failure. But just because original design basis did not identify dam failure as <u>bounding</u> is not a reason to exclude.

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Sec. 1.3.1 / p. 2	1st paragraph, 5th sentence: "…small/distant dams whose failure would like have negligible impacts…"	Typographical/editing error, "like" instead of "likely"	Suggest change to: "…small/distant dams whose failure would likely have negligible impacts…"	Typo fixed. Changed to "…small/distant dams whose failure would likely have negligible impacts…"
Sec. 1.3.2 / p. 4	2nd full paragraph of p. 4, last sentence: "The details of the screening process will vary according to the loading case being considered (e.g., hydrologic, seismic, other).	The screening process described in Section 3 does not distinguish among dam failure mechanisms. See Sec. 3.2, p. 23, 1st paragraph.	Make the guidance consistent.	OK. Can delete sentence. Fixed – Sentence deleted.
1.3.2, p. 4	"In addition failure due to other (non-hydrologic, non-seismic) causes (e.g., geologic or structural defects, misoperation, etc.) under specific loading conditions must be considered."	This statement is too broad and could lead to an extensive search and justification for an endless list of potential failure mechanisms and combinations of failures beyond hydrologic and seismic.	Modify the statement to be specific on the scope of <u>other failures</u> by referencing <u>Operation Failures</u> which are described in section 2.2.3. The other failure modes are associated with <u>Sunny Day failure</u> as described in Section 6.	Can provide clarification, but if the aim is to credit non-failure, then comprehensive analysis is required. Text Modified to read: In addition failure due to non-hydrologic, non-seismic causes (i.e., sunny day failures) must be considered. Sunny day failures encompass a wide variety of mechanisms (e.g., geologic or structural defects, misoperation, etc.),
Sec. 1.3.2 / p. 4	4th full paragraph of p. 4, last sentence: "In lieu of a detailed analysis, one can simply assume that the dam fails under appropriate loading and move on to estimation of the consequences."	In lieu of a detailed analysis, does the licensee have any alternate options to justify that a dam (which is not screened-out according to Section 3) will not fail, rather than simply assuming dam failure?	Explain what is meant by a detailed analysis – analyze non-failure or analyze how the failure would occur. Clarify if there are any alternative options to simply assuming dam failure in lieu of a detailed analysis. For example, if a federal agency can provide justification that the dams they own and operate will not fail under the scenarios described in this ISG, clarify if the licensee can rely on the assertion of a federal agency in lieu of a detailed analysis.	In general, comprehensive analysis, performed in accordance with standard engineering practice, is required to support determination of non-failure. Details of sharing analysis results performed by other federal agencies still being worked out No change made to text.
1.3.2, p. 4	"Dam failure flood hazard estimation will require collecting data on the dam (s) to be	What can be done if records cannot be located? Are there any	If detailed historical information cannot be obtained, recent (last 5 years) inspection	All available information should be used to evaluate flood hazards and potential failure

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	analyzed (e.g., design documents, construction records, maintenance, and inspection program, planned modifications)"	reasonable assumptions that can be made? Are there a minimum set of records needed.	reports and evaluations by the dam regulator can be used to determine if there are flaws or vulnerabilities that should be evaluated for dam failure risk.	modes. Lack of information cannot be used to rule out vulnerabilities. No change made to text.
1.3.2, p. 4	"Transport of sediment and debris by flood waters should be considered."	Not clear what this statement is requiring and how to perform a sediment and debris analysis beyond engineering judgment. Where is sediment a concern? What scale/type of debris is of concern?	If an analysis is required and expected to be part of the report, this statement would need to be expanded to further characterize when sediment and debris needs to be considered and the specific concerns that need to be addressed. If the concern is to consider sources of large debris in the routing path that could be transported to the nuclear site, it should be stated as such.	Debris is discussed in Section 4.2.7 Need to develop staff position on reservoir/river sedimentation. Added section 4.2.2.1 to discuss reduction in reservoir capacity due to sediment accumulation.
1.3.2, p 4	"Comparison of the estimated capacities to the applied loads is used to assess the credibility of failure modes associated with those cases. The assessment may consider factors of safety incorporated into the dam design or dam capacity assessments, with appropriate justification. Likewise, uncertainties in capacity and loading estimates should be considered to arrive at an appropriately conservative decision. If it cannot be demonstrated that the dam-failure likelihood over the expected remaining life of the nuclear power plant is extremely low (or consequences of failure are negligible), failure should be postulated and the flooding consequences estimated."	How does this reconcile with paragraph 1.4.2 that describes risk criteria.	Clarify the relationship between the deterministic and risk based criteria.	This is intro/overview level discussion. This section is meant to convey, in general terms, two concepts that are discussed in more detail is later sections: 1) In certain cases we allow credit for margins 2) NRC risk tolerance is very low. Note: Will clarify that hydrologic need not be probabilistic, but can be. Added the following text to the end of this paragraph: It is recognized that such assessments will often require a combination of deterministic, qualitative probabilistic, and/or quantitative probabilistic analysis. For example, current NRC guidance accepts deterministic analysis of hydraulic hazards (e.g., PMP,

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				PMF). Deterministic analyses of capacity to withstand loads that were arrived at by probabilistic or deterministic analysis are also accepted.
Page 5	"credible failure modes/scenarios"	How will "credible" be defined?		Refer to section 1.4 No changes to text.
1.3.2, p 5	"In summary, the dam-failure flood hazard analysis will comprise the following steps.."		Should include the works "potentially critical"	Will clean up wording. Changed text to read: "In summary, the dam-failure flood hazard analysis for potentially critical dams will comprise the following steps.."
Sec. 1.4.1 / p. 6	1st paragraph, 2nd sentence: "…little or no consequences (NRC, 2012)."	Ambiguous acronym reference. In this case, "NRC" refers to National Research Council, but the NRC acronym in the ISG usually refers to Nuclear Regulatory Commission. This comment applies each time this reference is cited (pp. 7, 8, 10, possibly others).	Clarify acronym.	Will fix this. Citation will become NAS (2012) (National Academy of Sciences) Fixed as stated above.
Page 6, Figure 2	Decision diamond on Figure 2	What are the criteria for determining a yes or no outcome of the "Fail?" decision diamond?		This is overview. Refer to sections on detailed analysis (4,5,6,7,8,9,) No change to text.
1.4.1, p. 7	"Historical rates for dam failure provide useful information about generic failure probabilities. However, each dam and its environment are unique and failure probability estimates, when used, should be developed based upon site and dam specific data and information."	The statement says "…failure probability estimates, when used…" which could imply that failure probability estimates are required.	Modify statement to say "…failure probability estimates, if used…". This would be consistent with the staff's position that a deterministic approach is preferred.	OK with this change in wording. Modified statement to say "…failure probability estimates, if used…".
Sec. 1.4.2 / p. 7	General comment: This section states that the probability target for judging the likelihood of a particular failure mode/scenario (either from a single hazard or appropriate	If it can be demonstrated that a dam will not fail during a flood with probability of 10^{-6} per year, can hydrologic dam failure be excluded	More clarification is required to clarify that dams not failing for 10^{-6} flooding can be considered as safe and potential failure during PMF does not need to be evaluated.	Staff discussion needed. Make part of discussion w/ ICODS.

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	combination) is $1x10^{-6}$ annual probability. From the above statement it appears that dams which are safe for floods with a probability of 10^{-6} per year need not to be checked for failure during PMF.	without considering PMF?		
1.4.2, p. 8	Staff Positions Bullet 2 : "…on limited data will viewed with great skepticism."	Typo	…on limited data will *be* viewed with great skepticism."	Typo fixed. Changed to "on limited data will *be* viewed with great skepticism."
1.4.2, p. 8	Last bullet - staff position states "…acceptable to use the $1x10^{-4}$ annual frequency ground motions, at spectral frequencies important to the dam, for seismic evaluation of dams, instead of $1x10^{-6}$, as discussed above. However, appropriate engineering justification must be provided to show that the dam has sufficient seismic margin. Otherwise the $1x10^{-6}$ ground motions should be used."	• It is not clear how the 10^{-4} and 10^{-6} criteria should be used. If sufficient margin cannot be established with the 10^{-4} criteria, how could adequate justification be achieved with the 10^{-6} criteria when it is associated with a larger earthquake? • What constitutes sufficient margin if a 10-4 seismic hazard analysis is performed verses a 10-6 seismic hazard analysis?	• Clarify how the two seismic criteria are to be used • Provide guidance on what amount of margin is sufficient.	Staff discussion needed Interaction w/ ICODS needed
Sec 1.4.2 / p. 8	2nd bullet on p. 8, next to last sentence: "However, appropriate engineering justification must be provided to show that the dam has sufficient seismic margin."	No quantitative criteria for "sufficient margin" are provided.	The 10^{-4} annual frequency ground motion is comparable to GMRS. Factor of safety in NRC regulatory guidance for liquefaction and slope stability for GMRS can be used to demonstrate "sufficient margin."	Staff discussion needed Interaction w/ ICODS needed
Sec. 1.4.2 / p.8	2nd bullet on p. 8, last sentence: "Otherwise 10^{-6} ground motions should be used."	The 10^{-6} ground motion criteria appears to be more conservative than NRC ISG-20, "PRA based Seismic Margins Analysis" where 1.67 * GMRS is used as a screening criteria. Comment also applies to Sec 5.3.1, p. 48, 1st paragraph.	"Otherwise 10^{-6} ground motions should be used." should be replaced by "Otherwise dam seismic capacity greater than 1.67*(10^{-4} ground motions) should be demonstrated."	1.67*GMRS is developed for NPPs. Staff discussion needed Interaction w/ ICODS needed
1.5.2	TVA has more than 49 dams in the national inventory of dams.	Where was this data collected?	The National Inventory of Dams recognizes 155 dams owned by TVA.	Source was NAS report, that cited FEMA report. Will check this.

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				Checked NAS and FEMA reports. Boith say "49 dams". Checked TVA website, which lists ~49 reservoirs. Understood that single reservoir may have more than one dam. Changed wording to "Approximately 49 major dams".
Sec. 1.5.2 / p. 9	4th full sentence: "Other federal agencies such as the USACE, the USDA Natural Resources Conservation Service and the UDOI Bureau of Reclamation…"	Typographical/editing error, "UDIO" instead of "USDOI" for US Dept. of Interior	Suggest change to: "Other federal agencies such as the USACE, the USDA Natural Resources Conservation Service and the USDOI Bureau of Reclamation…"	Typo fixed. Changed to "…USDOI…"
Sec. 1.5.3 / p. 11	Staff Position, 1st bullet: "If a federally owned dam is identified as critical to the flooding reanalysis, the licensee should contact NRC promptly. NRC will act as the interface between these agencies and licensees. Memoranda of Agreement or other mechanisms are being developed to facilitate sharing of data (including necessary safeguards to protect sensitive information) between NRC and the appropriate federal agencies."	If information from a federal agency is considered classified, would this information be limited to the government agencies or would the licensee be involved?	Following the development of the Memoranda of Agreement, include in this ISG information regarding how to handle requests for information that may be considered classified by a federal agency.	MoA still under development.
Sec. 1.5.3 / p. 11	Staff Position, 1st bullet: "It is important to note that in many cases federal agencies that own or operate dams have a conducted detailed failure analysis. To the extent these analyses are applicable, they should be used in the Recommendation 2.1 flooding reanalysis."	Details of the agency's existing dam failure analyses may not be provided to the licensee or may be considered classified. If the full details of the agency's existing analyses are not available to the licensee, it may not be possible to determine that the analyses are applicable and meet the criteria for the Recommendation 2.1 flooding reanalysis.	Clarify whether the onus is on the licensee or the federal agency to determine that the existing dam failure analyses performed by federal agencies are applicable and meet the criteria for the Recommendation 2.1 flooding reanalysis, in the event that the details of these analyses are not provided to the licensee.	MoA still under development.
1.5.3, p 11	"In most cases dams and levees will be owned and operated by private entities and regulated by a state agency. In this case, the licensee should interact directly with the owner and regulator."	NRC assistance may be important	Clarify NRC assistance in this situation	Will consider what form of assistance is appropriate and practical NRC will consider this question on a case-

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				by-case basis, if the licensee encounters difficulties in obtaining information, NRC should be notified Modified text to add: "The licensee should notify NRC if they encounter difficulties in obtaining information. On a case-by-case basis, NRC may be able to provide some assistance in interfacing with state agencies."
Sec. 2.2.1.2 / p. 20	2nd paragraph, 1st sentence: "…overtopping which initiates embankment erosion; and structural overstressing."	Typographical/editing error, number 3 is missing from the list.	Suggest change to: "…overtopping which initiates embankment erosion; and 3) structural overstressing."	Typo fixed. Added missing number 3.
Sec. 2.2.1.2 / p. 20	2nd paragraph, 3rd sentence: "For example, cohesionless soils are less able to withstand erosion from due to overtopping…"	Typographical/editing error, "from due to"	Suggest change to: "For example, cohesionless soils are less able to withstand erosion from overtopping…"	Typo fixed. Changed to For example, cohesionless soils are less able to withstand erosion from overtopping…"
Sec. 2.2.1.2 / p. 20	3rd paragraph, 1st sentence: "…without loss or strength or liquefaction…"	Typographical/editing error, "or" instead of "of"	Suggest change to: "…without loss of strength or liquefaction…"	Typo fixed. Changed "or" to "of"
Sec. 2.2.3 / p. 22	Last bullet in list: "Inability to warn in advance…"	Unlike the other bullets in the list, this bullet seems more like a consequence of failure rather than a causative failure mechanism, except possibly in the case of a cascading failure sequence, which is discussed in the next section.	Suggest deleting bullet, or clarifying how it might apply as a failure mechanism.	Will provide clarification Reworded to focus on failures that may result in inability to warn in advance. Modified text as follows: Failure to detect flows or a breakdown in the communication process to get people out of harms way. For example, power and phone lines may be cut by a large earthquake or flood. This may result in inability to warn in advance of life-threatening downstream flows.
Sec. 3 / p. 23	General comment: There needs to be a clearer distinction between "inconsequential" dams, which are removed from consideration	Clarity of important subject.	According to the ISG, inconsequential and noncritical dams are not treated the same. Inconsequential dams are removed from	Will review this section and tighten up wording.

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	in the analysis, and "noncritical" dams, which are "screened out" (Figures 10-13) but whose postulated failure effects are carried forward in the analysis. The terminology used in the ISG seems to be inconsistent; e.g., the 1st sentence of Section 3 states "This section discusses screening criteria used to identify those dams that may be screened out and not given further consideration in the analysis." The term "screened out" as applied in this sentence and in Figures 10-13 clearly means something different.		consideration and no effects of their postulated failures are included in the final dam failure analysis. However, the cumulative, conservative effects of postulated failures of non-critical dams are carried forward in the analysis (e.g., last sentence of Item 1.d, p. 24). Further clarification on this topic near the beginning of the section would be helpful. Fig. 1 from Section 1 could be reproduced here, or at least referred to. The ISG needs to use precise terminology; the text should be revised to apply the terms "screened" and "screened out" consistently. A suggested change would be to use the term "removed" only for inconsequential dams and the term "screened out" only for noncritical dams. Also, a discussion of how the effects of noncritical dams are to be carried forward and used in the final analysis is needed.	Note: Look at providing additional guidance on how to add in cumulative effects. Text modified in several places to tighten up wording. "Inconsequential" dams are "removed". "Noncritical" dams are "screened". Provided cross reference to Section 1.3.1 and Figure 1.
Sec. 3.1 / p. 23	1st paragraph, 2nd sentence: "The USACE states that is that there is…"	Typographical/editing error, "is that" should be deleted.	Suggest change to: "The USACE states that there is…"	Typo fixed. Changed to "The USACE states that there is…"
3.2 , p 23	Simplified Modeling Approaches: "…basis for simplified screening of upstream dams."	It appears the discussion is regarding simplified modeling, not screening in this instance.	"…basis for simplified modeling of upstream dams."	OK. Will adopt proposed change. Adopted proposed change to "modeling".
Sec. 3.2 / p. 24	Item 1.b: "…from available hydraulic models of the watershed…"	Hydrologic (not hydraulic) models are generally associated with watersheds. The presumed intent was to refer to an available hydraulic model of the floodplain. Comment also applies to Item 2.c, p. 24.	Suggest change to: "from available hydraulic models of the floodplain…"	OK. Will re-word this. Changed to "hydrologic and hydraulic model"
Sec. 3.2 / p. 24	Item 1.b, general question: Rather than using a stage-discharge function, would it be acceptable to use an established 500-year WSEL at the site, such as from a FEMA FIS, USACE flood study, or other appropriate	It might be more precise to use an established 500-year WSEL from an existing, credible study than estimating the stage from a rating curve. Comment also applies to	Suggest adding text to allow use of an established 500-year WSEL at the site from an existing, credible flood study.	OK to leverage existing current and credible information. Modified text to indicate a progression from using available 500-year WSEL to existing

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	source?	Item 2.c, p. 24.		stage/storage or rating curves, to development of stage-storage curves using appropriate methods.
Sec. 3.2 / p. 24	Item 1.d, general question: The goal of this step seems to be "to segregate potentially critical dams from dams with negligible cumulative effect of failure at the site. However, the last sentence states, "The cumulative effect of the 'noncritical' dams will be carried forward and eventually added to refined estimates for the critical dams." If the cumulative effect of failure of noncritical dams is negligible, why should it be carried forward and added to the effects of the critical dams?	The problem seems to be with the word "negligible." Comment also applies to Item 2.e, p. 24.	Suggest revising to replace the word "negligible."	OK. Will replaced negligible with more suitable term. Used the term "small". Small cumulative effect means that detailed modeling of these is not required to account for their effect
Sec. 3.2, / p. 24	Item 2.a, 2nd sentence: "Due to the potentially large numbers of at this stage of the analysis…"	It appears there is a word missing between "of" and "at"	Provide missing word to clarify the intent of the sentence.	Typo fixed. Dams is the missing word.
Sec. 3.2 / p. 25	Item 4, 1st paragraph: "unit hydrographs, design storms, , antecedent conditions…	It is unclear how design storms would apply to this screening method. Also, there is an extra comma in the sentence.	Suggest deleting reference to design storms, or clarifying how the use of design storms would apply to this screening method. Also delete the extra comma.	OK. Will remove reference to design storm. Removed reference to design storm.
Chapter 4		Flood hazard analysis in general and Probabilistic Flood Hazard Analysis in particular are not covered to the same degree that PSHA is covered.		True. We don't have specific guidance on PFHA at this time. No change to text.
4.1.1, p. 31	4.1.1 Concrete Dams	Failure conditions and modes are discussed in this section but there is no discussion on how much of the dam must be assumed to fail. Partial failure should be discussed	Include discussion of partial failure that recognizes that sections of the dam may fail without the loss of the entire dam. An engineering analysis would be required to justify the assumed failure based on the dam design and specific "weakness" leading to the assumed failure.	Discussed in Section 7.1 on Breach Modeling No change to text.
Sec. 4.1.3 / p. 32	Staff Position bullet: "…should include consider the potential for loss…	Typographical/editing error, "should include consider"	Suggest change to "…should consider the potential for loss…" or "should include	Type fixed. Changed to ".. should consider.."

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			consideration of the potential for loss…"	
4.1.3, p. 32	"Analysis of hydrologic failure modes should include consider the potential for loss or degraded function of spillways, gates, outlet works and other appurtenances."	The statement could be read that the analysis must assume that the appurtenances fail.	Modify wording to state: "Analysis of hydrologic failure modes should include consideration of the potential for loss or degraded function of spillways, gates, outlet works and other appurtenances. If failure is not assumed, provide an engineering justification."	OK with proposed wording. Added "If failure is not assumed, provide an engineering justification."
Sec. 4.1.3 / p. 32	General question: If an owner/operator of dams upstream of a NPP is not agreeable to providing information that would allow the licensee to evaluate of the operability and continued functionality of spillway gates and other appurtenances during an extreme flood, is it necessary to assume failure of these appurtenances?	Information may not be available to the licensee to evaluate the continued functionality of spillway gates and other appurtenances during an extreme flood.	Clarify if the licensee may justify the operability of spillway gates and other appurtenances in the absence of information from the dam owner/operator, or if it is necessary to assume failure of these appurtenances.	Lack of information is not sufficient justification to assume non-failure. As discussed in section 1.5, NRC will, to the extent practical, interface with dam owners/operators/regulators to obtain information needed for analysis. No change to text.
Sec. 4.1.4 / p. 32	1st paragraph, 2nd sentence: "…rocks or concrete to minimize prevent erosion and failure."	Typographical/editing error. The presumed intent was "minimize."	Suggest change to "…rocks or concrete to minimize erosion and failure."	Typo fixed. Changed to "…minimize erosion and prevent failure."
4.2 , p 33	General Comment: Recognizing that there is a section devoted to Multiple Dam Failure due to Single Storm Scenario, the guidance appears to apply primarily to single dam failures. It does not seem to be fully developed to address cascading failures or failure of multiple dams on adjacent tributaries (either from seismic or precipitation event).	Extrapolation of the current guidance to cascading failures or failure of multiple dams on adjacent tributaries is excessively conservative in most cases.	Revise guidance to include cascading failures or failure of multiple dams on adjacent tributaries.	Refer to section 4.2.8 on multiple dam failures. No change to text.
4.2.1.p. 33	"Embankment dams should be evaluated for potential failures due to internal pressures from a hydrologic inflow event (flood). Potential failure modes that should be evaluated include deterioration or plugging of drains and internal erosion mechanisms."	Since drains and internal erosion are not visible, an acceptable method to evaluate for potential failures should be offered here.	Evaluation would include reviewing the dam design to assure that appropriate filters, drains, and monitoring points are included. Seepage monitoring, piezometers, observation wells and visual observations of the seepage points over the life of the dam	OK, with proposed wording. Add requirement that there be no unremeditated deficiencies Added text: "Evaluation should generally

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			does not indicated deterioration of the dam.	include reviewing the dam design to assure that appropriate filters, drains, and monitoring points are included. Monitoring records of piezometers, observation wells or other observation methods can be used to show absence of unremediated deficiencies."
4.2.2, p 34	Staff Position-First Bullet/First Sub-bullet: It was expected that the ISG would address the depth and duration of embankment overtopping in greater detail.	The decision not to fail should be based on the severity (depth and duration) of overtopping, characteristic of failure (overtopping from precipitation or cascading dam failures), in addition to the physical properties of the embankment.	Revise discussion to address depth and duration of overtopping.	Requires dam-specific engineering analysis. No change to text.
4.2.2, p 34	Staff Position-Second Bullet: "The potential for overtopping due to nonfunctioning gates, outlets and other appurtenances should be considered."	This statement could be read that the failure of the appurtenances must be assumed versus being evaluated to determine if the failures should be assumed.	Modify the wording to state, "The potential for overtopping due to nonfunctioning gates, outlets and other appurtenances should be evaluated to determine the appropriate failure assumptions with appropriate engineering justification."	OK. See page 35. Changed to use the proposed text: The potential for overtopping due to nonfunctioning gates, outlets and other appurtenances should be evaluated to determine the appropriate failure assumptions with appropriate engineering justification."
Sec. 4.2.2.1 / p. 34	Staff Position bullet: "The default starting water surface elevation used in flood routings for evaluation of overtopping is the higher of the maximum observed or the maximum normal pool elevation."	• The requirement of using the maximum observed reservoir elevation may be too conservative if the maximum observed reservoir elevation is the result of a large (e.g. 10^{-3}) flood event. Conceptually, this requirement implies the PMF event would occur immediately after a large antecedent flood event, effectively resulting in a "super PMF" and violating the definition of the PMF. A	• For the hydrologic dam failure evaluation, suggest changing default starting reservoir water surface elevation requirement to maximum normal pool or other elevation with appropriate justification. Flood inflow hydrographs normally start from some base flow. The reservoir pool would be at normal levels at the beginning of such an event. An average pool level for the month in which the flood is anticipated to occur could be used. For example, for a plains snowmelt flood in the central US, an average pool	Max normal pool elevation is OK. Will consider other levels with sufficient justification. NRC will consider additional wording to clarify the level of justification needed for other levels. Changed text to allow max normal pool or other level w/ justification: "The default starting water surface

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		significant flood event may also be required to reach the maximum normal pool, depending on the amount of flood control storage in the reservoir. Comment also applies to Section 4.2.8, Staff Position, 1st bullet. • Since the maximum observed water level is likely the result of an extreme precipitation event, using maximum observed water level as a starting point is equivalent to assuming two concurrent floods. • "the maximum observed pool elevation" may be a very extreme event, which if considered in conjunction with runoff from a PMP could result in an unreasonable predicted maximum pool elevation. • The "highest observed" starting water surface referenced here would likely be from an extreme event, to which the analyst would be adding another hypothetical extreme even • Use of the maximum observed or full pool reservoir elevations is overly conservative in combination with an antecedent storm. Antecedent storms surcharge reservoirs and in combination with the maximum observed full pool (which may	for the month of March or April could be used. • . The default starting water surface elevation used in flood routings for evaluation of overtopping or sunny day failure is the maximum normal pool elevation. Other starting water surface elevations may be used with appropriate justification.	elevation used in flood routings for evaluation of overtopping is the maximum normal pool elevation. Other starting water surface elevations may be used, with appropriate justification." Added guidance on justification for other (lower) water levels: "Justification may include the operating history of the reservoir, but should consider whether anomalous conditions such as drought have influenced the record."

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		have resulted from an event close to the antecedent) or full pool is extremely conservative.		
Sec. 4.2.2.2 / p. 35	Staff Position bullet: "Reservoir surcharge capacity can be credited in used in flood routings…"	Typographical/editing error, "credited in used in"	Suggest change to "Reservoir surcharge capacity can be credited in flood routings…"	Typo fixed. Changed to "Reservoir surcharge capacity can be credited in flood routings…"
Sec 4.2.2.3 / p. 35.	Staff Position, 2nd bullet: "…at least one turbine should always be assumed to be down (e.g., for maintenance or other reasons) in performing flood routings."	• Dam operators typically perform their maintenance activities outside of the flood season. Assumption that one unit is out of service is excessive. • Overly conservative assumption	• Assume all units are usable, use full power plant discharge capacity. • In large river systems with multiple generating dams does each generating dam have to consider one turbine out of service?.	**Scheduled** maintenance occurs outside flood season. "one turbine" rule from USBR training manual Need to think about the multiple dam questions. Capacity factor info available?? No change to text at this time.
4.2.2.3	"The potential for flood-borne debris to reduce spillway capacity should be considered."	There is no industry standard on how to address debris. Additional guidance should be provided on how to address flood-borne debris blockage.		Staff discussion needed No change to text at this time.
Sec. 4.2.2.3 / p. 35	3rd sentence under Potential for Reservoir Debris to Block Spillway: "As a rule of thumb, spillway bays with a clear distance less than 40 feet (less than 60 feet in the Pacific Northwest) are vulnerable to debris plugging."	• The criteria for considering potential debris blockage at a spillway are not clear. If a spillway is gated with 40-foot wide gates, are there criteria for how much blockage should be considered or how the spillway capacity may be reduced by flood-borne debris? • "This statement needs a reference." Could not find the source	• If debris blockage is considered as a potential vulnerability of a spillway, clarify criteria regarding spillway capacity reduction.	Will provide reference. Staff discussion needed on capacity reduction. No change to text at this time.
Sec. 4.2.2.4 / p. 36	Staff Position bullet: "[NEED position regarding winds]"	It is recognized that this text was added as a placeholder.	Suggest adopting the criteria from ANS 2.8 Section 5.5.4.2.3, p. 12, which specifies the	Addressed. Used 2-yr wind.

Section / Page	Comment	Concern	Proposed Resolution	[Draft] NRC Response
			following event combination of wind and PMF: "Probable maximum flood surcharge level plus maximum (1%) wave height resulting from the sustained 2-yr wind speed applied in the critical direction." Although this combination is specified in the context of investigating the potential for overtopping of earth and rockfill embankments, it would also seem applicable in the generic sense for PMF evaluation of any type of dam.	Section is not specific to dam type. Added sentence on winds: "Coincident wind waves should be estimated at the dam site based on the longest fetch length and a sustained 2-year wind and added to the stillwater elevation."
4.2.3, p 36	"Static stability of the dam and key appurtenances under hydrologic loads associated with the dam's PMF should be demonstrated. Otherwise the dam should be assumed to fail."	Failure of an appurtenance does not automatically result in a subsequent dam failure. What needs to be demonstrated to show stability, a new structural analysis or qualitative judgment?	Modify the wording to state: "Static stability of the dam and key appurtenances under hydrologic loads associated with the dam's PMF should be demonstrated. Otherwise the appurtenance should be assumed to fail and the impact on the dam determined." Clarify what is needed to demonstrate stability.	If dam cannot withstand load, fail the dam. If appurtenance cannot withstand load, fail the appurtenance and estimate impact of its failure on stability of the dam. If dam stability not impacted, still must consider downstream impact of uncontrolled release (if any) associated with appurtenance failure. Added clarification: "If the dam cannot withstand the applied loads, the dam should be assumed to fail. If the appurtenance cannot withstand the load, assume failure of the appurtenance and estimate impact of its failure on stability of the dam. If the dam stability is not impacted, one still must consider the downstream impact of uncontrolled release (if any) associated with appurtenance failure."
Sec. 4.2.5 / p. 37	1st paragraph: "Both concrete-line spillways and unlined and grass-lined earthen spillways are subject to process that may	Typographical/editing errors, "concrete-line spillways" and "are subject to process"	Suggest change to: "Both concrete-lined spillways and unlined and grass-lined earthen spillways are subject to processes	Typo fixed. Changed to "Concrete-lined spillways, as well as unlined or grass-lined earthen spillways, are subject to process

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	lead to failure…”		that may lead to failure…”	that may lead to failure during high flows associated with flooding.”
4.2.6, p 38	Staff Position: As written, the guidance is ambiguous as to the evaluation(s) that should be conducted for gate failure. Further, it does not address gate failure for multiple upstream dams.	There are infinite permutations for failure of gates given the information provided.	Clarify the guidance for gate failure.	Staff discussion needed. No change to text at this.
4.2.7.1, p 38	Staff Position: The potential for basin to generate mud/debris flows should be considered.	What is the significance and concern with mud/debris as it relates to dam failure analysis or impact to the reservoir? Are basin specific studies being recommended or required?	The purpose analyzing mud/debris needs to be described including the hazard/risk associated with mud flows.	Considering removing this section. No change to text at this time.
4.2.7.2, p 39	Staff Position: Impact loadsstructures due to waterborne debris should be considered. In general, methods outlines in the FEMA Coastal Construction Manual and average size/weight for objects specified in ASCE Standards are acceptable.	What structures need to be evaluated for impact loads for the HRR versus the IA? Does this apply only to the dams and appurtenances? If this analysis is intended for the NPP site, discrete velocities will be required at each structure being evaluated. The debris sources along with the size and depth of the flood will determine the volume	Clarify position on the conditions being used to generate the debris (PMF or dam failure, etc) and where impact loads must be evaluated. If IA assumes all flooded SSC's are lost, would debris dynamic load analysis would not be required, or is it only intended to determine if flood retaining structures survive the debris impacts?	Debris impact on dam is the concern here. Gates and associated mechanical equipment, appurtenances, parapets, etc.. Debris loading at the site due to the dam break flood wave should also be considered. Added two staff positions: • Loads due to waterborne debris carried by flood waters should be considered with regard to impacts on the dam (i.e., gates and associated mechanical equipment, appurtenances, parapets, etc.). • In the case of dam break flood waves, debris impacts to SSCs important to safety should be considered.
4.2.8, p 40	Staff position: “Flood waves from multiple	Clarify that the failures need not be	Clarify that the failures need not be forced to	Not meant to force flood waves to reach site

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	dam failures should be assumed to reach the NPP site simultaneously unless appropriate justification for differing flood arrival times is provided."	forced to cause the flood waves to reach the site at the same time. This approach was meant for the high level evaluation. The models would work out the timing of the flood waves reaching the site.	cause the flood waves to reach the site at the same time. Hydrologic failure would be triggered based on peak water level, so the time of failure would be different.	at same time. The point is that differences in timing need to be supported with appropriate justification, not just assumed. No change to text.
5, p 42 to 61	The seismic chapter contains a number of acronyms and not all of them are defined (e.g., UHRS, GMPE, etc.)		Check acronyms to ensure all are explained	Will check
Sec. 5.1.1.1 / p. 43	Staff Position bullet: "… USGS maps… can be used directly for very high-level screening level analysis…"	It is not clear what is meant by "very high-level screening level analysis."	Suggested change: "USGS maps can be used directly to screen out dams where site-specific seismic analysis is not required."	Plan is to remove this statement. Rational: At his point in the analysis, dams under consideration are "potentially critical". UHRS should be used. Can be developed w/ existing tools with minimal effort. Removed staff position.
Sec. 5.1.1.1 / p. 43 And Sec 5.3.1 / p. 49	Staff Position bullet, Sec. 5.1.1.1, p. 43: "… USGS maps… can be used directly for very high-level screening level analysis…" Staff Position, 1st sub-bullet, Sec. 5.3.1, p. 49: "The data and software tools available from USGS … are suitable for developing bedrock hazard curves and uniform hazard spectra at 10^{-4} annual frequency …"	For major rivers with multiple dams (e.g., Missouri River has 6 major dams), the CEUS SSC PSHA calculations and field geotechnical investigations for site response analyses will require an extremely large effort (cost and schedule) for a Utility to implement. Thus, the published USGS 2008 rock PGA for 2% chance of exceedance every 50-year ($4x10^{-4}$ /year probability of occurrence) should be acceptable to screen out dam failures in lieu of a site specific PSHA and GMRS (approximately $4x10^{-4}$ /year probability of occurrence) evaluations for low seismic regions of CEUS (2% exceedance every 50-year rock PGA <0.05g).	Suggested change: "USGS (2008) rock PGA maps for 2% exceedance every 50 year can be used directly to screen out seismic induced dam failures for CEUS regions with rock PGA of <0.05g."	Site-specific amplification functions not needed. EPRI generic site amplification OK. No change to text.
5.2.3, p 47	"Gates *and may* fail…"	Typo	"Gates *may* fail…"	Typo fixed. Changed to "Gates may fail…"

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5.2.4, p 47	Staff position for levee failure during a seismic event – • assumption of starting water level is not indicated. • Also, failure should not have to be assumed if adequate justification of non-failure can be provided.		• Starting water level should be consistent with that assumed for a seismic dam failure evaluation • Change sentence to allow for adequate justification of non-failure in addition to specific performance criteria	Provisional answer – 100 yr flood or design level Seismic failure of levee only needs to be considered if levee failure could inundate site. Need to review for applicability…
Sec. 5.5, 5.6, and 5.7	General comment on NRC's approach for addressing dam failure hazards in the ISG.	The ISG appears to "resolve" the flooding due to dam failure primarily though a permutation of analyses by the plant owner either to show dam will not fail in its current state or through measures to cope with the resulting flood. It fails to recognize that it is preferable, less disruptive, and less expensive to avert catastrophic dam failures through proper inspections, maintenance, and spillway flow control practices rather than to cope with the consequences of dam failures. The NRC approach to cope with consequences of hazards form natural phenomenon (seismic, snow melt, rainfall, hurricanes, etc.) is justified. However, for man-made hazards (dam failures, spillway gate failures, etc.) that can be greatly mitigated through good design and maintenance practices, the NRC approach should rely on prevention over measures to cope with the consequences to enhance public good and plant safety downstream.	For major dams where federal agencies (e.g., USACE) have the responsibility for dam design, dam safety, and controlling spillway flow for flood control, the ISG should state that the NRC will, through inter agency agreement, determine the 10^{-6} probability "coping" flood levels for the downstream plants considering the critical parameters including dam design parameters, current condition of the dam, dam maintenance practices, seismic hazards at the dam site, spillway flow control practices, and river hydrographs because the downstream plant utility is not in a position to determine, or in future control, these critical parameters that greatly influence dam failure probabilities and dam failure flood wave levels at the plant site. The NRC specified 10^{-6} /year flood level at the plant site shall consider the joint probabilities of combined events (dam break with river flood, dam break with intense precipitation, etc.) that account for the limited duration of the maximum flood levels for these events.	
5.5 / pg. 52	Third paragraph: sources contributing to	The information in this paragraph is		Will clarify. Considering adding a figure.

Section / Page	Comment	Concern	Proposed Resolution	[Draft] NRC Response
	ground motion	unclear. Need to revise to clarify wording.		
Sec .5.6 / p. 53	Staff Position, 1st bullet: "Dam failure due to an earthquake should be considered for both maximum normal operating ("full pool") and average reservoir levels."	• The "maximum full pool level" generally corresponds to a 10%/year frequency. Thus, the joint event failure probability considering the maximum normal operating full pool level is conservative by an order of magnitude. • Head water/tail water relationship prescribed is not possible for multiple reservoirs being simulated in a continuous hydraulic model for cascading dam failures.	• Suggested change: "Dam analysis to show sufficient margin for 10^{-4} ground motions should consider median (or average) reservoir levels. Maximum operating full pool level (10 percentile) should be considered with 10^{-3} ground motions." • Revise guidance for the head water/tail water relationship as applied to cascading dam failures.	SRP requires "full pool" Use 10-4 ground motions 2nd Comment OK for flood routing, but should not take credit for tail water in stability calculation. Structural calculations should not benefit from high water levels
Sec. 5.6 / p. 53	"Given the hazard frequency target of $1x10^{-6}$ discussed in Section 1.4.2, the dam failure flood wave at the site should be combined with flows of a frequency that result in a combined annual probability of $1x10^{-6}$. For example, if the dam fails under a 10^{-4} ground motion, combine the dam break flood wave with a 100-year flood. If the dam fails under a 10^{-3} ground motion, combine the dam break flood wave it with a 1000-year flood."	• In the example, the combined event probability does not reasonably account for the fact that the 1000-year flood is a seasonal event and the maximum flood water level at the plant site for the 1000-year river flood is present for a limited part of the year only. The earthquake ground motion (and the resulting flood wave) and the 1000-year flood are independent events. Thus, the joint probability of occurrence of the combine event should consider the limited duration of the maximum flood level for a 1000-year flood. • The combining of an earthquake and a flood simply multiplying their annual probabilities of	• Suggested change: "For example, if the dam fails under a 10^{-4} ground motion, combine the dam break flood wave with a 10-year flood. If the dam fails under a 10^{-3} ground motion, combine the dam break flood wave with a 100-year flood. This example assumes that the high flood level at the plant site for the 10-year and 100-year floods will last approximately 1-month (10% of one year) or less before receding." • See methodology in: Event Combination Analysis for Design and Rehabilitation of U.S. Army Corps of Engineers Navigation	Open to considering 1st option. Will review USACE report. Note: Need to consider situation where failure is just assumed.

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		occurrence does not allow for the very small duration within a year for the earthquake to coincide with a longer but still only a fairly small fraction of a year for the duration of most floods. • This paragraph is change from previously expressed NRC positions as discuss in public meetings • What combination should be applied if seismic failure is just assumed?	Structures by Bruce R. Ellingwood, Contract Report ITL-95-2, July 1995, US Army Corps of Engineers, Waterways Experiment Station • Use event combinations as previously described in public meetings: 1. seismic hazard frequency target of $1x10^{-4}$ with 25 year flood, 2. 0.5 x seismic hazard frequency target of $1x10^{-4}$ with 500 year flood.	
5.8.2.1	"If the results of post-earthquake sliding stability analyses for critical failure surfaces indicate a safely factor well above 1.0 (e.g. 1.25 or greater)..."		Use governing/applicable dam safety criteria factors of safety as criteria for sufficient margin against sliding stability	Quoted factor of safety is from federal guidance document (FEMA). Will provide reference. Added Ref (FEAM. 2005)
Sec. 6 / p. 62	6th bullet in list: "Erosion or cavitation in waterways and channels, including spillways." 8th bullet in list: "Failure of spillway gates or valves to operation during flood (e.g., mechanical or electrical breakdown or clogging with debris)"	Both of these mechanisms seem related to hydrologic dam failure rather than sunny day, and are specifically discussed in the context of hydrologic dam failure in Section 4 of the ISG.	Suggest deleting these two bullets from the list.	OK Bullets 6 and 8 removed.
Sec. 6.1.1 / p. 63	4th paragraph, 4th sentence: "For concrete buttress dams founded on alluvial soils, are subject to failure…"	Typographical/editing error, "For concrete buttress dams…"	Suggest change to: "Concrete buttress dams founded on alluvial soils are subject to failure…"	Typo fixed. Changed to "Concrete buttress dams founded on alluvial soils are subject to failure…"
Sec. 6.1.3 / p. 64	General comment: It is unclear whether the sunny day failure mechanism is applicable to levees, since levees are normally subject to water loading only during flooding events.	It is recognized that levee failure should be assumed if the levee is overtopped. Levee failure at elevations less than overtopping should be investigated; however, it	Suggest consideration be given to removing levees from the sunny day failure mechanism section, and adding the information about levee failures included here to the hydrologic failure mechanism,	Will remove. Some parts may be added to section 4. Text moved to section 4.2.9. Staff positions added.

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		is debatable whether these conditions can be considered "sunny day."	with additional information as needed.	
6.2, P 65	"Sunny day failure may be excluded from further consideration if it can be shown by the licensee that the probability of failure is 10^{-6} per year or less. The 10^{-6} value is chosen since there is not sufficient data to allow for accurate calculations of this event. Reasonable arguments justifying the case for a lower failure probability include but are not limited to a recurring dam inspection and monitoring program, expert assessments that the dam is in good condition, and detailed inspection reports."	What methodology for estimating a probability of failure is 10^{-6} per year or less would be acceptable to the NRC for sunny-day failure including piping or internal erosion failures.		Updated staff position provides criteria: Sunny day failure may be excluded from further consideration if it can be shown by a dam specific engineering assessment that the probability of failure is $1x10^{-6}$ per year or less using current best practices. As of this writing, the methods discussed in the USBR Dam Safety Risk Analysis Best Practices Training Manual (USBR, 2011) are considered by the staff to represent current best practice. Therefore, the staff expects these risk results to be based on a thorough engineering analysis similar in scope and rigor to the comprehensive facility review process described in USBR (2011). Note: We will be reviewing the target and its appropriateness. We will also be reviewing the potential for extrapolating out to targets of 10-6. No additional new text at this time.
6.2, p. 65	First sentence, "Analysis of sunny day failure can be organized in to three *basis* steps:"	Typo	First sentence, "Analysis of sunny day failure can be organized in to three *basic* steps:"	Typo fixed. Changed to "Analysis of sunny day failure can be organized into three basic steps:"
Sec. 6.2.1 / p. 65	Staff Position bullet: "Reasonable arguments justifying the case for a lower failure probability include but are not limited to…"	It is unclear what "lower failure probability" means in this context. Does it mean lower than 10^{-6} failure	Additional description of how to apply probability to the sunny day failure mechanism and possible pathways to take	See comment above (USBR approach) No additional new text at this time.

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		probability?	credit for non-failure would be helpful.	
Sec. 6.2.1 / p. 65	The Staff Position states that reasonable arguments for a lower than 10^{-6} per year risk of sunny day failure can be made using the existence of recurring dam inspection, monitoring program, expert assessments that the dam is in good condition and detailed inspection reports.	Federal agency dam owners generally have all of this information at hand. Utilities would have to request this data from the Federal agency dam owners.	Propose that the NRC ask the federal agency dam owners to agree via an MOU to provide this data to certify that their dams need not be analyzed in detail for a sunny day failure.	MoA process is TBD, but there is no expectation that such certification can be obtained. No new text at this time.
Sec 6.2.2 / p. 66.	The Staff Position to use the maximum observed or maximum normal pool elevation for the sunny day breach analysis is excessive.	• "the maximum observed pool elevation" may be a very extreme event and not reflect sunny day conditions, which if considered in conjunction with runoff from a PMP could result in an unreasonable predicted maximum pool elevation. Such an extreme historical event may have a very low frequency and short duration relative to historical operation depending on the riverine system and the upstream watershed. • The implication of the term "sunny day" is that it occurs during non-flood conditions. Use of the maximum observed pool links it to the inflow of record for the dam.	• The default starting water surface elevation used in flood routings for evaluation of overtopping or sunny day failure is the maximum normal pool elevation. Other starting water surface elevations may be used with appropriate justification.	Default is maximum observed. Max normal pool can be used with justification. Examples of justification: Water levels above max normal pool are Infrequent, and duration is short. Text modified to read: "…the default initial water level used in breach analysis and flood routings for evaluation of sunny-day failure should be the higher of the maximum observed pool elevation or the maximum normal pool elevation. Other water levels may be used with justification (e.g., records showing that water levels above max normal poll are infrequent and of short duration)."
Sec. 7, p. 67	General comment: Most of the introductory material in this section seems specific to embankment dams.	General organization of section.	It might be more appropriate to move the information that is specific to embankment dams to Section 7.2, since Section 7 is presumably meant to provide general	OK. Can reorganize in this way. Earthen embankment ext moved to section 7.2

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			introductory material for both concrete and embankment dams.	
7, p 68	Earthen dams do not tend to fail completely, nor do they tend to fail instantaneously.	This statement applies to a non-cascading dam failure. Cascading failures can be very rapid due to high levels of overtopping over the entire crest of the dam with multiple simultaneous breach points across the dam	Discussion is needed to acknowledge the differences between a cascading dam failure and a non-cascading dam failure.	Statement as written is well supported. Can provide references. We have not seen references that discuss or examine the differences outlined here. No change to text.
7., p.68	Last sentence, "Dam breach analysis of composite dams…should consider the failure portion or portions of the dam that would produce the largest peak outflow."	Largest Peak outflow in many instances would result from a total failure which, for embankments, would likely result from cascading dam failures.	Discussion should be included regarding cascading failure in the subsequent sections.	Please discuss available technical literature on cascading dam failures. No change to text at this time.
P 71	"However, their paper does not provide clear criteria for selecting the erodibility index."	Xu and Zhang (2009) do not provide detailed criteria for selecting the erodibility index because they state that they used definitions in a paper by Briaud, which provides detailed definitions.		Paper does not give any examples that would indicate how closely Briud definitions are followed. No change to text at this time.
p 71	"In addition, anecdotal evidence suggests that their relation for failure time may be biased in favor of longer times (Wahl, 2013)."	• Xu and Zhang define failure time differently than in other empirical breach parameter studies. This means that one must use their failure time estimates in a breach model (e.g. HEC-RAS) in a way that is consistent with their definition. It is not a fundamental deficiency or flaw in the method. • The difference in reported failure time is more appropriately characterized as a difference in how it is defined based on the starting and ending point. Not	• Remove the statement	Xu & Zhang definition of failure time is same as that used in some other studies. Not unique definition. However, their example of Teton dam does not seem to follow their own definition, so there is a question of consistency. NRC is working with ICODS to coordinate review of Xu & Zhang model. No change to text at this time.

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		sure that anecdotal evidence is appropriate for an ISG document		
7.2.2, p 71	Xu and Zhang – "However, their paper does not provide clear criteria for selecting the erodibility index."	Xu and Zhang do not provide detailed criteria for selecting the erodibility index because they state that they used the J. L. Briaud (2009) definitions which is the current state of practice.	Revise the statement to say "The paper references the J. L. Briaud (2009) criteria for selecting the erodibility index."	Paper provides no example to show how they implement Briuad criteria. Briaud criteria not developed specifically for dams. No change to text at this time.
P 72	Uncertainty in Predicted Breach Parameters and Hydrographs		It is useful to recognize that "uncertainty" in regression equations is associated with "unexplained variance" and that physical arguments/engineering justifications can be made as to where in the range of "uncertainty" a particular dam would be expected to fit given its physical characteristics that are not specifically included in the "explained variance" represented by the mathematical form of the regression equation. Therefore it may not be appropriate to perform sensitivity analyses over the entire range of uncertainty on predicted breach parameters (or predicted peak breach flow rates).	Don't understand the comment. Please elaborate. No change to text at this time.
Sec. 7.2.3 / pp. 73-74	Staff Position bullet, last sentence: "Justification for the chosen mode and input parameter should be justified, including documentation of uncertainty and sensitivity studies."	Typographical/editing error, "Justification… should be justified…"	Suggest change to: "Justification for the chosen mode and input parameter should be provided, including documentation of uncertainty and sensitivity studies."	Typo fixed. Changed to "Justification for the selected model and input parameters should be provided, including documentation of uncertainty and sensitivity studies."
Sec. 9.1.6 / p. 78	General comment about calibration data sets.	Any available calibration data sets are likely to be for much smaller flood events than those considered in this flood hazard reevaluation, and therefore may have limited applicability.	Suggest adding discussion about the applicability of available calibration data sets to the large flood events considered in this flood hazard reevaluation.	True statement. Use large storms of record to calibrate (when available). Clarification added with two staff positions.

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Sec 9.2 / p. 79	Staff Position, 1st bullet: "For inundation mapping of the NPP site, two-dimensional models should be used."	A 2-D analysis may theoretically be more accurate on the local scale but the variations seen would be minor and would be washed out in the big picture by the conservative decisions made upstream and downstream. A 2-D analysis may benefit the accuracy of a small project or a varied landscape, but in the case of a riverside plant on flat ground, the benefits disappear.	Suggest removing the requirement for a 2-D analysis with appropriate justification.	OK with this. Added following text to first staff position: However, use of one-dimensional models may be appropriate in some cases. Therefore use of one-dimensional models will be accepted on a case-by-case basis, with appropriate justification.

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

NRC Interim Staff Guidance on Estimating Flooding Hazards Due to Dam Failure

JLD-ISG-2013-01

Public Meeting

May 2, 2013

Presentation Outline

- Accessing and Commenting on ISG *
- Schedule
- Purpose of Dam Failure ISG
- Sources of Guidance
- Content of ISG

*ISG= Interim Staff Guidance

Accessing and Commenting

- Please refer to Docket ID NRC–2013–0073 when contacting the NRC
- JLD-ISG-2013-01 published in Federal Register
  - Federal Register / Vol. 78, No. 80 / Thursday, April 25, 2013 / Notices (pp 24439-24441)
  - Comment period closes on May 28th 2013
- Federal Rulemaking Web site:
  - *http://www.regulations.gov*
  - *Search* for Docket ID NRC–2013–0073.
- NRC's Agency-wide Documents Access and Management System (ADAMS):
  - *http://www.nrc.gov/readingrm/adams.html.*
  - ADAMS Accession No. ML13057A863
- NRC's Public Document Reading Room
  - Room O1–F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

ISG Schedule

- 4/25/13 – Draft Issued for Public Comment
    - ISG noticed in the Federal Register for comment
- 5/2/13 – NRC Public Meeting on Draft ISG
- 5/28/13 – Close of Public Comment Period
- 6/7/13 – Issue Final ISG

Purpose of Dam Failure ISG

- Per NRC regulations, nuclear power plant licensees must determine the effects of potential flooding at their site from all credible potential mechanisms, including potential dam failures

- Consideration of potential upstream dam failure(s) is necessary to understand the total nuclear risk and to appropriately establish the nuclear power plant's licensing basis

- This ISG supplements existing NRC guidance and standard review plans

- This ISG provide guidance on approaches and methods acceptable to the NRC staff for reevaluating flooding hazards due to dam failure for the purpose of responding to enclosure 2 of the March 12, 2012, Request for Information (ADAMS Accession No. ML12053A340).

Sources Used

- Based mainly on guidance and technical references developed by federal agencies
  - FEMA
    - Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failure
    - Selecting and Accommodating Inflow Design Floods for Dams
    - Earthquake Analysis and Design of Dams

Sources Used (Cont.)

- USACE
  - Safety of Dams – Policy and Procedures
  - Engineering Design – Design and Construction of Levees
  - Engineering Design – Retaining and Flood Walls
- USBR
  - Dam Safety Risk Analysis Best Practices Training Manual
- Others
  - State of Colorado Dam Breach Analysis Guidelines
  - NEI Draft White Paper

Dam Failure ISG Content

1. Introduction
2. Background
3. Simplified Modeling Approaches
4. Hydrologic Failure
5. Seismic Dam Failure
6. Sunny-Day Failure
7. Operational Failures and Controlled Releases
8. Dam Breach Modeling
9. Levee Breach
10. Flood Wave Routing

1. Introduction

- 1.1 Purpose
- 1.2 Scope
- 1.3 Framework for Dam Failure Flood Hazard Estimation
- 1.3.1 Screening
- 1.3.2 Detailed Analysis
- 1.4 Failure Probability
- 1.4.1 Historical Dam and Levee Failure Rates
- 1.4.2 NRC Approach to Man-made Hazards
- 1.5 Interfacing with Owners and Regulators of Dams and Levees
- 1.5.1 Dam Safety Governance
- 1.5.2 Dam Safety Guidance
- 1.5.3 Obtaining Information on Dams and Levees
- 1.6 Organization of guidance

1.2 Scope

- The March 2012 Information Request specified three Tiers for submittal of re-evaluated flooding hazards.
- Plants in Tier 1 should have already submitted their flood re-analysis by March 11, 2013 (unless an extension has been granted), which predates issuance of this ISG.
  - Therefore, this ISG is not strictly applicable to Tier 1 sites with completed flood re-evaluations, and their dam failure flood hazard evaluations will be reviewed using present-day guidance, as described in the Request for Information.
- This ISG is applicable to Tier 2 and Tier 3 sites, as well as most Tier 1 sites that have been granted an extension.
- Instances where Tier 1 sites have been granted a very short extension (e.g. a few weeks), will considered on a case-by-case basis.

1.3 Framework for Dam Failure Flood Hazard Estimation

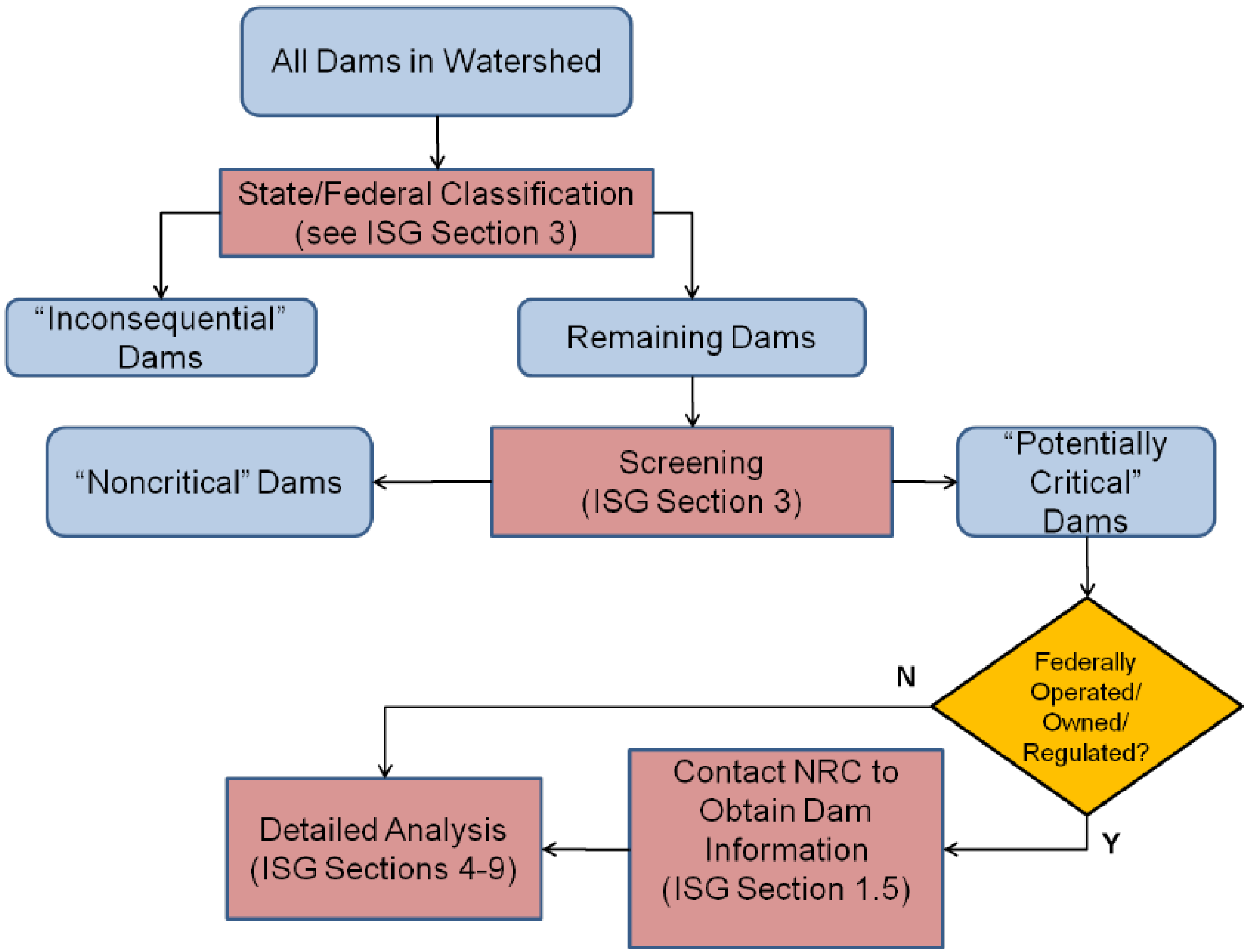

Figure 1. Levels of Analysis

1.3 Framework for Dam Failure Flood Hazard Estimation (Cont.)

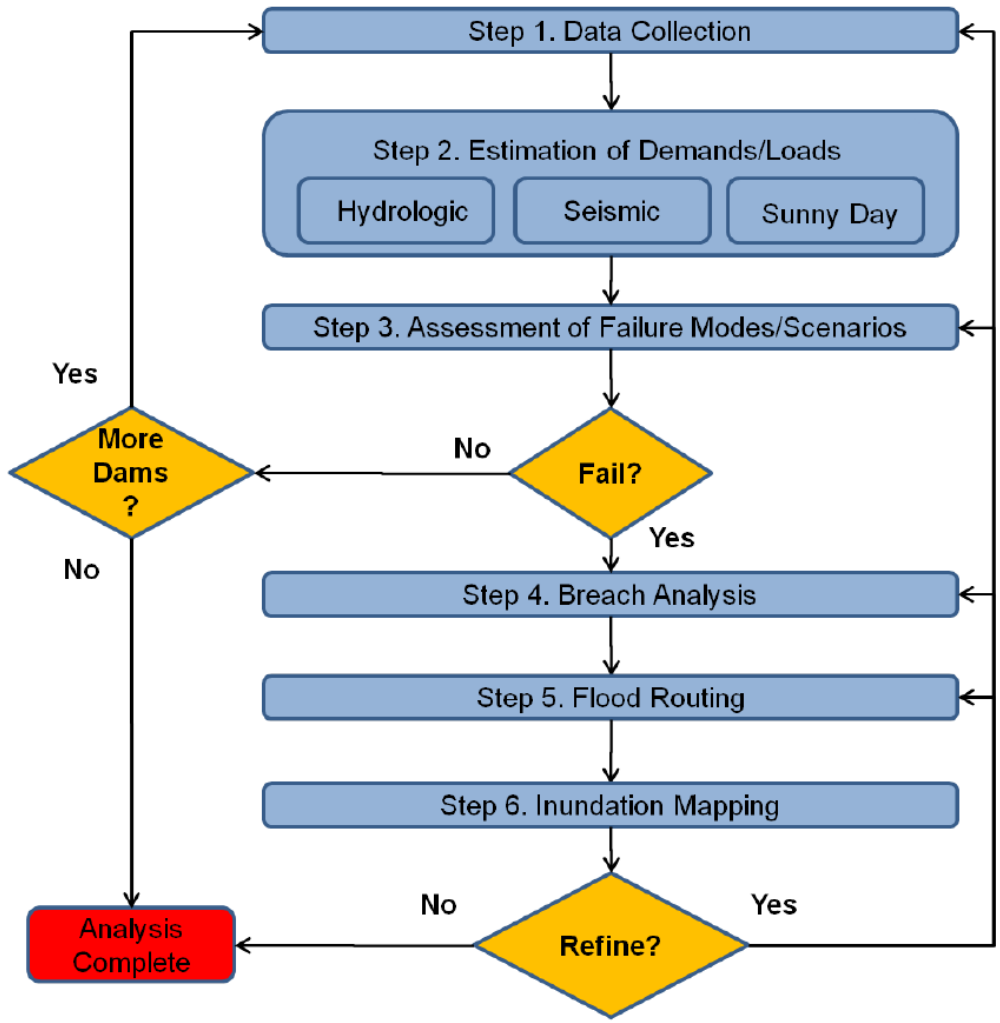

Figure 2. Overview of Detailed Dam Failure Flood Hazard Analysis

1.4 Failure Probability

- 1.4.1 Historical Dam and Levee Failure Rates
  - Expressed in terms of dam years, numerous studies of dam failures in the U.S. and worldwide have indicated an average failure rate on the order of 10^{-4} per dam year
  - Historical rates for dam failure provide useful information about generic failure probabilities. However, each dam and its environment are unique and failure probability estimates, if used, should be developed based upon site and dam specific data and information

1.4.2 NRC Approach to Man-made Hazards

- In general, both the probability of the hazard and the capacity/fragility of the dam would factor into the failure like hood determination. However, to the extent that the dam capacity or fragility is not known, more weight must be placed on the hazard probability.
- Therefore, the hazard probability target for judging the likelihood of a particular failure mode/scenario (either from a single hazard or appropriate combination) is $1x10^{-6}$ annual exceed probability with justification (i.e., dam failure may be excluded from further consideration if it can be shown by a dam specific engineering assessment that the probability of failure is 1x10-6 per year or less using current best practices).
- As of this writing, the methods discussed in the USBR Dam Safety Risk Analysis Best Practices Training Manual (USBR, 2011) are considered by the staff to represent current best practice. Therefore, the staff expects these risk results to be based on a thorough engineering analysis similar in scope and rigor to the comprehensive facility review process described in USBR (2011).

1.4.2 NRC Approach to Man-made Hazards (Cont.)

- When considering hydrologic failure due to large floods, extreme caution should be exercised with regard to attempts to estimate the probability of deterministic estimates such as the probable maximum precipitation (PMP) or probable maximum flood (PMF). Methods that involve extreme extrapolation of distributions such as log- Pearson and others based on limited data will be viewed with great skepticism.
- When considering seismic dam failure and probabilistic seismic hazard assessment (PSHA), it is important to note that the hazard of interest to the NPP is a catastrophic failure resulting in uncontrolled release of the reservoir, not lower levels of damage that may degrade the services that the dam provides. It is also recognized that the seismic design of dams typically includes significant margins and factors of safety. In order to account for this level of margin before failure, it acceptable to use the 1×10^{-4} annual frequency ground motions, at spectral frequencies important to the dam, for seismic evaluation of dams, instead of 1×10^{-6}, as discussed above. However, appropriate engineering justification must be provided to show that the dam has sufficient seismic margin. Otherwise the 1×10^{-6} ground motions should be used.

1.5.3 Obtaining Information on Dams and Levees

- In the case of dams and levees owned or operated by U.S. federal agencies, the federal agency responsible (owner/operator) for the dam should be involved in any discussions, including possibly reviewing any analysis performed.
- Evaluation of dams is complex, requiring extensive expertise and site specific knowledge. It is critical for the owner/operator of the dam to assist NRC or its licensees when modifying the assumptions or methods used to developi the inundation maps for a specific area. If a federally owned dam is identified as critical to the flooding reanalysis, the licensee should contact NRC promptly.
- NRC will act as the interface between these agencies and licensees.
- Memoranda of Agreement or other mechanisms are being developed to facilitate sharing of data (including necessary safeguards to protect sensitive information) between NRC and the appropriate federal agencies.
- It is important to note that in many cases federal agencies that own or operate dams have conducted detailed failure analysis. To the extent these analyses are applicable, they should be used in the Recommendation 2.1 flooding reanalysis.

1.5.3 Obtaining Information on Dams and Levees (Cont.)

- In some cases, the dam or levee will be owned or operated by a private entity, but regulated by a federal agency. In this case, NRC will interface with the federal regulatory agency to obtain available information. Interactions between the licensee and the owner should be coordinated with NRC and the federal regulator.
- In most cases dams and levees will be owned and operated by private entities and regulated by a state agency. In this case, the licensee should interact directly with the owner and regulator. The licensee should notify NRC if they encounter difficulties in obtaining information. On a case-by-case basis, NRC may be able to provide some assistance in interfacing with state agencies.

2. Background

- 2.1 Classification of Dams and Levees
- 2.1.1 Concrete Dams
- 2.1.2 Embankment Dams
- 2.1.3 Levees
- 2.2 Classification of Dam Failures
- 2.2.1 Influence of Dam Type on Failure Modes
- 2.2.1.1 Concrete Dams
- 2.2.1.2 Embankment Dams
- 2.2.2 Failure of Spillways, Gates, Outlet Works, Appurtenances
- 2.2.3 Operational Failures and Controlled Releases
- 2.3 Multiple Dam Failures

3. Simplified Modeling Approaches

- 3.1 Criteria for “Inconsequential” Dams
- 3.2 Simplified Modeling Approaches
- 3.2.1 Representing Clusters of Dams

3.1 Criteria for "Inconsequential" Dams

- Dams identified by the USACE as meeting the requirements described in Appendix H (Dams Exempt from Portfolio Management Process) of ER 1110-2-1156, "Safety of Dams – Policy and Procedures", (USACE, 2011c) may be removed from consideration for site impacts.
- Dams identified by other federal or state agencies as having minimal or no adverse failure consequences beyond the owner's property may be removed from consideration.
- Dams owned by licensees may not be removed.
- Other inconsequential dams may be removed with appropriate justification (e.g. can be easily shown to have minimal or no adverse downstream failure consequences).

3.2 Simplified Modeling Approaches (Cont.)

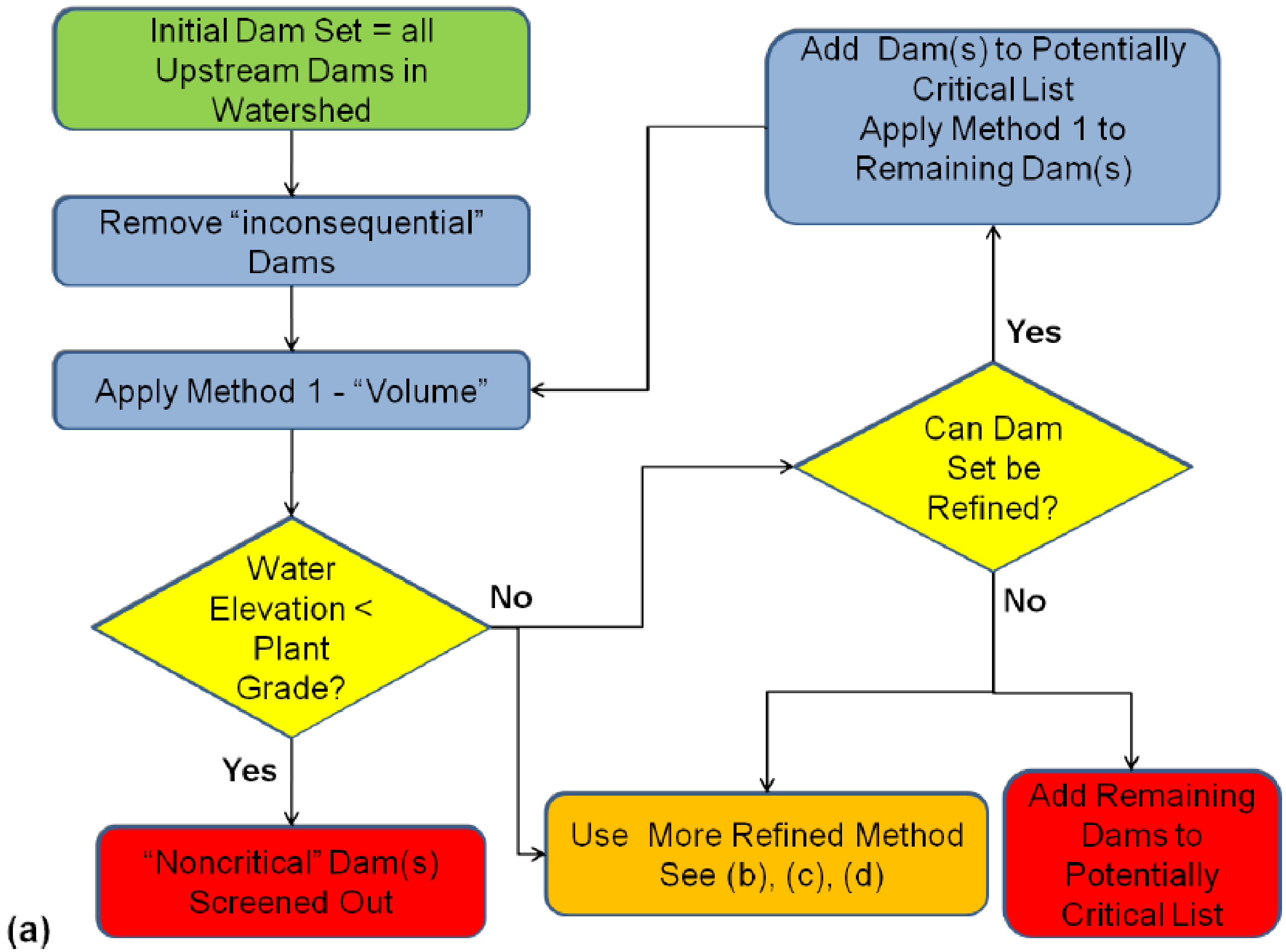

Figure 10. Screening Method Flowchart (a) – Method 1 (Volume)

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3.2 Simplified Modeling Approaches (Cont.)

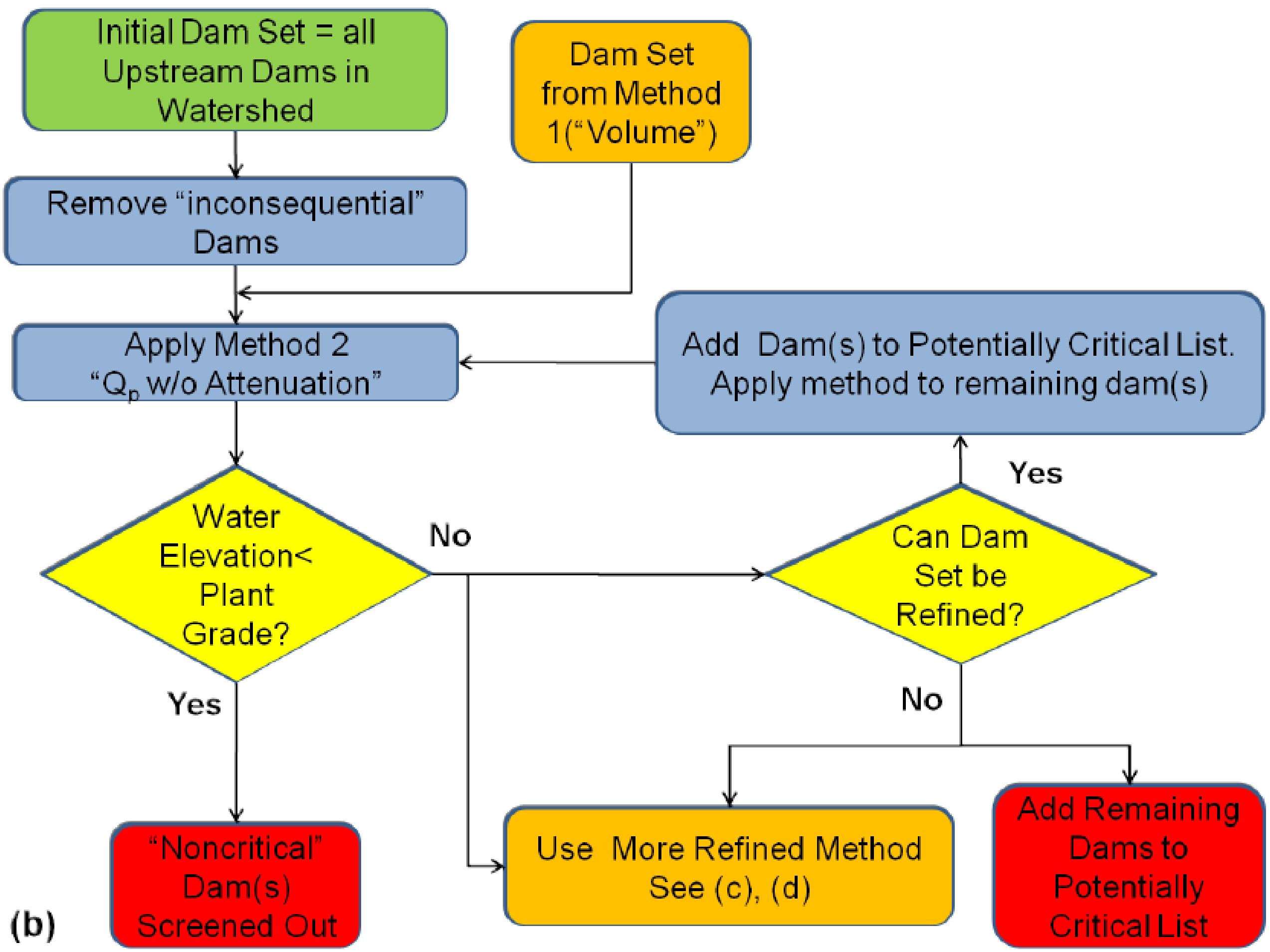

Figure 11. Screening Method Flowchart (b) – Method 2 (Peak Flow without Attenuation)

3.2 Simplified Modeling Approaches (Cont.)

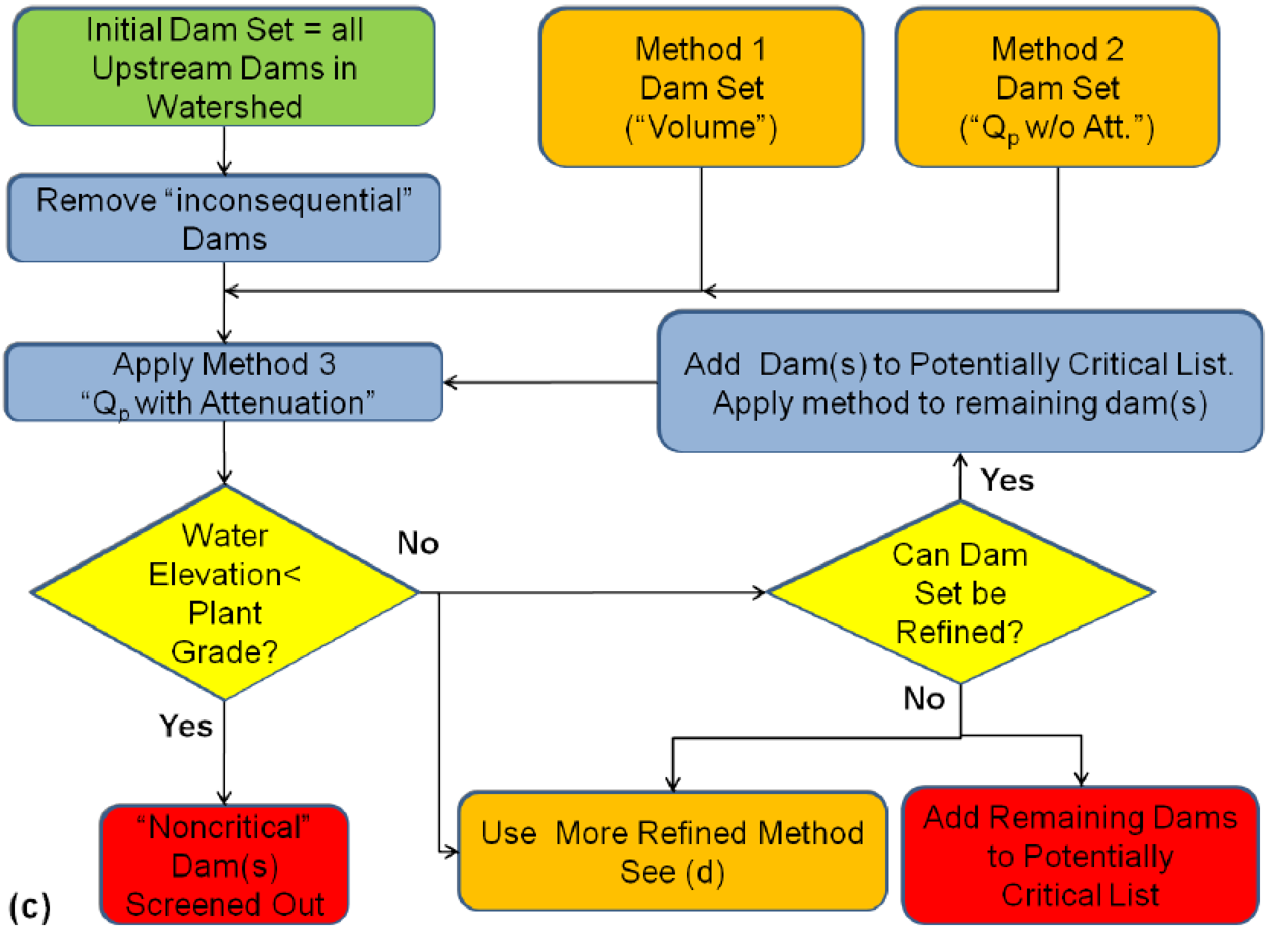

Figure 12. Screening Method Flowchart (c) – Method 3 (Peak Flow with Attenuation)

3.2 Simplified Modeling Approaches (Cont.)

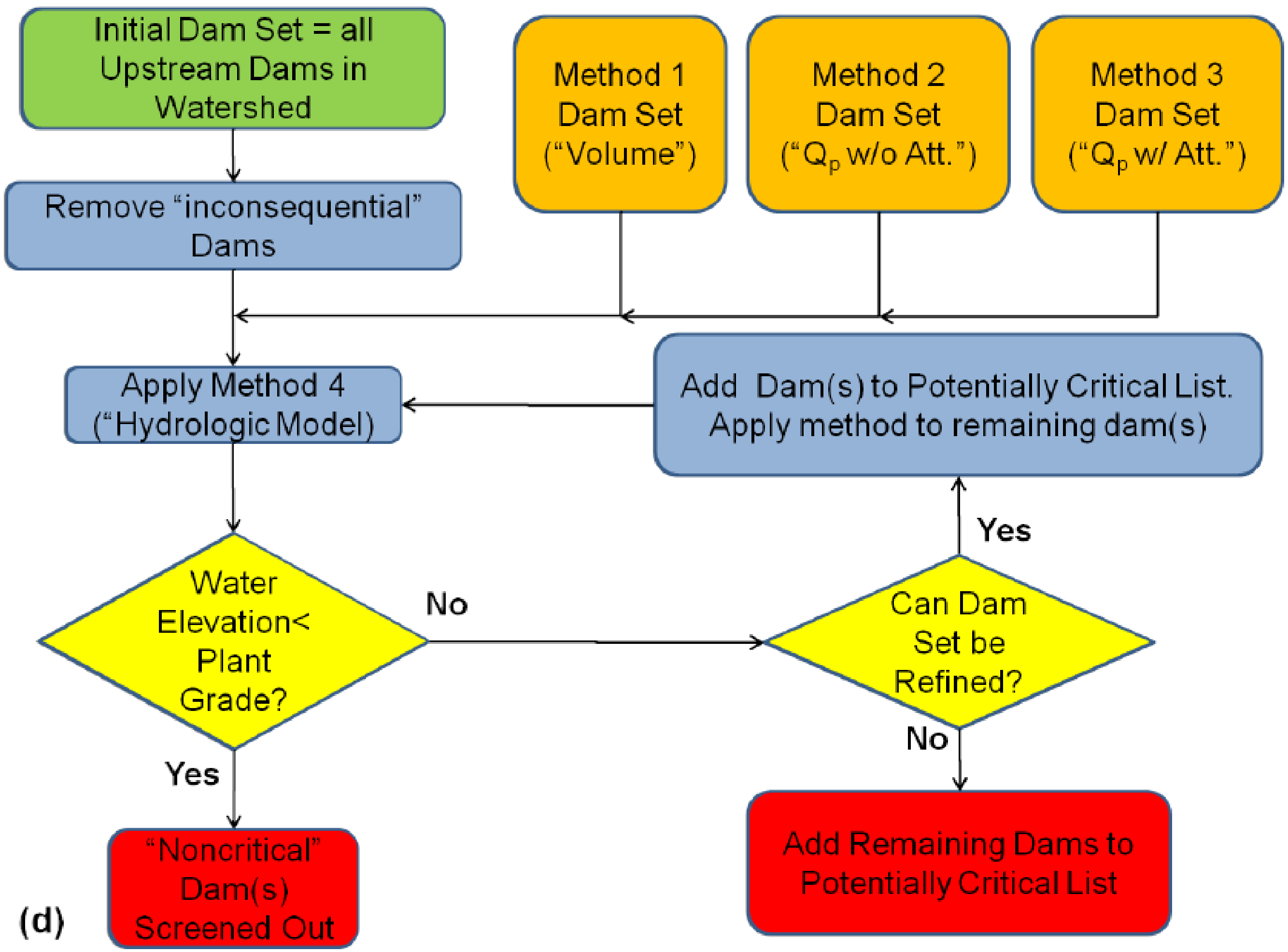

Figure 13. Screening Method Flowchart (d) – Method 4 (Hydrologic Method)

3.2.1 Simplified Modeling Approaches (Cont.)

Dam	Location of hypothetical dam	Comment
Dams 1, 2 and 3	DS of 1, 2 and 3	Illustrated in Figure 14
Dams 1 and 2	At or DS of 2	Dam 2 is closer to site
Dams 1 and 3	At or DS of 3	Dam 3 is closer to site.
Dams 2 and 3	At or DS of 2	Dam 2 is closer to site.

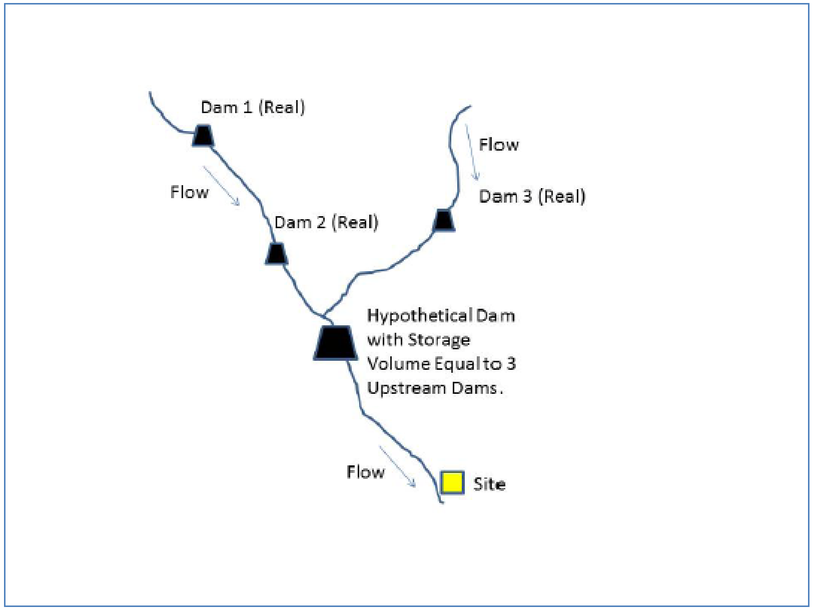

Figure 14. Hypothetical Dam Representing Storage Upstream

4. Hydrologic Dam Failure

- 4.1 Hydrologic Failure by Structure Type
- 4.1.1 Concrete Dams
- 4.1.2 Embankment Dams
- 4.1.3 Spillways, Gates, Outlet Works and Other Appurtenances
- 4.1.4 Levees
- 4.2 Analysis of Hydrologic Failure Modes
- 4.2.1 Internal Pressure
- 4.2.2 Overtopping
- 4.2.2.1 Reservoir Capacity
- 4.2.2.2 Starting Reservoir Elevation
- 4.2.2.3 Reservoir Surcharge Capacity
- 4.2.2.4 Spillway Discharge Capacity
- 4.2.2.5 Wave Action
- 4.2.3 Structural Overstressing of Dam Components
- 4.2.4 Surface Erosion from High Velocity and Wave Action
- 4.2.5 Failure of Spillways
- 4.2.6 Failure of Gates
- 4.2.7 Debris
- 4.2.7.1 Mud/Debris Flows
- 4.2.7.2 Waterborne Debris
- 4.2.8 Multiple Dam Failure due to Single Storm Scenario
- 4.2.9 Levee Failures

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4.1.1 Concrete Dams

- Concrete dams should be evaluated for potential hydrologic failure modes including, but not limited to:
  - overtopping of the main dam, overtopping erosion of a dam abutment or foundation
  - erosion of an unlined tunnel or spillway chute
  - erosion of a channel downstream from a stilling basin due to flow in excess of capacity
  - erosion of the spillway foundation where floor slabs have been damaged or lost
  - overstressing of the dam, foundation, or abutments
  - cavitation damage to spillway and outlet flow surfaces

4.1.2 Embankment Dams

- Embankment dams should be analyzed for conditions leading to and the effects of:
  - Overtopping
  - Increases in internal seepage pressures

- Analysis of hydrologic failure modes should consider the potential for loss or degraded function of spillways, gates, outlet works and other appurtenances. If failure is not assumed, provide an engineering justification.

4.1.3 Spillways, Gates, Outlet Works and Other Appurtenances

- Analysis of hydrologic failure modes should consider the potential for loss or degraded function of spillways, gates, outlet works and other appurtenances.
- If failure is not assumed, provide an engineering justification.

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4.1.4 Levees

- In general, earthen embankment levees should be assumed to fail when overtopped.
- The case for nonfailure must be developed using detailed engineering analysis supported by site-specific information, including material properties of the embankment and foundation soils, material properties of embankment protection (if any), levee condition, etc.
- Other forms of levees (e.g., pile walls, concrete flood walls) should be evaluated for potential failures applicable to the particular type of levee.

4.1.4 Levees(Cont.)

- Levees are generally not designed to withstand high water levels for long periods.
  - No generally accepted method for predicting how long a levee will continue to function under high loading conditions.
  - Historical information is the best available basis for predicting levee performance. The historical information should be from levees that have similar design and construction characteristics as the levee being analyzed.
- The potential for loss or degraded function of levee control works should be considered.
- Because levees are typically designed to function as a system, the potential for failure of an individual segment should be evaluated for its impact on the functioning of the levee system as whole.
- Levees should not be assumed to fail in a beneficial manner without appropriate justification.

4.2.1 Internal Pressure

- Dams should be evaluated for potential failures due to internal pressures from a hydrologic inflow event (flood).
- Potential failure modes that should be evaluated include deterioration or plugging of drains and internal erosion mechanisms.
  - Evaluation should generally include reviewing the dam design to assure that appropriate filters, drains, and monitoring points are included.
  - Monitoring records of piezometers, observation wells or other observation methods can be used to show absence of unremediated deficiencies.

4.2.2 Overtopping

- Dams unable to pass their individual PMF should be considered for failure.
- Embankment dams should generally be assumed to fail when overtopped. If failure is not assumed when a dam is overtopped, justification should include detailed engineering analysis supported by site-specific information, including material properties of the embankment and foundation soils, material properties of embankment protection (if any), dam condition, etc.
- Concrete dams are not assumed to fail due to minor overtopping, but must be evaluated for failure due to loss of foundation or abutment support. Impact of the flood flows on structures such as tunnels, spillways, chutes and stilling basins should be examined.
- The potential for overtopping due to nonfunctioning gates, outlets and other appurtenances should be evaluated to determine the appropriate failure assumptions with appropriate engineering justification.

4.2.2 Overtopping(Cont.)

- **4.2.2.2 Starting Reservoir Elevation**
  - The default starting water surface elevation used in flood routings for evaluation of overtopping is the maximum normal pool elevation. Other starting water surface elevations may be used, with appropriate justification. Justification may include the operating rules and history of the reservoir. For example, if the flood being considered is associated with a distinct season and the operation of the dam has seasonal variations that are codified and have historically been followed, then it may be reasonable to select a starting reservoir elevation consistent with the operating rules and history. But consideration should be given to possible instances where the operating history and/or rules have been influenced by anomalous conditions such as drought
- **4.2.2.3 Reservoir Surcharge Capacity**
  - Reservoir surcharge capacity can be credited in flood routings for evaluation of overtopping, with appropriate justification and documentation.

4.2.2 Overtopping(Cont.)

- **4.2.2.4 Spillway Discharge Capacity**
  – Release capacity through appurtenances other than the spillway (e.g., outlets, turbines) may be credited as part of the total available release capacity, with appropriate engineering justification that these appurtenances will be available and remain operational during a flood event. Access to the site during a flood event should be considered.
  – The generators and transmission facilities to support the credited turbine(s) must be shown to be operational under concurrent flood and expected prevailing weather conditions if the turbines are credited as part of the total available release capacity. However, at least one turbine should always be assumed to be down (e.g. for maintenance or other reasons) in performing flood routings.
  – The potential for flood-borne debris to reduce spillway capacity should be considered. Use historical information to assess debris production in the watershed. Describe structures, equipment and procedures used to prevent spillway blockage by waterborne debris.
- **4.2.2.5 Wave Action**
  – Overtopping due to wave action should be evaluated, in addition to stillwater levels. Coincident wind waves should be estimated at the dam site based on the longest fetch length and a sustained 2-year wind and added to the stillwater elevation.

4.2.3 Structural Overstressing of Dam Components

- Static stability of the dam and key appurtenances under hydrologic loads associated with the dam's PMF should be demonstrated using current methods and standards.
- If the dam cannot withstand the applied loads, the dam should be assumed to fail.
- If the appurtenance cannot withstand the load, assume failure of the appurtenance and estimate impact of its failure on stability of the dam.
  – If the dam stability is not impacted, one still must consider the downstream impact of uncontrolled release (if any) associated with appurtenance failure.

4.2.4 Surface Erosion from High Velocity and Wave Action

- Surface erosion of earthen embankments, spillways, channels, etc. due to wave action, high velocity flows, and ice effects should be considered.

4.2.5 Failure of Spillways

- Dams should be evaluated for potential failure due to spillway failure.
- Concrete spillways should be evaluated for relevant failure modes including stagnation pressure failures, cavitation, concrete deterioration (e.g., delamination, alkali-silica reaction, freeze-thaw damage and sulfate attack) and other relevant modes.
- Other (non-concrete) spillways should be evaluated for potential failures including failure of the grass or vegetation cover in the spillway; concentrated erosion that initiates a headcut; deepening and upstream advance of the headcut; and other relevant modes.

4.2.6 Failure of Gates

- The evaluation should consider the potential for gate failure under flooding conditions to lead to an uncontrolled release of the reservoir.
- With regard to fuse plugs, one should consider uncertainty about the exact depth and duration of overtopping needed to initiate breach and the uncertainty about the exact rate of breach development. (note typo in draft ISG)

4.2.7 Debris

- **4.2.7.2 Waterborne Debris (equation mangled in PDF)**

$$F_i = wV/g\Delta t$$

where F_i is the impact force, w is the weight of the object, V is the flood velocity, g is the acceleration of gravity, and Δt is the duration of the impact. The object is assumed to be at or near the water surface level when it strikes the building. Therefore, the object is assumed to strike the building at the stillwater level.

  - The potential for a basin to generate mud/debris flows should be considered.
  - Loads due to waterborne debris carried by flood waters should be considered with regard to impacts on the dam (i.e., gates and associated mechanical equipment, appurtenances, parapets, etc.).
  - In the case of dam break flood waves, debris impacts to SSCs important to safety should be considered.
  - In general, methods outlines in the FEMA Coastal Construction Manual and average size/weight for objects specified in ASCE Standards are acceptable.
  - Licenses should consider regional and/or local conditions before the final debris weight is selected. On navigable waterways, for example, the potential for impact from water craft and barges should be considered in addition to trees, logs and common man-made objects.

4.2.8 Multiple Dam Failure due to Single Storm Scenario

- Potentially critical dams should be evaluated for potential of hydrologic dam failures to lead to cascading failures of downstream dams and simultaneous dam failures causing flood conditions at the site. Operational rules may be considered but the starting water surface elevation must be as specified in Section 4.2.2.1.
- Flood waves from multiple dam failures should be assumed to reach the NPP site simultaneously unless appropriate justification for differing flood arrival times is provided.
- Two cases of multiple dam failure should be considered: (1) failure of individual dams on separate tributaries upstream from the site and (2) cascading or domino-like failures of dams upstream from the site.

4.2.8 Multiple Dam Failure due to Single Storm Scenario (Cont.)

- Failure of individual dams on separate tributaries upstream from the site
  - One or more dams may be located upstream from the site but on different tributaries so the flood generated from the failure of an individual dam would not flow into the reservoir impounded by another dam. These individual dam failures should be analyzed together because of the potential for a severe storm to cause large floods on multiple tributaries.

4.2.8 Multiple Dam Failure due to Single Storm Scenario (Cont.)

- Cascading or domino-like failures of dams upstream from the site
  - Failure of an upstream dam may generate a flood that would become an inflow into the reservoir impounded by a downstream dam and may cause failure by overtopping of the downstream dam. If several such dams exist in a river basin, each sequence of dams within the river basin could fail in a cascade.
  - Each cascading failure sequences should be investigated to determine one or more sequences of dam failures that may generate the most severe flood at the site.
  - Simplified estimates of the total volume of storage in each of the potential cascades should provide a good indication of the most severe combination.
  - In multiple cascades that cannot be separated by simple hydrologic reasoning, all of the candidate cascades that are comparable in terms of their potential to generate the most severe flood at the site should be simulated using the methods described in Section 10
  - The most severe flood at the site resulting from these cascades should be considered in determining the design-basis flood.

4.2.8 Multiple Dam Failure due to Single Storm Scenario (Cont.)

- Scenarios
  - Depending on the storage capacities of the reservoirs impounded by dams in a given cascading scenario, it may be reasoned that the scenario that would release the largest volume of stored water may likely lead to the most severe flooding scenario.
  - Distance a flood has to travel to reach a plant site also may affect the severity of the flood at the site.
  - If a definite conclusion cannot be reached, all possible cascading scenarios should be simulated to determine the most severe scenario.

4.2.9 Levee Failures

- If the performance of levees is potentially important to estimation of inundation at the NPP site, failures should be treated in a conservative manner, but realistic manner.
- If credit is taken for a specific levee behavior (either failure or nonfailure), engineering justification should be provided.
- Assumptions regarding conveyance and off-stream storage should be supported with engineering justifications.

5. Seismic Dam Failure

- 5.1 Overview
- 5.2 Seismic Failure by Structure Type
- 5.2.1 Concrete Dams
- 5.2.2 Embankment Dams
- 5.2.3 Spillways, Gates, Outlet Works and Other Appurtenances
- 5.2.4 Levees
- 5.3 Analysis of Seismic Hazards Using Readily Available Tools and Information
- 5.3.1 Ground Shaking
- 5.3.2 Fault Displacement
- 5.3.3 Liquefaction
- 5.4 Assessment of Seismic Performance of Dams Using Existing Studies
- 5.4.1 Ground Shaking
- 5.4.2 Fault Displacement
- 5.4.3 Liquefaction
- 5.5 Multiple Dam Failure Due to a Single Seismic Event
- 5.6 Modeling Consequences of Seismic Dam Failure
- 5.7 Detailed Site Specific Seismic Hazard Analysis
- 5.8 Detailed Analysis of Seismic Capacity of the Dam

5.1 Overview

- PSHA is considered to be the state of practice for evaluating seismic hazards for dam failure

5.1 Overview (Cont.)

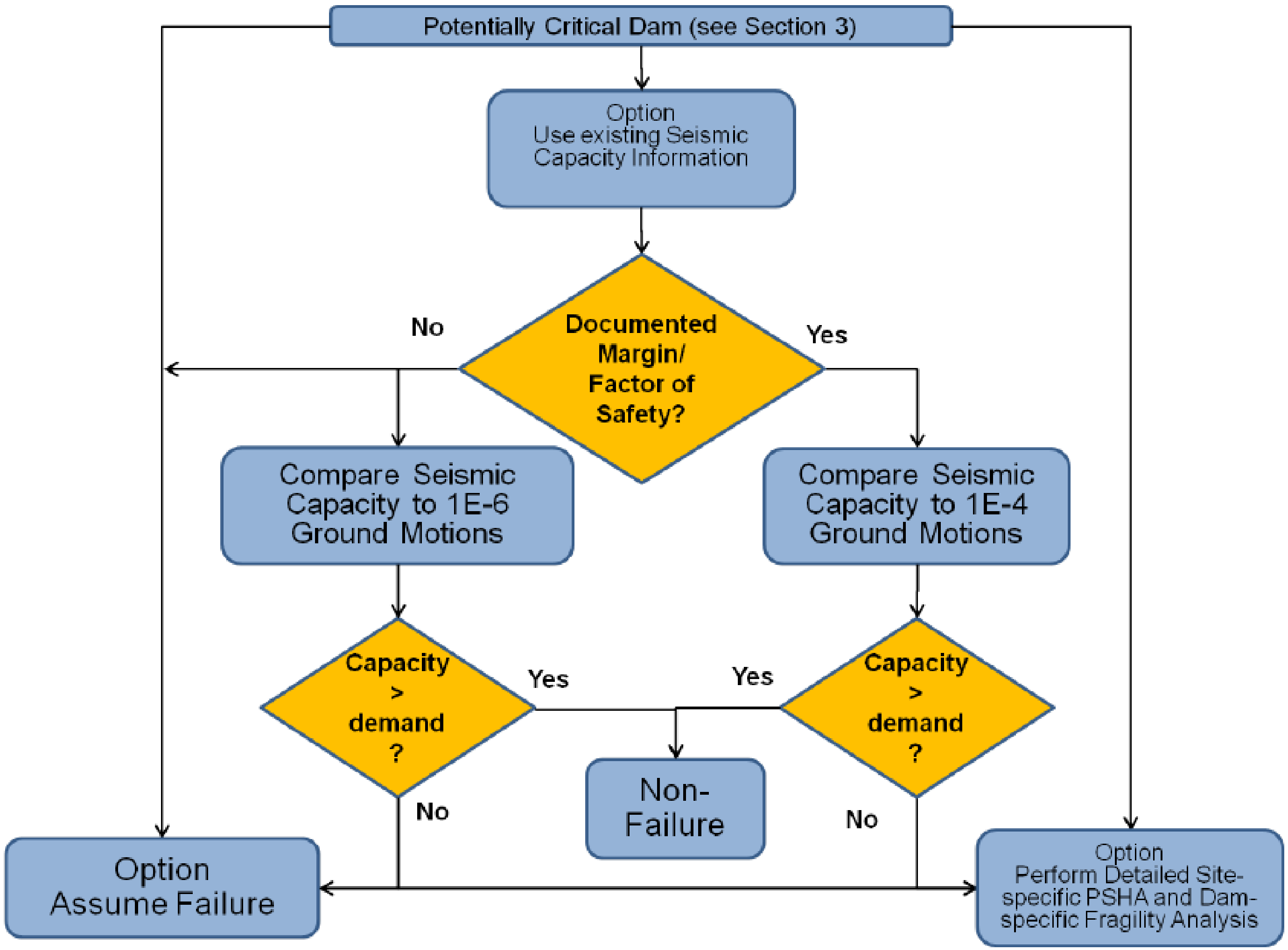

Figure 15. Seismic Dam Failure Analysis Options

5.2 Seismic Failure by Structure Type

- Concrete Dams
  - Seismic analysis of concrete dams should include assessment of ground shaking, surface displacement, and forces due to water in the reservoir.
  - Both structural and foundation failure modes should be considered.
  - Foundation liquefaction/deformation potential should be considered.
  - Structural failure modes considered should take into account the unique concerns for the type of dam in question.
- Embankment Dams
  - Seismic analysis of embankment dams should include assessment of ground shaking and surface displacement.
  - Both structural and foundation failure modes should be considered.
  - Deformation and liquefaction potential of both the dam and the foundation should be considered.

5.2 Seismic Failure by Structure Type (Cont.)

- **Spillways, Gates, Outlet Works and Other Appurtenances**
  - Seismic evaluation of dams should include consideration of whether a seismic event could lead to dam failure and subsequent uncontrolled release of the reservoir due to loss or degraded function of spillways, gates, outlet works and other appurtenances.
- **Levees**
  - Survival of a loaded levee during an earthquake event should be justified through appropriate engineering analysis.
  - Levees should not be assumed to fail in a beneficial manner, without appropriate engineering justification.

5. Seismic Dam Failure (Cont.)

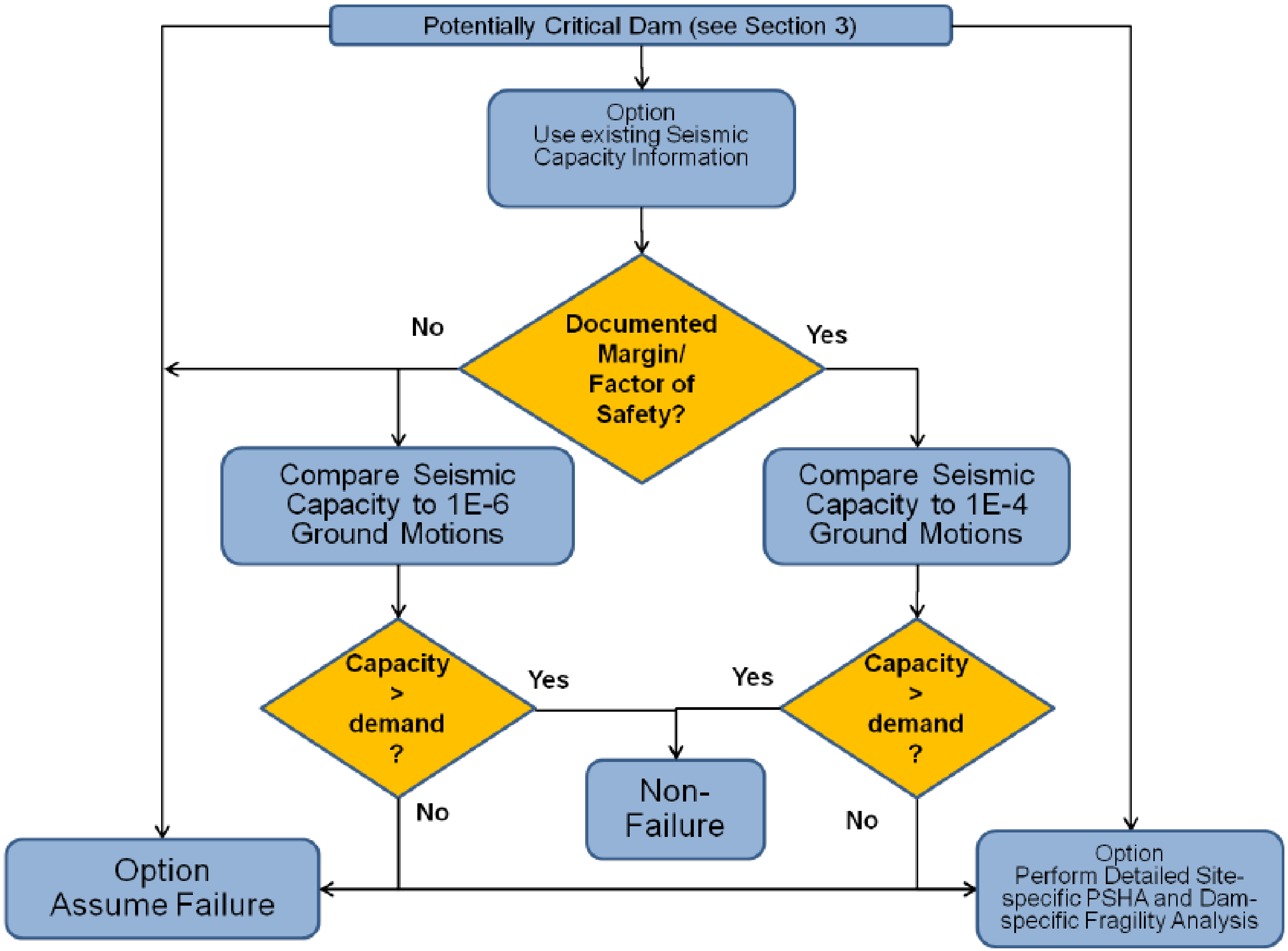

Figure 15. Seismic Dam Failure Analysis Options

5.3 Seismic Hazard Analysis Using Readily Available Tools and Information

- **5.3.1 Ground Shaking**
  - – The seismic hazard at the dam site should be characterized using probabilistic seismic hazard assessment (PSHA) for the spectral frequencies of interest to the dam:
    - The data and software tools available from USGS, which were used to develop the most recent version of the National Seismic Hazard Maps (this is the 2008 version as of the publishing of this guidance) are suitable for developing bedrock hazard curves and uniform hazard spectra at 1×10^{-6} annual frequency of exceedance. (USGS, 2008)
    - The site amplification functions developed by the Electric Power Research Institute (EPRI, 1989) should be used to perform a site response analysis as described in NUREG/CR-6728 (USNRC, 2001).
  - – As an alternative to use of the USGS seismic hazard curves, it is acceptable to performance a site-specific PSHA consistent with the methodologies suitable for use in characterizing seismic hazard at U.S. nuclear power plant sites, as described in Regulatory Guide 1.208 (USNRC, 2007).

5.3 Seismic Hazard Analysis Using Readily Available Tools and Information (Cont.)

- **5.3.2 Fault Displacement**
  - Dam sites should be evaluated for the potential for surface fault displacement to cause damage to the dam.
  - The potential for primary and secondary surface faulting should be considered.
  - It is acceptable to utilize existing analyses that demonstrate that a dam is not susceptible to fault displacement.

5.3 Seismic Hazard Analysis Using Readily Available Tools and Information(Cont.)

- **5.3.3 Liquefaction**
  - The dam site should be evaluated for liquefaction potential.
  - Regulatory Guide 1.198 provides guidance on acceptable methods for evaluating the potential for earthquake-induced instability of soils resulting from liquefaction and strength degradation.

5.4 Seismic Performance Analysis Using Existing Studies

- **5.4.1 Ground Shaking**
  - The seismic demands on the structure should be defined using the site-specific hazard spectrum (based on the UHRS and accounting for site amplification) as described in Section 5.4.1. The design spectrum (or spectrum determined by other seismic analyses) is compared against the site-specific hazard spectrum to assess the failure potential of the dam. If the capacity of the structure exceeds the site-specific seismic demands at the spectral frequencies of relevance to the dam, with appropriate margin to account for uncertainties in the analysis, the dam can be assumed not to fail due to seismic ground shaking.
  - In cases where information does not exist to characterize the capacity of the dam by response spectrum or define capacities at the frequencies of relevance to the dam (e.g., in the case when the dam design was based on pseudo-static analysis using a single demand such as peak ground acceleration and the dam has not been reevaluated to define capacity in terms of other intensity measures), the licensee may leverage such analysis with appropriate justification. Examples of appropriate justification include demonstration of the conservatism and applicability of the analysis, in light of the UHS developed in Section 5.4.1 including effects of site amplification of a range of spectral frequencies.
  - Dams that cannot be shown to have sufficient capacity should be assumed to fail and breach parameters computed as described in Section 7 Moreover, dams that are susceptible to seismic failure should be evaluated for the potential for multiple dams to fail during a single seismic event as described in Section 5.5. Alternatively, it is acceptable to perform more detailed assessment of the performance of the dam (i.e., performing new assessments) as described in Section 5.8.

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5.4 Seismic Performance Analysis Using Existing Studies

- **5.4.2 Fault Displacement**
  - Existing studies or data on dam or foundation materials can be used to assess performance of the dam with respect to surface displacement, in light of the seismic hazard defined for the site, with appropriate justification of their applicability and with appropriate conservatism to account for uncertainties.
- **5.4.3 Liquefaction**
  - Existing studies or data on dam or foundation soils can be used to assess performance of the dam with respect to liquefaction or loss of strength, in light of the seismic hazard defined for the site, with appropriate justification of their applicability and with appropriate conservatism to account for uncertainties.

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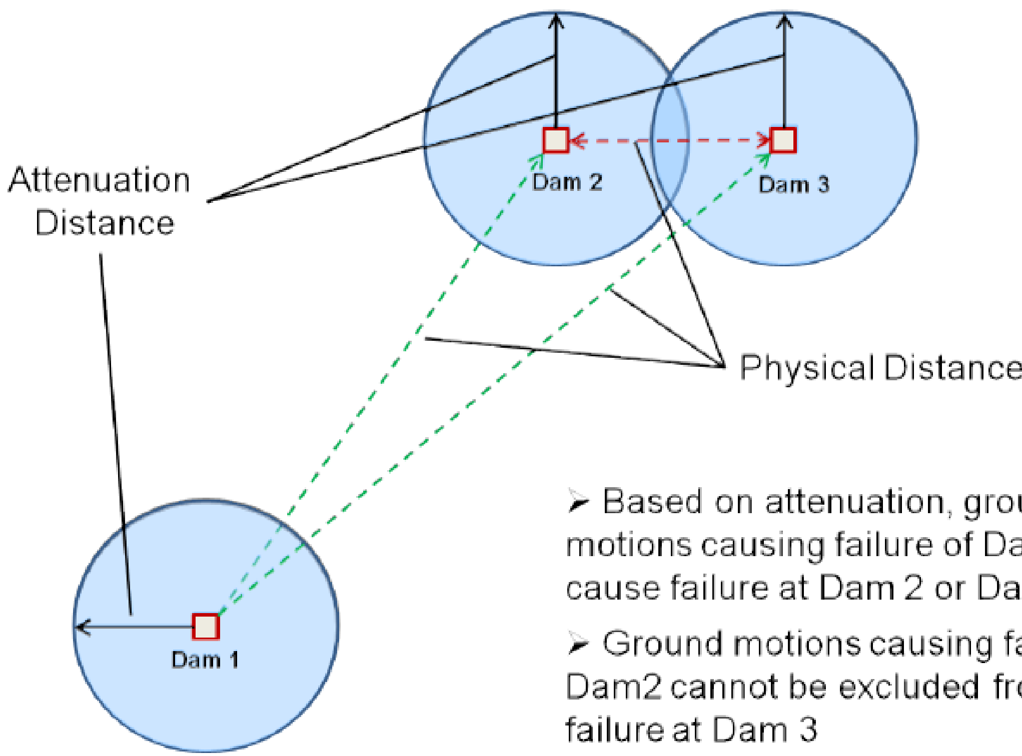
5.5 Multiple Dam Failure Due to a Single Seismic Event

- Set of dams that are vulnerable to failure at or below the ground motion level associated with a 1E-4 annual frequency of exceedance.
- Hierarchical Approach
  - Using knowledge about the attenuation of ground motion with distance relative to the distance between dams
  - Refinement through deaggregation of the seismic hazard

5.5 Multiple Dam Failure Due to a Single Seismic Event (Cont.)



- Based on attenuation, ground motions causing failure of Dam 1 do not cause failure at Dam 2 or Dam 3.
- Ground motions causing failure at Dam2 cannot be excluded from causing failure at Dam 3
- Ground motions causing failure at Dam2 cannot be excluded from causing failure at Dam 3

Figure 16. Using Knowledge about the Attenuation of Ground Motion with Distance

5.5 Multiple Dam Failure Due to a Single Seismic Event (Cont.)

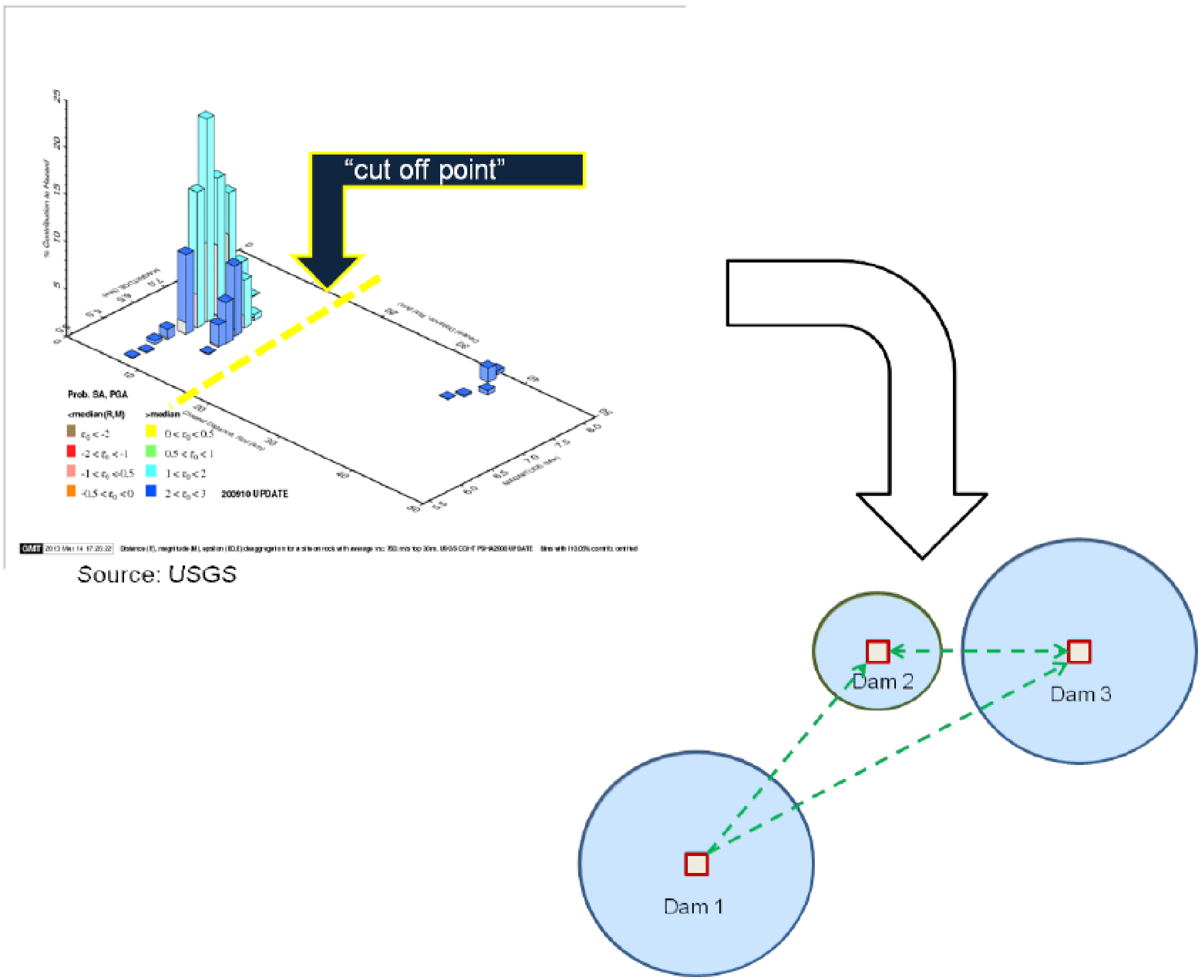


Figure 17. Refinement of Seismic Influence Using Deaggregation

5.6 Modeling Consequences of Seismic Dam Failure

- Dam failure due to an earthquake should be considered for both the maximum normal operating (“full-pool”) and average reservoir levels. Normal, non-flood tailwater conditions should be used.
- Reservoir and downstream tributary inflows should be seasonally consistent with the selected reservoir level.
- Given the hazard frequency target of $1x10^{-6}$ discussed in Section1.4.2, the dam failure flood wave at the site should be combined with flows of a frequency that result in a combined annual probability of $1x10^{-6}$. For example, if the dam fails under a 10^{-4} ground motion, combine the dam break flood wave with a 100-year flood. If the dam fails under a 10^{-3} ground motion, combine the dam break flood wave it with a 1000-year flood.

5.7 Detailed Site Specific Seismic Hazard Analysis

- Because each dam and its immediate environment form a unique system, it is not feasible to provided detailed guidance that will be applicable in all cases. Therefore, detailed, site-specific seismic hazard analyses will be reviewed on a case-by-case basis. The following discussion is meant to provide a general overview of the pieces that would normally be part of a detailed seismic hazard evaluation
- Ground motion prediction equations approved by the NRC for Recommendation 2.1 Seismic are acceptable for use in dam failure analysis for Recommendation 2.1 Flooding.

5.8 Detailed Analysis of Seismic Capacity of the Dam

- **5.8.1 Concrete Dams**
  - Pseudostatic methods are generally discouraged from use in stability analysis of structures.
  - Structures that fail to meet prescribed pseudostatic stability requirements (i.e., sliding safety factors and resultant location) should be subjected to in-depth study using dynamic analyses to assess the performance of the dam and foundation during an earthquake.
  - Detailed evaluation of the seismic performance of a concrete dam should be performed using (as appropriate) linear-elastic response spectrum analysis, linear-elastic time-history analysis, or non-linear time-history methods. Guidance provided on these methods in FEMA Dam Safety Guidelines (FEMA, 2005) should be used to perform the evaluation.
  - A nonlinear analysis should be performed if the response of the dam would be influenced significantly by nonlinearity from material behavior or changes in geometry.
  - Detailed evaluation of the seismic performance of a concrete dam should be performed using (as appropriate) linear-elastic response spectrum analysis, linear-elastic time-history analysis, or non-linear time-history methods. Guidance provided on these methods in FEMA Dam Safety Guidelines (FEMA, 2005) should be used to perform the evaluation.

5.8 Detailed Analysis of Seismic Capacity of the Dam(Cont.)

- **Embankment Dams**
  - Detailed seismic evaluation of embankment dams should include the following (as appropriate): post-earthquake stability analysis, deformation analysis, and assessment of liquefaction potential.
  - If there are no potentially liquefiable materials present, evaluation can usually be done by the Newmark sliding-block approach. In situations where excess pore pressure could develop, more rigorous finite-element or finite-difference analyses should be conducted.
  - Embankment dams should be evaluated to ensure sufficient factors of safety against sliding of critical failure surfaces.
  - Embankment dams should be evaluated to ensure sufficient factors of safety against triggering of liquefaction.

6. Other (Sunny Day) Failures

- 6.1 Overview of Sunny Day Failures by Structure Type
- 6.1.1Concrete Dams
- 6.1.2 Embankment Dams
- 6.2 Analysis of Sunny Day Failures
- 6.2.1 Probability of Sunny Day Failure Modes
- 6.2.2 Breach Analysis Initial Water Surface Elevation

6. Introduction

- Example causes/initiators
  - Deterioration of concrete (e.g., weathering, cracking, chemical growth)
  - Deterioration of embankment protection (e.g., grass cover, riprap, or soil cement)
  - Excessive saturation of downstream face or toe of embankment.
  - Excessive embankment settlement.
  - Cracking of embankment due to uneven settlement.
  - Excessive pore pressure in structure, foundation, or abutment.
  - Excessive loading due to buildup of silt load against dam.
  - Excessive leakage through foundation.
  - Embankment slope failure.
  - Leakage along conduit in embankment.
  - Channels from tree roots or burrowing.
  - Landslide in reservoir.
  - ……….

6. Introduction (Cont.)

- The possibility of sunny day failures should be carefully evaluated to ensure that all plausible mechanisms for flooding from dam breaches and failures at and near a site are considered.
- Dams failed due to hydrologic and seismic events shown to have negligible impacts at the site do not require evaluation for the sunny-day scenario since the sunny-day scenario is bounded by the other two events.
- The level of effort required for evaluating sunny-day failure is typically lower since it only involves identifying the worst-case individual or cascading failure scenario.

6. Introduction (Cont.)

- Base flow conditions for a sunny day failure are typically ignored because of the small discharge and volume compared to that of a dam breach.
- Additional inflow (e.g. from a storm event) is not required when analyzing a sunny day breach.
- A sunny day breach can be used to model piping failures for hydrologic, geologic, structural, seismic, and human-influenced failure modes.

6.1.1 Concrete Dams

- Potential failure initiators common to all types of concrete dams.
  – plugging of drains (leading to increased uplift pressures),
  – gradual creep that reduces the shear strength on potential sliding surfaces, and
  – degradation of the concrete from alkali-aggregate reaction, freeze-thaw, or sulfate attack.
  – Weak lift joints within dams.
- For concrete gravity dams founded on rock, the leading cause of dam failures has been related to sliding on planes of weakness within the foundation, most typically weak clay or shale layers within sedimentary rock formations.
- For concrete gravity dams founded on alluvial soils, the leading cause of failure is piping or “blowout” of the soil material from beneath the dam.

6.1.2 Embankment Dams

- Most common sunny day failure modes for embankment dams are initiated by or heavily influenced by various seepage-related internal erosion phenomena.
  - Piping
  - Scour
  - Heave
- Phenomena discussed above may affect the embankment (including spillway walls), the foundation or both

6.2.1 Probability of Sunny Day Failure Modes

- Sunny day failure may be excluded from further consideration if it can be shown by a dam specific engineering assessment that the probability of failure is 1×10^{-6} per year or less using current best practices.
- As of this writing, the methods discussed in the USBR Dam Safety Risk Analysis Best Practices Training Manual (USBR, 2011) are considered by the staff to represent current best practice.
- Staff expects risk results to be based on a thorough engineering analysis similar in scope and rigor to the comprehensive facility review process described in USBR (2011).

6.2.2 Initial Water Surface Elevation

- To account for floods of long duration, which may result in higher than normal water levels for extended periods, the default initial water level used in breach analysis and flood routings for evaluation of sunny-day failure should be the higher of the maximum observed pool elevation or the maximum normal pool elevation.
- Other water levels may be used with justification (e.g., records showing that water levels above max normal poll are infrequent and of short duration).

7.1 Operational Failures

- Operational failures that may lead to uncontrolled releases and threaten to inundate the NPP site should be considered.
- Examples
  - Failure of a log boom allows reservoir debris to drift into and plug the spillway, leading to premature overtopping of the dam.
  - Gates fail to operate as intended causing premature overtopping of the dam.
  - Loss of access to operate key equipment during a flood leads to overtopping of the dam or other uncontrolled releases.
  - Loss of release capacity leads to overtopping of the dam.
  - Mechanical equipment failure due to changes in operation without a corresponding change in maintenance.
  - Overfilling off-stream storage leads to overtopping and failure of the dam.
  - Failure to detect hazardous flows or a breakdown in the communication process to get people out of harm's way

7.2 Controlled Releases

- The potential for controlled releases that may threaten to inundate the NPP site should be considered.
- Examples:
  - Releases performed in order to prevent dam failure during flood conditions
  - Releases performed to rapidly drawdown a reservoir to prevent incipient failure after a seismic event
  - Releases performed to rapidly drawdown reservoir to prevent incipient sunny day failure.

8. Dam Breach Modeling

- 8.1 Breach Modeling for Concrete Dams
- 8.2 Breach Modeling of Embankment Dams
- 8.2.1 Regression Equations for Peak Outflow from Breach
- 8.2.2 Regression Equations for Breach Parameters
- 8.2.2.1 Uncertainty in Predicted Breach Parameters and Hydrographs
- 8.2.2.2 Performing Sensitivity Analyses to Select Final Breach Parameter
- 8.2.4 Physically-Based Combined Process Breach Models

8.1 Concrete Dam Breach

- Concrete gravity dams
  - Tend to have a partial breach as one or more monoliths sections formed during construction of the dam are forced apart and overturned by the escaping water
  - The time for breach formation depends on the number of monoliths that fail in succession, but is typically on the order of minutes
- Concrete arch dams
  - Tend to fail completely
  - Assumed to require only a few minutes for the breach formation.
  - Shape of the breach is usually approximated as a rectangle, or a trapezoid.
- Buttress and multi-arch dams
  - Sections are assumed to fail completely
  - Assumed to require only a few minutes for the breach formation.
  - Shape of the breach is usually approximated as a rectangle, or a trapezoid.

8.2 Embankment Dam Breach

- Overtopping Failure
  - Once a developing breach has been initiated, the discharging water will progressively erode the breach until either the reservoir water is depleted or the breach resists further erosion.
  - Erosion processes typically result in the progressive widening and deepening of the breach. In some cases, the breach will deepen until the bedrock foundation or some other erosion resistant strata is encountered. At this point, the breach depth stays approximately constant while the breach continues to widen.
  - The final breach shape is often modeled as trapezoidal.
- Piping Failure
  - Breach opening in the dam initially forms at some point below the top of the dam.
  - As erosion proceeds, the "pipe" through the dam enlarges until the top of the dam collapses, or the breach becomes large enough that open channel flow occurs.
  - Beyond this point, breach enlargement is similar to the overtopping case.

8.2.1 Regression Equations for Peak Outflow from Breach

- A number of regression equations have appeared in the literature in the past 35 years.
  - Some attempt to provide conservative estimates by developing equations that envelope the case study data, while others provide a best fit to the data.
- For screening-level analysis, use of simple equations that relate the peak outflow discharge to basic reservoir and embankment parameters is acceptable with adequate justification.
  - Selection of candidate methods should consider the assumptions inherent in the models and their applicability to the dam failure scenario being considered.
  - Sensitivity studies should be performed on a reasonable variation of input parameters, when applicable.
  - If there are multiple applicable models, a study should be performed to evaluate the effect of model selection (and input parameter sensitivity, when applicable) on the results of the analysis.
  - Justification for the chosen model and input parameters should be documented, including results of sensitivity studies.

8.2.2 Regression Equations for Breach Parameters

- Regression equations have been developed to predict parameters of the breach opening (e.g., size, shape, and rate of development) when given input data such as reservoir volume, initial water height, dam height, dam type, configuration, failure mode, and material erodibility.
- Breach parameters are then used in a computational model that determines the breach outflow through the parameterized opening using a weir or orifice flow equation.
- A number of regression equations have appeared in the literature in the past 35 years.

8.2.2 Regression Equations for Breach Parameters

- The state of practice in dam breach modeling shows a clear preference for regression-based approaches.
- Preferred approach uses regression equations to predict final parameters of the breach opening (.e.g. size, shape, time to fully develop) when given input data such as reservoir volume, initial water height, dam height, dam type, failure mode, and material erodibility.
- Because of the large uncertainties, inconsistencies and potential biases discussed above, one should not rely on a single method/equation.
- Compare the results of several models judged to be appropriate. Provide justification for choice of candidate models and final parameter choices. Explicitly address model and parameter uncertainty as well as parameter sensitivity in final results.
- Failure time uncertainties can be quite large.
  - Observations of failure time in case studies generally originate from non-professional eyewitness; and
  - Lack of clear and consistent definition of failure time across (and sometimes within) studies.
- Need to understand how failure time is defined in the relations used and ensure that there is consistency with the way failure time will be used in the modeling of the breach formation process.

8.2.3 Physically-Based Combined Process Models

- The state of practice in dam breach modeling shows a clear preference for regression-based approaches
- Use of physically-based breach modeling will be considered on a case-by-case basis.
- If used, the parameters describing erosion and hydraulic properties should be developed from site-specific studies.
- Generic values or values obtained from the literature are, in general, not sufficient.
- Uncertainty and sensitivity studies should be performed to evaluate the effect of model and input parameter selection on the results of the analysis.
- Justification for the selected model and input parameters should be provided, including documentation of uncertainty and sensitivity studies.

9. Levee Breach Modeling

- In general, levees should be assumed to fail when overtopped.
  - The case for nonfailure must be developed using detailed engineering analysis supported by site-specific information, including material properties of the embankment and foundation soils, material properties of embankment protection (if any), levee condition, etc.
- Levees generally not designed to withstand high water levels for long periods. However, there is no generally accepted method for predicting how long a levee will continue to function under high loading conditions.
  - Historical information is the best available basis for predicting levee performance. The historical information should be from levees that have similar design and construction as the levee being analyzed.
- Since there is no widely accepted method for modeling breach development in the case of levees, conservative assumptions regarding the extent of the breach and the failure time should be used.
- In general, inundation mapping of the NPP site from an onsite or nearby levee will require two-dimensional modeling.

10. Flood Wave Routing

- 10.1 Applicability and Limitations of Hydrologic Routing Models
- 10.2 Hydraulic Models

10.1 Hydrologic Routing

- Commonly used Hydrologic methods
  - Muskingum
  - Modified Puls (also known as storage routing)
  - Muskingum Cunge
- Applicability and Limitations of Hydrologic Routing Models
  - Backwater Effects
  - Floodplain Storage
  - Interaction of Channel Slope and Hydrograph Characteristics
  - Configuration of Flow Networks
  - Occurrence of Subcritical and Supercritical Flow
  - Availability of Calibration Data Sets

10.2 Hydraulic Models

- Hydraulic routing provides more accuracy when modeling flood waves from dam breach because it includes terms that other methods neglect and therefore, it is not subject to the restrictions discussed for hydrologic models.
- Typically, a dynamic hydraulic model should generally be used to route the dam failure flood wave to the plant.
- For inundation mapping of the NPP site, two-dimensional models are generally preferred by the staff. However, use of one-dimensional models may be appropriate in some cases. Therefore use of one-dimensional models will be accepted on a case-by-case basis, with appropriate justification.
- Transport of sediment and debris by the flood waters should be considered.
- Large uncertainty exists in relationships between water elevation and discharge (rating curves), especially at high river discharges. Typically, observed data are extrapolated well beyond field-observed data when discussing dam breach scenarios. Some estimation of the likely variation in maximum water surface stage at the NPP site should be reported to account for this uncertainty in the rating curve.