Appendix A

Background Information on the USACE Dam Safety Action Classification System

A. INTRODUCTION

1. The Dam Safety Action Classification process is intended to provide consistent and systematic guidelines for appropriate actions to address the Dam Safety issues and deficiencies of USACE dams. USACE dams are placed into Dam Safety Action Classes (DSAC) based on their individual Dam Safety risk considered as probability of failure and potential failure consequences. Consequences of the dam failure considered are lives lost, economic, environmental, and other impacts. All dams will be evaluated in a screening analysis and classified according to the DSAC. Dams will be reclassified as new dam safety related information about the dam is developed through monitoring or studies. The intent is that the classification of a dam is dynamic, changing as project characteristics change or as more refined information becomes available.

2. The structure and make-up of the DSAC table resulted from the need to formally recognize different levels and urgencies of actions that are commensurate with the different safety status of USACE dams. These actions range from immediate recognition of an urgent and compelling situation requiring extraordinary action through to normal operations and Dam Safety activities for safe dams.

3. In the past, the USACE Dam Safety program essentially recognized two categories of actions: those for dams considered safe, which comprised routine Dam Safety activities, normal operation and maintenance; and those for dams that were considered in need of remediation, for which investigations, remediation funding justification documents, and design and construction of remediation measures were additional activities. However, these two categories do not provide formal recognition of an adequate range of actions and degrees of urgency, especially for dams with Dam Safety issues that are very high or extremely high risk, which warrant heightened actions that are not provided for in the current business-as-usual procedures. Three action classes are termed "unsafe" and two are termed "safe". The choice of three "unsafe" action classes is to provide adequate parsing in the range of levels of actions. It is expected that only a minority of USACE dams will be classified in the top two "unsafe" classes. These five action classes are now included in the USACE Dam Safety program and summarized in the DSAC table. At the top, DSAC I is for those dams considered to be critically near failure and for which urgent actions are needed to avoid catastrophe in the near-term. DSAC II is for dams with confirmed (unsafe) and unconfirmed (potentially unsafe) dam safety issues; failure could begin during normal operations or be initiated as the consequence of an event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public safety. DSAC III is for dams with confirmed and unconfirmed dam safety issues where the combination of life or economic consequences with probability of failure is moderate to high. DSAC IV is for dams that are not declared safe because they don't meet current guidelines, but which are not considered unsafe enough to warrant heightened attention and for which remediation is considered to be quite low priority, although investigations to confirm their DSAC classification should be given normal priority. At the bottom is DSAC V for dams that are determined to be safe. Examples of Dam Safety Action Classifications are given in Section C of Appendix A.

USACE Dam Safety Action Classification Table*

Dam Safety Action Class	Characteristics of this class	Actions for dams in this class
I URGENT AND COMPELLING (Unsafe)	**CRITICALLY NEAR FAILURE** Progression toward failure is confirmed to be taking place under normal operations. Almost certain to fail under normal operations from immediately to within a few years without intervention. **OR EXTREMELY HIGH RISK** Combination of life or economic consequences with probability of failure is extremely high.	Take immediate action to avoid failure. Validate classification through an external peer review. Implement interim risk reduction measures, including operational restrictions, and ensure that emergency action plan is current and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Expedite investigations to support justification for remediation using all resources and funding necessary. Initiate intensive management and situation reports.
II URGENT (Unsafe or Potentially Unsafe)	**FAILURE INITIATION FORESEEN** For confirmed (unsafe) and unconfirmed (potentially unsafe) dam safety issues, failure could begin during normal operations or be initiated as the consequence of an event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public safety. **OR VERY HIGH RISK** The combination of life or economic consequences with probability of failure is very high.	Implement interim risk reduction measures, including operational restrictions as justified, and ensure that emergency action plan is current, and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Expedite confirmation of classification. Give very high priority for investigations to support justification for remediation.
III HIGH PRIORITY (Conditionally Unsafe)	**SIGNIFICANTLY INADEQUATE OR MODERATE TO HIGH RISK** For confirmed and unconfirmed dam safety issues, the combination of life or economic consequences with probability of failure is moderate to high.	Implement interim risk reduction measures, including operational restrictions as justified, and ensure that emergency action plan is current and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Prioritize for investigations to support justification for remediation considering consequences and other factors.
IV PRIORITY (Marginally Safe)	**INADEQUATE WITH LOW RISK** For confirmed and unconfirmed dam safety issues, the combination of life or economic consequences with probability of failure is low and may not meet all essential USACE guidelines.	Conduct elevated monitoring and evaluation. Give normal priority to investigations to validate classification, but no plan for risk reduction measures at this time.
V NORMAL (Safe)	**ADEQUATELY SAFE** Dam is considered safe, meeting all essential USACE guidelines with no unconfirmed dam safety issues. **AND RESIDUAL RISK IS CONSIDERED TOLERABLE.**	Continue routine dam safety activities, normal operation and maintenance.

* At any time for specific events a dam, from any action class, can become an emergency requiring activation of the emergency plan

B. DAM SAFETY ACTION CLASSIFICATION DEFINITIONS

1. Adverse Consequences: The outcome of the failure of a dam or its appurtenances, including immediate, short and long-term, direct and indirect losses and effects. Loss may include human casualties, project benefits, monetary and economic damages, and environmental impact. (Adapted from USACE).
2. Conditionally unsafe: Assertion that the existence or occurrence of one thing or event (e.g., initiation of dam failure) depends on the existence or occurrence of another thing or event (e.g., extreme flood or extreme seismic event).
3. Confirmed (Unconfirmed): Through investigation or other means, Dam Safety issue is firmly established as of concern or not. Unconfirmed – not confirmed.
4. Critically near failure: Failure sequence has been initiated and continues under normal loading. Without intervention (e.g., interim risk reduction measures or remediation), dam is expected to fail.
5. Dam Safety issue: A potential deficiency that if and when confirmed, could result in failure of the dam.
6. Essential USACE guidelines: USACE Dam Safety-related policies are documented in regulations (e.g. ER's, EM's, EC's, EP's, ETL's and policy letters) that provide design, construction, and operation guidance. Essential guidelines are those specific requirements contained in these documents judged to be critical to the safety of the dam.
7. Failure: In the context of Dam Safety, failure is generally confined to issues of structural integrity, and in some contexts to the special case of uncontrolled release of the contents of a reservoir through collapse of the dam or some part of it. (ICOLD)
8. Interim risk reduction measures: Measures taken to reduce the probability of failure or the consequences of failure. Interim measures are a short term approach to managing Dam Safety risks while long-term solutions are under development.
9. Likelihood: Used as a qualitative description of probability and frequency. (ICOLD). A description of the occurrence chance of a particular event.
10. Marginally safe: Safe with reservations, barely within the lowest standards or limits of safety.
11. Normal Operations: Loading on the dam resulting from day-to-day pool operations to achieve authorized purposes. (For the purposes of a screening analysis for dry dams, or where pool elevations fluctuate widely and no historical normal pool elevation has been established, the normal loading is usually correlated to a 1 to 10 year return period.)
12. Operation restrictions: Changes to operating pool levels and durations, or reduced lockages, power generation, water supply, or conservation operations.
13. Peer review: Peer review is a form of deliberation involving an exchange of judgments about the appropriateness of methods and the strength of the author's inferences. Peer review involves the review of a draft product for quality by specialists in the field who were not involved in producing the draft.
14. Probability: A measure of the likelihood, chance, or degree of belief that a particular outcome or consequence will occur. A probability provides a quantitative description of the likelihood of occurrence of a particular event. This is expressed as a value between 0 and 1. (USACE)
15. Reliability: For gate and mechanical systems reliability is defined as the likelihood of successful performance of a given project element. It may be measured on an annualized basis or for some specified time period of interest or, for example, in the case of spillway gates, on a per demand basis. Mathematically, Reliability = 1 - Probability of unsatisfactory operation.
16. Remediation: Implementation of long-term structural and non-structural measures that resolve Dam Safety issues.
17. Residual risk: The remaining level of risk at any time before, during and after a program of risk mitigation measures has been taken.
18. Risk: Measure of the probability and severity of adverse consequences.
19. Safe (Unsafe): Involving little or no chance of dam failure. Meets all required USACE guidelines and criteria. Unsafe: Unacceptable chance of dam failure.

20. Tolerable Risk : A risk within a range that society can live with so as to secure the benefits provided by the dam. It is a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to keep under review and reduce it still further if and as we can.[HSE, 1999a].

C. DAM SAFETY ACTION CLASSES Five classes of action were selected to portray the range of actions District Dam Safety officers are to take in executing their Dam Safety responsibilities. The USACE dams are to be placed into Dam Safety Action Classes (DSAC) based on their individual Dam Safety risk considered as probability of failure and potential failure consequences.

DSAC I: URGENT AND COMPELLING (Unsafe)

Characteristics.
Dams in this class are CRITICALLY NEAR FAILURE OR EXTREMELY HIGH RISK under normal operations. These dams are ones where progression toward failure is confirmed to be taking place and are almost certain to fail under normal operations any time within a few years without intervention; or the dams have Extremely High Risk with a combination of life or economic consequences with high probability of failure.

Actions. A summary of the actions to be considered and pursued by the district for this class of dams are:

- Take immediate action to avoid failure.
- Validate classification through an external peer review.
- Implement interim risk reduction measures, including operational restrictions, and ensure that emergency action plan is current and functionally tested for initiating event.
- Conduct heightened monitoring and evaluation.
- Expedite investigations to support justification for remediation using all resources and funding necessary.
- Initiate intensive management and situation reports.

Examples of Critically Near Failure dams:

Dam A:

Dam A is experiencing foundation, abutment, and embankment piping or internal erosion due to seepage through these features under normal pool elevations. All of the seepage items may lead to the formation of piping, which can quickly progress to rapid breaching of the embankment. Loss of strength in the foundation or embankment may result in a slope stability failure which could result in dam overtopping though the lowered dam crest.

Recent subsurface investigations have revealed significant degradation of the foundation and embankment soils. Extremely soft zones were found in multiple borings. Piezometers within the embankment downstream of the existing cutoff wall show significantly higher than expected pressures in reaction to the pool. Movement monuments have indicated continual and increasing settlement of portions of the embankment crest. A temperature survey of the piezometers shows cooler zones in the rock foundations which indicate direct seepage from the pool. Numerous and excessive wet areas persist in areas just downstream of the embankment. These wet areas have progressively increased over the years.

Dam B:

Dam B is experiencing foundation and abutment seepage and piping, and embankment piping along the conduit during all pool elevations. The conduit is founded on soil and constructed in soil materials. The periodic inspections indicated that a small amount of differential settlement has occurred at one of the conduit joints. It was constructed with seepage collars that likely prevented adequate compaction of the soil around the conduit and the seepage collars provide a seepage path along this interface that could lead to piping of the embankment. The left abutment is composed of granular glacial deposits and has experienced significant seepage during Normal pool events. The project has had several test fillings and subsequent

seepage collection features were added after each test filling. The seepage is so severe that permanent operational restrictions have been imposed on the project to prevent high pools.

The most likely mode of failure for this project is seepage and piping of foundation or abutment materials which may rapidly progress to breaching of the dam.

An example of an Extremely High Risk Dam.

Dam C:

Items of concern include foundation and abutment seepage and piping under the embankment. The dam abuts highly karstic limestone formations. One documented cavity in the left rim is 77 feet deep and 15 feet wide. On the right rim, primary seepage pathways through the karst system have not been defined by previous subsurface investigations. In stream seepage measured downstream of the dam during zero releases have increased more than 40% from 90 cfs to 127 cfs in 15 years. Rim grouting has been performed twice previously with limited success. The seepage has potential to erode the earth embankment. There is a wet area downstream of the embankment that has appeared in the last 10 years.

Initial foundation treatment, which consisted of minimal excavation and a single line grout curtain, is inadequate. The initial grout curtain and a curtain installed later encountered large clay-filled, solution features in the limestone. There is a potential for erosion of this clay-filled material, which would jeopardize the integrity of the embankment. Piezometer levels are higher than expected; however, some have steadily increased or decreased over the last 20 years indicating erosion of the foundation materials.

There is a large metropolitan area (1,000,000 people) with high potential life loss and less than one hour of warning time for the flood wave. This project is considered to have extremely high risk.

DSAC II: Urgent

Characteristics. Dams in this class are considered to have Failure Initiation Foreseen in that, for confirmed (unsafe) and unconfirmed (potentially unsafe) dam safety issues, failure could be initiated during normal operations or from a hydrologic or seismic event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public safety. Or, dams in this class have Very High Risk in that the combination of life or economic consequences with probability of failure is very high.

Actions. A summary of the actions to be considered and pursued by the district for this class of dams are:

- Implement interim risk reduction measures, including operational restrictions as justified, and ensure that emergency action plan is current and functionally tested for initiating event.
- Conduct heightened monitoring and evaluation.
- Expedite confirmation of classification.
- Give very high priority for investigations to support justification for remediation.

An example of a Failure Initiation Foreseen condition:

Dam D:

The most likely mode of failure for this project is breaching of the dam by erosion or piping through cracks in the core caused by significant displacements of the upstream shell during an Operating Basis Earthquake (OBE) or greater earthquake. Foundation seepage may lead to the formation of piping, which can quickly progress to rapid breaching of the embankment.

Detailed evaluation of the dam foundations indicates that a loose layer of alluvial materials will liquefy during an OBE earthquake or greater earthquake. The predicted large displacements during the earthquake will cause significant cracking or loss of the integrity of the dams' core section. The displacements are large enough to result in complete failure of the upstream shell of the dam. This will result in piping of the remaining dam embankment and will quickly progress to breach. The intake tower is located in the central part of the embankment just upstream of the core. Large displacement of the upstream shell will likely cause damage to the intake tower.

The population at risk is located less than one hour travel time of the flood wave at the mouth of a narrow canyon. Loss of life is expected to be very high if the dam were to fail from an earthquake.

Dam E:

The most likely failure mode is embankment, abutment, and foundation seepage and piping. Deficiencies in the design and construction techniques contribute to a condition of active piping at moderately high pools – 0.05 to 0.01 pool frequency. Most of the embankment is founded on alluvial and glacial soils without any seepage cutoff. Additionally, the rock below the foundation soils was not inspected or treated and has a history of solutioning. The grout curtain installed on the remainder of the foundation does not meet current standards. There is a history of seepage on the downstream embankment slope, the toe of the downstream embankment, zones downstream of the toe, and along the abutment contacts with the higher pool levels. Piezometric data show a 10 foot rise in the phreatic line over the last 20 years. There has been a continual and steady settlement of the dam crest to the left of the concrete section since at least 1978. It is likely that the settlement is the result of internal erosion caused by seepage. It is possible that seepage through the lift joints in the concrete section may be entering embankment materials.

An example of a Very High Risk condition:

Dam G:

Dam is overtopped by several feet at 80% of the probable maximum flood (PMF) and also has potential for foundation seepage creating a piping failure at pool levels for infrequent events. The very large population immediately downstream and a major downtown urban area within 10 miles of the dam has the potential for very high consequences and thus the risk for this project is considered to be very high even through the failure mode is driven by a near PMF event.

DSAC III: HIGH PRIORITY (Conditionally unsafe)

Characteristics. Dams in this class, for confirmed and unconfirmed Dam Safety issues, are considered to be Significantly Inadequate or have Moderate to High Risk in that the combination of life or economic consequences with probability of failure is moderate to high.

Actions. A summary of the actions to be considered and pursued by the district for this class of dams are:

- Implement interim risk reduction measures, including operational restrictions as justified, and ensure that emergency action plan is current and functionally tested for initiating event.
- Conduct heightened monitoring and evaluation.
- Prioritize for investigations to support justification for remediation considering consequences and other factors.

An example of a Significantly Inadequate Dam:

Dam H:

Two failure modes have been identified for this dam - overtopping and piping. The most probable is a piping failure of the foundation overburden materials, initiating at the left cut slope of the outlet channel. A pervious sand and gravel deposit overlying the bedrock is exposed in the outlet channel and does not have adequate seepage control filters. Dam is estimated to be overtopped by several feet by the probable maximum flood and the embankment is breached by erosion.

During pools up to the record event, seepage has been observed downstream of the toe of the dam in the cut slopes on both sides of the outlet works stilling basin. Construction of remedial seepage control filters and relief wells were constructed several years after the dam was completed but appear to be insufficient to reduce the seepage to acceptable levels based on piezometer response. Seepage on the left cut slope is still occurring and is anticipated to increase in severity under higher pool levels. The seepage being experienced along the outlet channel is occurring through a sand and gravel layer located immediately above the bedrock surface.

An example of a Moderate to High Risk Dam.

Dam I:

Dam has a long term history of downstream movement in the clay shale foundation. The piezometric data indicate high uplift in the foundation clays that are the result of the original loading by the embankment during construction. The available inclinometer data show distinct zones of movement at high pool levels as well as a very slow creep over time. Analysis shows the factors of safety for the more extreme pool elevations approach 1.0. The dam has been loaded to top of spillway gates for a pool of record, but there is still an additional 30 feet of storage above that elevation, thus the pool elevation of concern is a rare event. There is significant data to indicate a conditionally unsafe project (potential for failure only when the pool is very high) and the very large volume of water behind this dam at the higher pool elevations would create very high economic and environmental consequences with low to moderate loss of life consequences.

DSAC IV: PRIORITY (Marginally Safe)

Characteristics. Dams in this class are considered to be Inadequate with Low Risk.
For confirmed and unconfirmed Dam Safety issues, the combination of life or economic consequences with probability of failure is low and may not meet all essential USACE guidelines.

Actions. A summary of the actions to be considered and pursued by the district for this class of dams are:

- Conduct elevated monitoring and evaluation.
- Give normal priority to investigations to validate classification, but no plan for interim risk reduction measures at this time.

Examples of Inadequate with Low Risk condition Dams:

Dam J:

The embankment has a potentially preferential seepage path along the top of the outlet conduit and may result in piping of embankment materials during extreme hydrologic events. The dam does not have a foundation seepage cutoff system. Seepage has been apparent at the toe of the dam since the initial filling. High foundation seepage pressures are anticipated for the Extreme events. With the relief well system functional, it is estimated that the seepage pressure would be 2 feet above the ground surface at the toe during an Extreme event. It is likely that the high seepage pressures may cause some piping in the form of sand boils potentially causing embankment instability due to loss of foundation material.

After the pool of record it was found that significant scouring occurred just below the outlet apron. There is currently a 140 foot long, 120 foot wide, and 13 foot (maximum) deep scour hole downstream of the outlet apron. There is potential for additional scouring and undermining of the outlet apron and wing walls under Extreme conditions.

The population centers downstream are all located on the elevated floodplain of a wide valley and the potential for economic consequences is low to moderate. The overall risk is considered low and some essential guidelines are met by this dam.

Dam K:

An overtopping failure mode may result from inadequate freeboard based on existing routings. The resultant consequences are low because of a wide downstream valley, low population density, and ample warning time. Thus the risk is low.

DSAC V: NORMAL (Safe)

Characteristics. Dams in this class are considered to be adequately safe, meeting all essential USACE guidelines with no unconfirmed Dam Safety issues such that the residual risk is considered tolerable.

Actions. Continue routine Dam Safety activities, normal operation and maintenance.

Example of an Adequately Safe Dam.

Dam L:

Dam meets the requirements for hydrologic capacity to pass the most current inflow design flood (IDF), there is no known seepage and piping issue and seepage control features meet current standards, the seismic capacity and performance of all the features of the project are appropriate for the current seismic loads, and there are no operations and maintenance issues that impact the operations of the project for all pool and loading conditions. The project staff and water management staff are appropriately trained and qualified to deal with project operations under emergency and flood conditions. With this high level of readiness and low probability of unsatisfactory project performance a review of the project's residual risk indicates that the risk is tolerable for all design loads and the dam is "safe."

Normal operations require due diligence by a district to perform the requisite monitoring, evaluation, maintenance, and training to actively manage the inherent residual risk associated with any dam with the goal to keep the residual risk at or below the that which is considered tolerable for the respective dam.

D. ACTIONS

The actions listed are an executive summary of the actions that a district Dam Safety officer should pursue based on the action classification assigned to each dam. **The basic concept is that dams in classes I, II, and III shall be treated as unsafe until confirmed safe.**

E. DOCUMENTATION

It is recommended that a district document their decision for assigning a class to a given dam using a short fact sheet that addresses the available information in summary form to include the failure modes of concern, the loading conditions of concern, the probability of failure, the consequences, and DSAC assignment.