

**FERC**  
**Risk-Informed Decision Making Guidelines**

**Chapter 4**

**Risk Management**

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## ACRONYMS

|       |  |
|-------|--|
| ALARP | as-low-as-reasonably-practicable                       |
| BOR   | U.S. Department of the Interior, Bureau of Reclamation |
| D2SI  | Division of Dam Safety and Inspections (FERC)          |
| DSMS  | dam safety modification study                          |
| DSRC  | dam safety risk classification                         |
| DSSMP | dam safety surveillance and monitoring plan            |
| DSSMR | dam safety surveillance and monitoring report          |
| EAP   | emergency action plan                                  |
| FEMA  | Federal Emergency Management Agency                    |
| FERC  | Federal Energy Regulatory Commission                   |
| ICOLD | International Commission on Large Dams                 |
| IES   | issue evaluation study                                 |
| IRRM  | interim risk reduction measure                         |
| IRRMP | interim risk reduction measure plan                    |
| NEPA  | national environmental policy act                      |
| PFM   | potential failure mode                                 |
| PFMA  | potential failure mode analysis                        |
| RIDM  | risk-informed decision making                          |
| USACE | U.S. Army Corps of Engineers                           |

## **CHAPTER 4 RISK MANAGEMENT**

### **4.1 INTRODUCTION**

#### **4.1.1 General**

Risk management encompasses activities related to making risk-informed decisions, prioritizing evaluations of risk, prioritizing risk reduction activities, and making program decisions associated with managing an inventory of facilities (FEMA, 2015). An inventory may be as small as one dam. Risk management is greatly facilitated and enhanced by having the knowledge base supplied by the risk analyses and risk assessment inputs for the dams within the inventory. Such knowledge allows a logical and consistent basis for substantiating and prioritizing risk reduction activities and/or making program decisions associated with managing an inventory of facilities. Risk management, because it uses the findings from a risk assessment process, includes considering the environmental, social, cultural, ethical, political, and legal factors. Risk management should be regarded as an ongoing and iterative process that needs to adapt to new information (FEMA, 2015).

#### **4.1.2 Definition**

According to the International Commission on Large Dams (ICOLD), risk management is the systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, assessing, communicating, mitigating, and monitoring risk.

#### **4.1.3 Purpose**

The primary goal of risk management is to implement actions to continue to review and monitor, investigate or further evaluate, or reduce risk, while considering the cost and benefits of any actions taken. When reducing risk either at a single dam or within an inventory of dams, actions should be taken as quickly and as efficiently as possible, recognizing that there will likely be limits on available funding/resources. Consideration should be given to how much risks are reduced compared with the costs necessary to achieve risk reduction. Generally, the priorities will be to address the dams with the highest risk first, assuming there is confidence in the risk estimates. However, there are many ways to prioritize dams for risk reduction. A key concept is focusing on risk reduction opportunities (interim and long-term actions, risk reduction and uncertainty reduction – obtaining better information or more certain understanding) not just magnitude of the existing risk. ‘Worst first’ or cost effectiveness are examples of prioritization approaches, but there are many others and in general a hybrid approach is likely the most appropriate.

#### **4.1.4 Philosophy and Approach**

It should be acknowledged that the methods used to calculate risk do not provide precise numerical results. Therefore, it would not be appropriate to rely solely on the numeric estimates in comparison to definite established criteria (i.e., risk-based evaluation criteria). Decisions are usually more complex than can be portrayed using only the numerical results of a risk analysis. The strength of the dam safety case should also be considered in the risk management phase.

In order to effectively prioritize and implement dam safety actions, information on the cost and duration of the actions and the magnitude of the risk reduction potential is needed. This type of information is necessary to evaluate the efficiency of risk reduction actions and can be used to fine-tune dam safety actions. A record of the baseline (or existing condition) risks, the dam safety case, and updates that resulted from risk reduction activities should be maintained for each dam within an inventory.

For dam owners with large dam inventories, it will be important to prioritize dam safety actions because funding will limit how quickly actions can be completed. If an owner is dealing with a large dam inventory, a risk categorization scheme may be helpful in making initial decisions regarding prioritizing dam safety actions.

The following principles apply to risk management (FEMA, 2015):

1. The objective of a dam owner should be to reduce dam safety risk as effectively and as efficiently as possible.
2. Each dam owner should have a transparent process for establishing priorities and the urgency of completing dam safety actions.
3. Incorporate flexibility in prioritizing work within an inventory, allowing for adjustments in planned work as new, high priority issues are identified.
4. Use a dedicated, established group to review and prioritize proposed dam safety actions within an inventory or when establishing urgency for action at a specific dam.
5. Independent review is critical to the credibility of this process.
6. The urgency of completing dam safety actions should be commensurate with risk.

## 4.2 DAM SAFETY RISK MANAGEMENT

### 4.2.1 General

The overall dam safety risk management process is a series of hierarchical activities that are used to assess, classify, and manage the risks associated with the inventory of dams within FERC's jurisdiction. The accompanying hierarchical documentation generated by the risk management process documents the risk management decisions for each dam and facilitates risk communication. The set of documents consists of the reports generated by the owners/licensees normal operations and maintenance (O&M) activities and those documents generated when the owner/licensee addresses a dam safety issue. The routine dam safety activities include: annual dam safety inspections performed by the owner/licensee and FERC, Part 12D inspections and reports, reservoir or water management plans, general operations and maintenance plans, emergency action plans (EAPs), and dam safety surveillance and monitoring plans and reports (DSSMP and DSSMR).

Risk management is the process of problem identification and initiating action to identify, evaluate, select, implement, monitor, and modify actions taken to alter levels of risk. Figure 4-1 shows the generalized FERC risk management process for dams. The risk management process emphasizes its ongoing and iterative nature and the usefulness of adapting to new information.

Some broad categories of risk management activities include:

- **Assess Risk Management Options.** Options for assessment activities include the process of identifying, evaluating, and selecting actions that can be taken to alter levels of risk. This is a deliberate process of systematically considering all options and their associated trade-offs. Risk management options generally fall into one or a combination of the following categories; risk avoidance to eliminate the risk; risk prevention to reduce the likelihood of the risk; risk mitigation to reduce the consequence of the risk; risk transfer by insuring against the risk; or risk retention by accepting and budgeting for the risk (ICOLD, 2005). Risk management means deciding the level of risk that is tolerable including the consideration of the costs and other consequences of different risk management actions. Risk management also means giving appropriate consideration to inherent variability and knowledge uncertainties identified during the risk assessment and other evaluations.
- **Implement Risk Management Decisions.** Implementation activities include executing all steps necessary to make the selected risk management alternative a reality. Part of implementation may include adaptive management processes to

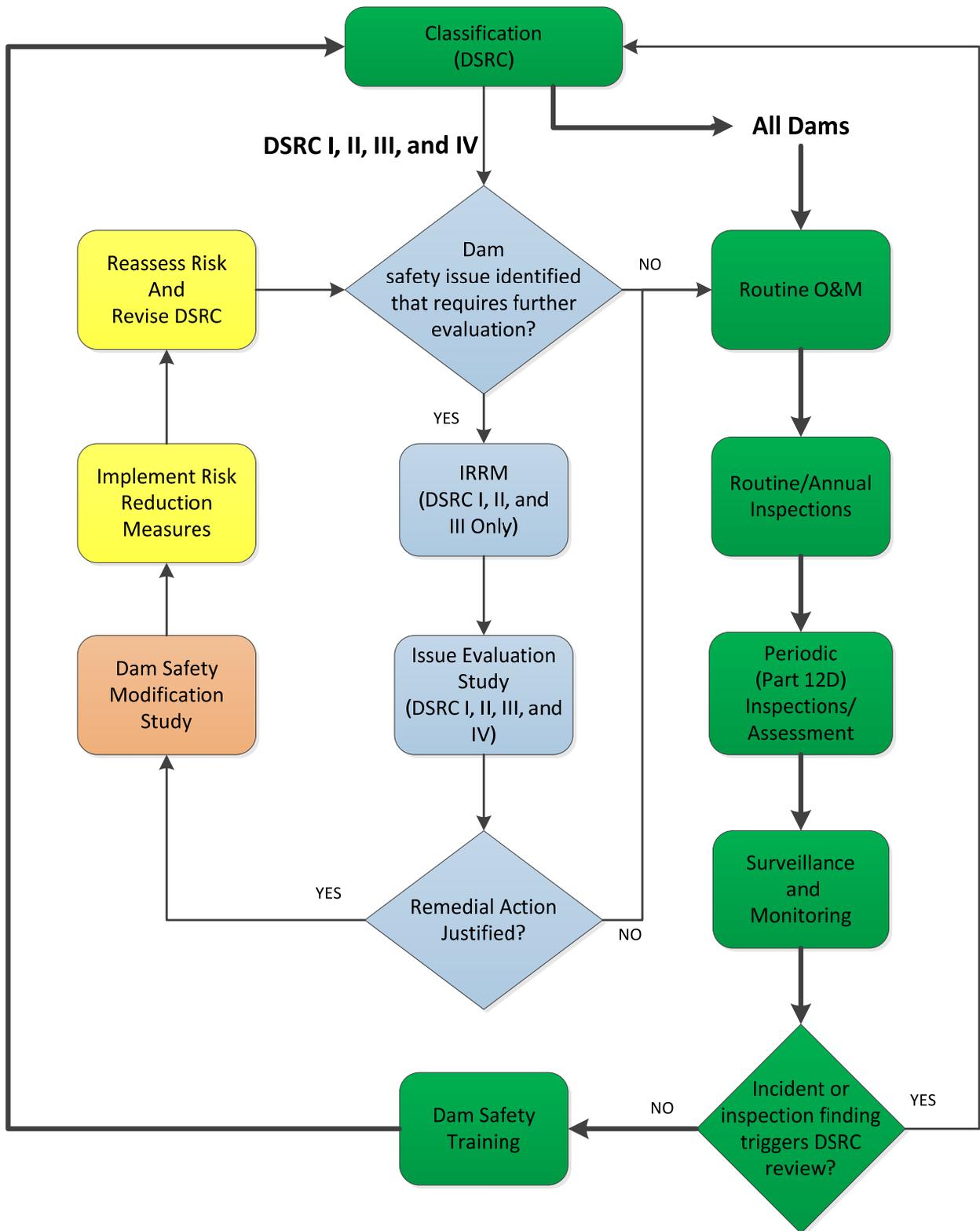


Figure 4-1. Generalized FERC Risk-Informed Dam Safety Risk Management Process

learn while acting when uncertainties identified in the preceding steps are significant and the costs of making a “wrong” decision (economic regret) are deemed to be high.

- **Monitoring and Review.** Monitoring and review activities are undertaken to improve understanding and reduce uncertainty over time through learning to assure the success of the implemented risk management measure(s). Over time, with experience, even the goals of the risk management measure(s) may be adjusted. Risk management policies may induce changes in human behaviors that can alter risks (i.e., reduce, increase, or change their character), and these linkages must be incorporated into evaluations of the effectiveness of such policies (OMB, 2007).

#### **4.2.2 Dam Safety Risk Classification (DSRC)**

The DSRC system provides consistent and systematic means to communicate risk for appropriate actions to address the dam safety issues and deficiencies of FERC regulated dams. FERC regulated dams are assigned a DSRC informed by the probability of failure and the incremental risk. The ‘incremental risk’ is the risk (likelihood and consequences) to the reservoir area and downstream floodplain occupants associated with the presence of the dam that can be attributed to breach prior or subsequent to overtopping, or component malfunction or misoperation. The risk associated with the non-breach scenario will be estimated and communicated, but it will not be used to inform the assignment of the DSRC.

The five risk classes used by the FERC dam safety risk management program are summarized in Table 4-1 and described below. The five classes depict the range of dams from those critically near failure to those considered to have very low risk and meet all *FERC Engineering Guidelines*. Between these two extremes are three classes that define distinctly different levels of actions and urgencies of action that are commensurate with a transition from critically near failure to very low risk. The choice of five action classes is to provide adequate parsing in the range of levels of actions.

The classification of a dam is dynamic over time as project characteristics are modified or more refined information becomes available affecting the loading, probability of failure, or consequences of failure.

The following is a brief summary of the five DSRC classes.

Table 4-1. FERC Dam Safety Risk Classification (DSRC) Table

| Urgency of Action (DSRC) | Description  | Characteristics   | Potential Actions  |
|--------------------------|--|---|--|
| I – VERY HIGH            | An active potential failure mode is in process or the likelihood of a failure is judged to be extremely high, such that immediate actions are necessary to reduce risk.                                | <b>CRITICALLY NEAR FAILURE:</b> There is direct evidence that failure is in progress, and the dam is almost certain to fail during normal operations if action is not taken quickly.<br>OR<br><b>EXTREMELY HIGH RISK:</b> Combination of life or economic consequences and likelihood of failure is very high with high confidence. | <ul style="list-style-type: none"> <li>• Take immediate action to avoid failure</li> <li>• Communicate findings to potentially affected parties</li> <li>• Implement IRRMs, including operational restrictions</li> <li>• Ensure that the EAP is current and functionally tested for initiating event</li> <li>• Conduct heightened monitoring and evaluation</li> <li>• Expedite investigations and actions to support long-term risk reduction</li> <li>• Initiate intensive management and situation reports</li> </ul> |
| II – HIGH                | Potential failure mode(s) are judged to present very serious risks, either due to a very high probability of failure or due to very high life loss, that justify an urgency in actions to reduce risk. | <b>RISK IS HIGH WITH HIGH CONFIDENCE, OR IT IS VERY HIGH WITH LOW TO VERY LOW CONFIDENCE:</b> Failure could begin during normal operations or be initiated as a result of an event. The likelihood of failure from one of these occurrences, prior to taking some action, is too high to delay action.                              | <ul style="list-style-type: none"> <li>• Communicate findings to potentially affected parties</li> <li>• Implement IRRMs, including operational restrictions, as warranted</li> <li>• Ensure that the EAP is current and functionally tested for initiating event</li> <li>• Conduct heightened monitoring and evaluation</li> <li>• Expedite investigations and actions to support long-term risk reduction</li> <li>• Expedite confirmation of classification</li> </ul>   |
| III – MODERATE           | Potential failure mode(s) appear to be dam safety deficiencies that pose a significant risk of failure and actions are needed to better define risks or to reduce risks.                               | <b>MODERATE TO HIGH RISK:</b> Confidence in the risk estimates is generally at least moderate, but can include facilities with low confidence if there is a reasonable chance that risk estimates will be confirmed or potentially increase with further study.   | <ul style="list-style-type: none"> <li>• Implement IRRMs, including operational restrictions, as warranted</li> <li>• Ensure that the EAP is current and functionally tested</li> <li>• Conduct heightened monitoring and evaluation</li> <li>• Prioritize investigations and actions to support long-term risk reduction</li> <li>• Prioritize confirmation of classification as appropriate</li> </ul>   |
| IV – LOW                 | Potential failure mode(s) appear to indicate a potential concern, but do not indicate a pressing need for action.  | <b>LOW RISK:</b> The risks are low to moderate with at least moderate confidence, or the risks are low with low confidence, and there is a potential for the risks to increase with further study.  | <ul style="list-style-type: none"> <li>• Ensure that routine risk management measures are in place</li> <li>• Determine whether action can wait until after the next Part 12D Report</li> <li>• Before the next Part 12D Report, take appropriate interim measures and schedule other actions as appropriate</li> <li>• Give normal priority to investigations to validate classification, but do not plan for risk reduction measures at this time</li> </ul>   |
| V – NO                   | Potential failure mode(s) do not appear to present significant risks and there are no apparent dam safety deficiencies.  | <b>VERY LOW RISK:</b> The risks are low to very low and are unlikely to change with additional investigations or studies.   | <ul style="list-style-type: none"> <li>• Continue routine dam safety risk management activities and normal operations and maintenance</li> </ul>   |

Note: Incremental risk is used to inform the decision on the DSRC assignment. Non-breach risk is not reflected in this table.

DSRC I (Very High Urgency). DSRC I is for those dams where progression toward failure is confirmed to be taking place under normal operations and the dam is almost certain to fail under normal operations within a few years without intervention; or the incremental risk – combination of life or economic consequences with likelihood of failure – is very high. The FERC considers this level of life-risk to be unacceptable except in extraordinary circumstances.

DSRC II (High Urgency). DSRC II is for dams where failure could begin during normal operations or be initiated by an event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public safety; or the incremental risk – combination of life or economic consequences with likelihood of failure – is high. The FERC considers this level of life-risk to be unacceptable except in extraordinary circumstances.

DSRC III (Moderate Urgency). DSRC III dams have issues where the incremental risk – combination life, economic, or environmental consequences with likelihood of failure – is moderate to high. The FERC considers this level of life-risk to be unacceptable except in unusual circumstances.

DSRC IV (Low Urgency). DSRC IV is for dams where the incremental risk – combination of life, economic, or environmental consequences with a likelihood of failure – is low and the dam may not meet all *FERC Engineering Guidelines*. The FERC considers this level of life-risk to be in the range of tolerability but the dam may or may not meet all as-low-as-reasonably-practicable (ALARP) or *FERC Engineering Guidelines*.

DSRC V (Normal). DSRC V is for dams where the incremental risk - combination life, economic, or environmental consequences with likelihood of failure – is very low and the dam meets all ALARP and *FERC Engineering Guidelines*. The FERC considers this level of life-safety risk to be tolerable.

Until fully evaluated, no dam will be considered a DSRC V; therefore, all dams will initially be assigned to DSRC I to IV.

Appendix 4A includes additional information and examples of DSRC.

### **4.2.3 Prioritization**

Prioritization for dam owners with a single dam is not an issue. However, for owners/licensees with multiple dams and those owners/licensees with tens of dams, prioritization is important.

Prioritization of dam safety actions can be done on a facility basis (where total risk is the focal point, and the goal is to reduce total risk to tolerable levels) or on an individual potential failure mode basis (where single potential failure modes are addressed).

For dam owners with a large inventory of dams, it will be important to prioritize dam safety actions because funding and resources will likely limit how quickly actions can be completed. If an owner is dealing with a large inventory, a risk reduction plan will need to be developed to assist in making an initial assessment at prioritizing dam safety actions.

DSRC I dams have a dam safety issue with very high urgency that requires taking immediate and expedited actions to avoid failure. Therefore, DSRC I dams with life-safety risk should be given the highest priority for expedited studies and, if warranted, risk reduction evaluations and designs.

Dams will be prioritized within their DSRC. For example not all DSRC II dams have the same priority.

Priority and urgency are different but should be compatible, thus higher priority dams are normally associated with the more urgent DSRC dams. Prioritization decisions for various studies can have a significant impact on the speed and efficiency of risk reduction for a dam owner's inventory of dams. Therefore, there may be times when a lower risk dam could be prioritized ahead of a dam with a higher risk when it is demonstrated that this action will be more effective and expeditious in reducing the owner's overall inventory risk.

Significant weight should be given to the tolerable risk guidelines, but other ALARP considerations should also be used to provide a more complete basis for prioritization of the queues.

Quantitative considerations include:

1. The level of incremental risk in relation to the tolerable risk reference line. The greater the estimated annual probability of failure and the further the estimated incremental life risk is above the tolerable risk reference line, the greater the urgency to act.
2. The cost-effectiveness of the reduction in the incremental risk (the project with lower overall cost for the same level of risk reduction would be given higher priority). The more cost-effective a risk management plan is in reducing the annual probability of failure and the life-safety risk to and below the tolerable risk reference line, the greater the rationale to select that plan.

3. Net benefits achieved.
4. The magnitude or severity of the economic and environmental impacts.

Qualitative or non-monetary considerations include:

1. Any relevant recognized good practice (*FERC Engineering Guidelines*) (risk management measures that satisfy all *FERC Engineering Guidelines* would be given more weight than those that do not).
2. Societal concerns as revealed by consultation with the community and other stakeholders.
3. Impacts on any facilities critical to national security and well-being.
4. The magnitude of impact on community, regional, or national well-being.

To prioritize actions within a DSRC category, consideration should be given to each of the following factors, which should contribute to increasing the priority of actions at a given dam:

- Both the failure probability (APF) and the average annualized life loss (AALL) exceed the threshold guideline values.
- The APF or the AALL is driven by a single potential failure mode.
- The APF or the AALL is driven by a potential failure mode manifesting itself during normal operating conditions.
- The range of risk estimates is tightly clustered and the mean and median are similar (for detailed uncertainty analyses only) and/or sensitivity studies instill confidence.
- Risk reduction or confirmation is relatively easy and inexpensive.

The above factors can also be considered if a dam appears to border two categories. If a dam owner has a small inventory of dams, the above factors alone can be used as the basis for establishing priorities. The initial effort to place the actions in one of the five risk categories would have limited value for small dam inventories.

## **4.3 RISK REDUCTION MEASURES**

### **4.3.1 General**

Risk reduction actions can take many forms, from monitoring to engineering studies to immediate corrective actions. These actions can be temporary or permanent. Actions may need to be staged to be both efficient and effective. Interim measures may be required to provide more immediate short-term risk reduction while other risk reduction measures are being investigated and evaluated.

### **4.3.2 Interim Risk Reduction Measures**

#### **4.3.2.1 Purpose**

Interim risk reduction measures (IRRM) are dam safety risk reduction measures that are intended to act as temporary or interim measures until such time as more permanent remediation measures can be effectively implemented. In some cases, IRRMs may become part of a long-term risk reduction effort. Interim risk reduction measures plans (IRRMP) must be developed for DSRC I, II and III dams and submitted to the Regional Engineer for review and acceptance. The DSRC table (Table 4-1) provides some general actions and characteristics for each DSRC, including preparation of an IRRMP, considerations for preparation of the plan, and example interim measures.

All dams are unique and have specific vulnerabilities and potential failure modes that require expert judgment in the development of the IRRMP's. IRRMs are a temporary approach to reduce dam safety risks while long-term solutions are being pursued. However, they should not (unless otherwise approved) take the place of long-term approaches.

Examples of IRRMs include reservoir restrictions and increased surveillance and monitoring.

#### **4.3.2.2 Objectives**

The IRRMP should recognize the need for two primary reservoir management objectives (USACE, 2014):

1. A recommended safe operating reservoir level that is maintained for the vast majority of time through non damaging releases to restore the reservoir to restricted level as quickly as reasonable.
2. A plan for which emergency measures such as rapid reservoir drawdown and recommendations on evacuation of the reservoir storage must occur. The

threshold event could be a combination of reservoir level and visual and/or measured signs of distress.

This approach to reservoir management recognizes that reservoir restrictions established for safety purposes cannot and should not be viewed as “must meet” requirements in all flood events, but that there does come a point when emergency measures are necessary.

Flood warning and evacuation plans are key components of life-safety risk reduction activities associated with potential flooding resulting from a possible dam failure and must receive priority attention in formulating IRRMs. It is imperative that evaluation and improvement in the emergency response plans of affected communities be done in a partnership with those communities. Familiarity with the IRRMP is the key to effective risk communications. It is important for dam owners/licensees to discuss issues consistently and openly with affected stakeholders.

#### **4.3.2.3 Plan Elements**

The IRRMP should as a minimum include the following:

1. Overall project description, brief construction history, operational history, and project purposes.
2. Overview of identified potential failure modes (PFMs).
3. Brief discussion of consequences associated with each identified potential failure mode.
4. Structural and nonstructural IRRM alternatives considered to reduce the probability of failure and/or incremental consequences associated with the potential failure modes (reservoir restrictions and modification of the reservoir regulation plan and evaluation and improvement in the emergency response plans of affected communities must always be included as options that are addressed). Updating of the project’s emergency action plan (EAP) to specifically address the potential failure mode(s) which are driving the DSRC assignment is required as part of the IRRMP.
5. General discussion of predicted reduction in the probability of failure and associated consequences, impact on project purposes, environmental impacts, and economic impact to region associated with potential IRRM, both positive and negative.
6. Recommendations and risk-informed basis for IRRM to be implemented.

7. Schedules for implementation of IRRM recommendations.
8. If necessary, proposed schedules for conducting a risk analysis to estimate the benefits for incremental evaluation of IRRM. If needed to support the IRRM plan, a risk analysis will be conducted using existing information and easily obtained consequence data. The primary purpose is to support and provide a basis for the selected interim risk reduction measures. The risk analysis should be scaled depending on the significance of the dam safety issue and the impact of the interim risk reduction measures. Risk may justify significant restrictions in project storage and release schedules. Reservoir restrictions should not be held up or delayed waiting for this risk analysis.
9. Review and update the EAP, as needed, to reflect site specific risks, which includes emergency exercises for DSRC I, II, and III dams conducted in the manners that are appropriate for the risk (PFMs) involved. A review of the frequency of emergency exercises should be performed given due consideration of the DSRC and downstream hazard potential of the project. The completion of these exercises should be incorporated into the official IRRMP for the project, if applicable.
10. Communication Plan (Internal and External). See Section 4.5 for additional considerations on communicating risk.

#### **4.3.2.4 Decision Process for Dam Safety Interim Risk Reduction Actions**

The decision process associated with dam safety-related actions will depend on the nature of the action under consideration, the consequences of the action in both the short and long term, and the potential for national and international interest and attention. In establishing IRRMPs, life safety is paramount, followed by prevention of catastrophic economic or environmental losses, and other considerations will be last. The process of identifying and evaluating IRRM must be conducted as expeditiously as possible and must be a collaborative effort. A risk analysis may be required as part of the IRRMP to support significant restrictions in project storage and release regulation schedules. However, reservoir restrictions should not be held up or delayed waiting for this risk analysis.

IRRM's should be formulated to lower risk as much as practically possible.

#### **4.3.2.5 Interim Risk Reduction Measures**

The following principles (and associated questions) can be used to determine if a proposed interim risk reduction measure is appropriate. Practical options will vary from dam to dam, and therefore a creative effort may be needed to identify the options that

exist for a specific project. The objective is to reduce the probability of catastrophic failure and associated consequences to the maximum extent reasonably practicable while long-term risk management measures are pursued. The IRRMP must be developed on an aggressive timeline to reduce the probability of failure or potential for loss of life once an unacceptable risk(s) has identified (see Section 4.3.2.7 for IRRMP submittal requirements). In general, interim risk reduction measures are not intended to be the means for permanently remediating dam safety concerns.

- **Expert Judgment.** Internal erosion has been identified as a primary potential failure mode for embankment dams. Internal erosion potential failure modes can take a long time to develop but may lead to catastrophic loss of the reservoir with little or no warning. As such, expert judgment is required to match the IRRM with the identified potential failure modes, geology, dam design and loading, and determination of where the dam is on a failure line continuum. Internal erosion is not the only potential failure mechanism where judgment comes into play. Almost any potential failure scenario will have uncertainties that need to be addressed by judgment.
- **Timeliness.** Will the measure be implemented in a timely manner (typically within six months or less) to reduce risk? Taking several years to implement a measure may mean it is not an interim risk reduction measure. Efforts that require significant investment in time and money for studies and investigations should most likely be included in the Dam Safety Modification Study (see Section 4.3.3.2) as a potential alternative.
- **Risk.** Does the measure increase the overall risk from the dam to the downstream public? Does the proposed measure have an adverse effect on other system or basin features (including other dams)? This may be a concern for measures that involve changes to the current approved water control plan and may require a risk estimate to be developed to adequately assess the proposed changes.
- **Emergency Actions.** While a specific action taken during a response to a dam safety emergency is not an interim risk reduction measure, the preparation and regular exercising of a comprehensive, site-specific EAP is a fundamental part of any IRRMP.

Examples of non-structural Interim Risk Reduction Measures include (USACE, 2014):

- **Reservoir restrictions or change in reservoir operations.** If this measure is considered viable then the owner/licensee should begin immediate action to update their reservoir operations plan to reflect the operational change or reservoir restriction. In the interim a deviation from the current reservoir operations plan should be implemented until the reservoir operations plan is updated to reflect the

operational change or reservoir restriction. National Environmental Policy Act (NEPA) and other environmental reviews may be required.

- Pre-position emergency contracts for rapid supply of other needed items/equipment.
- Stockpiling emergency materials, e.g., rock, sand, sand bags, emergency bulkheads, lighting plants, or other operating equipment, etc.
- Use of other reservoirs in the system, if present, may be required to mitigate the impact of regulation schedule changes. If the change in regulation schedule is required for other dams in the system, then a regulation deviation for those dams would be required as well.
- Improved and/or increased inspection and monitoring to detect evidence of worsening conditions to provide an earlier warning to the public for evacuation.
- Update the EAP and the inundation mapping to include project-specific failure mode(s). The National Weather Service (NWS) must be included in the EAP to take advantage of their television/radio announcement and stream forecasting capabilities. In parallel with updating the project's EAP the licensee must work with local authorities on evaluation of and improvement in the emergency response plans of the affected communities.
- Explicit procedures, communications systems, and training of appropriately skilled team members for prompt and effective emergency response in the event of the detection of worsening or catastrophic conditions.
- Conduct appropriate emergency exercises that plan for a range of failure scenarios (including the combined effects of multiple failure modes and different timing of detection) to improve warning and evacuation times.
- Coordination with local interests and federal and non-federal agencies, including the NWS and local emergency management agencies (EMA), with a focus on the specific potential failure mode(s) and the effectiveness of response including appropriate response exercises.
- Identify instrumentation/monitoring “trigger” or threshold pools that would initiate more urgent monitoring or emergency response. In addition, threshold values should be established for instrument readings where possible.

- Installation of early warning systems to increase the time available for evacuation should be included as an alternative.
- Preventive maintenance and repairs such as cleaning drains and improving spillway gate reliability where non-functioning components would exacerbate the existing conditions in an emergency.
- Acquisition of real estate (if possible) that would preclude potential loss of life and damages from a potential dam failure or other IRRM should be included as an alternative since life safety is paramount.

Examples of structural Interim Risk Reduction Measures (some can be incorporated in long term remedial measures) include (USACE, 2014):

- Isolate problem area (e.g., cofferdam around problem monolith(s) or other project feature).
- Improve seepage collection system.
- Lower the spillway crest to aid in prevention of failure (A consequence estimate may be warranted to ensure overall risk is not increased by this measure).
- Increase spillway capacity/construct another spillway. (A consequence estimate may be warranted to ensure overall risk is not increased by this measure).
- Breach/lower saddle dams along the reservoir perimeter. (A consequence estimate may be warranted to ensure overall risk is not increased by this measure).
- Strengthen weak areas (e.g., upstream or downstream blanket to cut off/slow seepage; install tie-backs/anchors; and install additional buttresses).
- Construct a downstream dike to reduce head differential.
- Construct stability berm.
- Increase dam height. (A consequence estimate may be warranted to ensure overall risk is not increased by this measure).
- Modify outlet discharge capability such as by installing temporary siphon(s).
- Increase erosion protection where necessary.

- Protect downstream critical facilities (e.g., medical and emergency services).
- Construct shallow cutoff trench to slow seepage.
- Target grout program specifically for suspected problem area(s) to slow seepage/leakage. (Note: If grouting is performed under reservoir head, there is the potential for the grout to travel and set up downstream, creating a barrier that increases pressures under the dam. This must be considered and monitored for any such grouting.)
- Remove significant flow restrictions (downstream bridge conditions may restrict maximum discharge from the outlet works. Upstream bridges or small dams may restrict flow caused by debris buildup that could result in a large release).

It should be clear from the examples provided above that IRRMs are those in which some kind of action is taken, (e.g., lower, construct, breach, improve, modify, etc.). IRRMs do not include such things as consider, study, provide further analysis, etc., although these types of activities could be performed in support of taking some form of ultimate action.

The above examples of IRRMs are a good guide for how interim measures differ from permanent measures; however, there are always situations for which judgment must be used in determining what measures are appropriate. As may be the case in some circumstances, some interim measures – whether structural or non-structural - may become permanent based on the recommendations of an additional engineering studies.

#### **4.3.2.6 Evaluation Factors for IRRM**

Some types of IRRM's may significantly impact authorized project purposes (e.g., water supply, recreation, fish passage, etc.), and others who depend indirectly on the project. Additionally, some IRRM's may result in more frequent discharges from the dam and from lower reservoir elevations than originally designed, impacting stakeholder interests. Public safety must always be given a higher priority over all other project purposes and benefits. In evaluating and formulating IRRM's, it must be kept in mind that each project has its own unique attributes that have to be addressed on a case by case basis using expert judgment. The following must be considered and addressed (USACE, 2014):

- Providing protection of life, property and the environment. Examples to consider are loss of life; increased sickness and disease; employment losses; business income losses; private property damage; infrastructure damage, including roads and utilities; losses in social and cultural resources, including community effects and historical resources; environmental losses, including aquatic and riparian habitat, threatened and endangered species; and hazardous/toxic/radioactive waste

(such as flooding a Superfund site). Early and frequent NEPA coordination with the IRRMP is highly recommended.

- Reducing the probability of failure and consequences of uncontrolled reservoir releases. Increasing the confidence that any changes associated with the dam that are related to development of a potential failure mode will be promptly detected.
- Increasing the confidence that emergency management agencies will be notified promptly.
- Increasing the warning time and effectiveness of evacuation of the populations at risk.
- Reducing the probability of the initiating loading (critical pool levels).
- Improving the organizational capability to implement IRRM (resources, time, funding, technology, etc.).
- Preserving the public trust.
- Addressing stakeholder issues and impacts.
- Understanding the degree of confidence in the scope of the problem and effectiveness of the interim solution.
- Capability for incorporating IRRM into the permanent solutions.
- Impacting authorized project purposes or other project benefits.
- Minimizing social disruption and environmental impacts.

#### **4.3.2.7 Submittal Requirements**

IRRMPs must be developed for DSRC I, II and III dams. IRRMP's for DSRC I dams must be submitted to the Regional Engineer for review and acceptance within 60 days after being designated as DSRC I, or within 90 days after being designated as a DSRC II, or within 120 days after being designated as a DSRC III, as designated from the results of a Level 2, 3, or 4 risk analysis, or as otherwise designated by the Regional Engineer. NEPA coordination should be started early in the IRRMP process and be continued to avoid later problems.

A standard IRRMP review checklist is provided in Appendix B to in the development and review the plans.

The Licensee shall perform an annual review of all DSRC I, II and III IRRMP's unless some event occurs that would trigger an earlier review, e.g., rise in piezometers readings, completion of a remediation phase, etc. These reviews should also include review of the communication plan with the plan for public involvement. The owner/licensee shall document their IRRMP annual review in a letter to the Regional Engineer. If significant changes are made or proposed to a previously approved IRRMP, the revised plan is to be submitted to the Regional Engineer for review and acceptance as a new plan.

### **4.3.3 Engineering Evaluations and Studies**

Based on the results of Level 2 risk analyses or other engineering studies, it may be determined that additional investigations and explorations, engineering analyses and studies, and follow-on risk analyses are appropriate. It may also be determined that foregoing additional engineering studies and proceeding directly to design and construction of risk reduction measures is more cost effective and timely.

In the context of collecting additional information and performing additional risk analyses (Level 3 and Level 4 risk analyses) to better quantify the risk, uncertainty, and confidence, two general types of risk studies are performed - Issue Evaluation Studies (IES) and Dam Safety Modification Studies (DSMS).

IES are studies to determine the nature of a safety issue or concern and the degree of urgency for action, if any. The purpose of the IES is to determine whether or not risks are considered to be tolerable, and if not, what actions to pursue, such as a DSMS. An IES focuses on identifying, evaluating, and determining if risks are unacceptable, tolerable, or not tolerable through the results of Level 3 or Level 4 risk analyses. Even if a particular potential failure mode or dam safety concern has been identified, a Level 3 risk analysis should be reviewed (if one has been previously performed) or performed to verify that the risks of all potential failure modes have been adequately and appropriately characterized; to identify which potential failure modes, if any, need further risk analysis work; and to identify key information, analyses, data gaps that may exist and will need to be addressed prior to conducting a Level 4 risk analysis.

The results of an IES are used to verify or revise the DSRC and guide the selection and gauge the effectiveness of interim risk reduction measures. IES results are also used to assist in making risk-informed decisions, and prioritizing dam safety studies and investigations.

DSMS are studies that evaluate and provide the rationale for dam safety modifications, typically for those potential failure modes identified during the IES as needing risk

reduction measures. The objective of a DSMS is to identify and recommend a risk management plan that supports the expeditious and cost effective reduction of risk that satisfies the tolerable risk guidelines for the long term.

#### **4.3.3.1 Issue Evaluation Studies**

The overall objectives of an IES are to evaluate a dam safety issue found during an incident, inspection, or study, in relation to the tolerable risk guidelines and determine if the issue warrants further actions either through interim measures, formal study, or both. The scope of the IES is to evaluate both confirmed and unconfirmed issues related to the performance, maintenance, and operational concerns of the dam.

Confirmed issues are those that pose a significant incremental risk (approaching or exceeding tolerable risk) with a high level of confidence (giving due regard for uncertainty) such that additional studies and investigations are not likely to change the decision that dam safety modifications are warranted. Examples of confirmed issues can be described as performance concerns, such as a lack of spillway capacity, or deficiencies that are demonstrated by signs of internal erosion, known flaws or defects, component distress or malfunction, unusual settlement, unsatisfactory instrument readings, etc. that can be specifically linked to one or more potential failure modes. Confirmed dam safety issues are typically addressed in an IES where there is sufficient performance data and documentation to prepare a risk estimate that contains minimum uncertainty and provides an adequate level of confidence that a DSMS is warranted.

Unconfirmed issues are issues that are judged to pose significant incremental risk (approaching or exceeding tolerable risk), but are based on data with such high uncertainty that the conclusions may be significantly influenced or changed if additional data was obtained. Examples of unconfirmed dam safety issues can be described as performance concerns where the contributing factors are unclear due to limited or outdated design documentation, or subtle changes in performance that cannot be visually inspected or obviously linked to a potential failure mode. In these cases, additional studies, investigations, and analysis may be needed to clearly identify the potential failure mode, or more accurately predict the system response probabilities of the potential failure mode causing the concern. Unconfirmed issues are typically addressed in IES where additional time is warranted to further investigate the dam safety issue prior to finalizing the risk estimate.

IES are required for all dams that have individual potential failure modes that have documented risks that are considered intolerable or unacceptable. The scope and level of rigor required for an IES is based upon the complexity of the dam safety issue and the ability to evaluate these issues and potential failure modes. The level of effort for this study is that level required to adequately characterize the level of risk, uncertainty, and confidence relative to the tolerable risk guidelines. Thus the scope of the study is to

identify all significant potential failure modes (or groups of credible potential failure modes) that are significant risk drivers and to determine the incremental and non-breach flood risk of the dam. For projects where a risk estimate has been prepared during a previous risk-informed study, that risk estimate should be updated to address the current issue or concern.

Based on the results of an IES, the following actions can be taken:

1. Confirm that dam safety issues do or do not exist (risks are intolerable or tolerable);
2. Verify or reclassify the current DSRC based on these findings;
3. Determine if a dam should be reclassified as DSRC I and thus warranting the expedited process for a DSRC I dam;
4. Gauge the effectiveness, and guide the selection, of current and additional interim risk reduction measures;
5. Use the IES results to review effectiveness of IRRMP's, identify data deficiencies, develop DSMS plans, and prioritize DSMS; and
6. Determine if there is basis (or not) to proceed to a DSMS.

#### **4.3.3.2 Dam Safety Modification Studies**

The objective of a DSMS is to evaluate, document, and select risk reduction alternatives for each potential failure mode that represents an intolerable risk based on the results of an IES. Recommended risk reduction alternatives are to be technically feasible and acceptable following current best practices, comply with applicable laws, and satisfy applicable tolerable risk guidelines. The risk associated with each failure mode being addressed by a risk reduction alternative must be reduced to a level that satisfies the tolerable risk on an individual potential failure mode basis, including ALARP considerations. The intent is to achieve remediation of those individual potential failure mode(s) being addressed by the plan to support the goal of having a dam with low risk for confirmed and unconfirmed dam safety issues where the combination of life, economic, or environmental consequences with the probability of failure is low; however, the dam may not meet all *FERC Engineering Guidelines*, but the incremental risk is considered tolerable. Each alternative risk management plan must be formulated to support effective and efficient risk reduction which may require a staged implementation approach. The principle of "Do No Harm" must be respected in development of the risk management plan.

DSMS are required for all dams that have individual potential failure modes that, based on the results of an IES or other studies, have risks that are unacceptable or intolerable.

A report documents the DSMS and includes a risk analysis for all potential failure modes that have been determined to contribute to significant risk for that dam. The report must also document additional efforts, if any, to further define the dam safety issue. The risk reduction risk analysis of the alternatives considered in support of the DSMS (Level 3 or Level 4) must address the life safety, economic, and environmental consequences associated with the identified significant potential failure modes. The goal of the risk management alternatives, including potential staged implementation options, is to achieve the tolerable risk guidelines by reducing and managing the incremental risk.

## **4.4 ROUTINE DAM SAFETY RISK MANAGEMENT**

The results of the risk analyses and the knowledge gained from performing the risk analysis on individual potential failure modes should be deliberately incorporated into the routine dam safety activities, including dam safety inspections, EAPs, dam safety surveillance and monitoring plans/reports, etc. Significant investment is required in understanding potential failure modes and the vulnerabilities from each potential failure mode during a risk analysis. That information should be used to focus and inform dam safety inspections, assist in the understanding of consequences and the EAP and information conveyed to EMAs, and to provide a better assessment of the existing surveillance and monitoring activities and the potential for revisions to location, frequency of reading, instrumentation type, etc. for each potential failure mode.

### **4.4.1 Dam Safety Inspections**

The results of the risk analysis should provide additional information and insights to the routine and special dam safety inspections. In performing dam safety inspections, the inspection should include a focused observation and evaluation that addresses each significant potential failure mode with an emphasis on the observations/ information that would support or refute early detection of the potential failure mode.

The results of the risk analysis for each potential failure mode should also inform such factors as:

- Frequency of inspections
  - Is the annual inspection frequency frequent enough to capture observations needed to determine if potential failure mode is active or not?
  - If not, what frequency is needed?
- When inspections should be performed
  - Time of the year (winter when ice loading is greatest?)
  - Event (beginning of irrigation season?)
  - Reservoir elevation stage/duration (when reservoir fills above a certain elevation? Or when the reservoir has been full for more than 3 months?)
- Technical discipline experts accompanying on inspection
  - Structural engineer or gate expert
  - Mechanical engineer
  - Geotechnical engineer
  - Engineering geologist
- Need for special inspections
  - Confined space of tunnels, adits, manholes, etc.

- Gate inspection
- Rope access
- Underwater
- Other

As is the case with any dam safety inspection, what you don't see may be as important as what you do see. For example:

- Seepage not present when it has been historically for similar reservoir elevations.
- Not being able to observe seepage exit location due to vegetation obscuring the exit location or the exit location (based on the PFM description) is located in a submerged part of the tailrace.

#### **4.4.2 Emergency Action Plans**

The frequency of emergency exercises should correspond directly to the DSRC rating and hazard potential of the project. That is, the higher the level of urgency (DSRC I being the highest level of urgency) the more frequently exercises should be conducted. As a minimum the EAP exercise schedule listed in Table 4-2 must be followed for all projects having significant life/property loss implications. Note that actual emergency events may be substituted for the appropriate exercise provided they are properly documented and the lessons learned from that event are incorporated into the updated EAP.

The definitions of the exercise levels are included in the *FERC Engineering Guidelines*. It is recommended that all exercises be based on a potential failure mode of concern for the particular dam. If an exercise has not been done in the last five years, it is recommended to start with a tabletop exercise and work up to the level appropriate for the DSRC. At their discretion and judgment, licensees may choose to periodically conduct something more elaborate (i.e., tabletop, functional, or full-scale) if they deem the situation warrants.

The information obtained from consequence evaluations performed as part of risk analyses should be used to help inform EMAs in their evacuation planning. The results of consequence evaluations for each potential failure mode can be used to help inform EMAs regarding:

- Time to failure
- Location, timing, depth, and velocity of inundation with respect to structures and population
- Rate of rise of inundation
- Timing of when potential evacuation routes become impassable
- Potential safe refuges for evacuated populations

- Potential locations of high density fatalities
- Potential populations needing assistance in evacuation (elderly, disabled, etc.)
- Potential for vertical evacuation (building elevation greater than inundation depth)

This information should be discussed with EMAs and used in EAP exercises to better prepare evacuation planning scenarios.

Table 4-2. Emergency Exercise Frequency

| <b>Exercises*</b>   |  |                          |                                       |
|---|--|--------------------------|---------------------------------------|
| <b>Classifications</b>  | <b>Drill</b>                           | <b>Tabletop Exercise</b> | <b>Functional/Full-Scale Exercise</b> |
| DSRC I and High Downstream Hazard Potential   |  | Year 1, 3, 5, etc...     | Year 2, 4, 6, etc...                  |
| DSRC II or III and High Downstream Hazard Potential   | Year 1, 3, 5, etc...                   | Year 2, 4, 6, etc...     | At Regional Engineer discretion       |
| DSRC IV or V and High Downstream Hazard Potential and All Significant Downstream Hazard Potential | Year 1 - 4 and 6 - 9, etc....          | Year 5, 10, etc...       | At Regional Engineer discretion       |
| All Low Downstream Hazard Potential   | <i>See FERC Engineering Guidelines</i> |                          |                                       |

\*Orientation Seminars must be held for all new dams and whenever new information is developed.

#### 4.4.3 Dam Safety Surveillance and Monitoring Plans

Instrumentation data is an extremely valuable asset that supplies insight into the actual behavior of the structure relative to design intent for all operating conditions. Instrumentation data demonstrates performance that is uniquely characteristic to the structure and provides a basis for predicting future behavior. Instruments are used where data is needed to enhance visual surveillance performed in order to ensure that the risk to life, property, and the environment presented by the project is within tolerable risks. Instrumented monitoring is also used to augment investigations of unexpected behavior.

The number of instruments, locations, types, and frequency of readings should be commensurate with the DSRC and significant potential failure modes identified for each project. *Note: There may be a set of credible potential modes that when combined they*

*are significant contributors to the risk associated with the dam. These credible potential failure modes should be evaluated and an appropriate level of instrumentation and monitoring should be implemented to provide an adequate level of information for evaluating the performance of the dam pertaining to these credible potential failure modes.*

The planning, design, and layout of an instrumentation program are integral parts of the project design and operation. A life cycle approach is needed; instruments that were critical for the construction phase may not be critical for the operations phase. The number and locations of instruments must be annually reviewed to assess if devices should be abandoned, added, or read at different time intervals. As structures age and new design criteria are developed, the historical data are relied upon to evaluate the safety of the structure with respect to current standards and criteria. Older structures may require additional instrumentation to gain a satisfactory level of confidence in assessing safe performance.

Instrumentation data can be of benefit only if the instruments consistently function reliably, the data values are compared to the documented design or performance limits and historical behavior, and the data are received and evaluated in a timely manner.

Automation of dam safety instrumentation is a proven, reliable approach to obtaining instrumentation data and other related condition and performance information, particularly when investigating and analyzing performance conditions that require frequent, and/or difficult access for obtaining measurements. Automated instrumentation should be periodically calibrated and verified manually, when possible. Automation should augment field visual inspection and not take the place of it. It is recommended that automation be accomplished to provide data sufficient to document the behavior of the structure in response to loadings, to increase warning times, and reduce exposure of field personnel to harsh conditions. Where feasible, automation should include verification procedures.

Redundancy and use of automated data collection should be considered for high risk features or for locations that have limited on site staff or are difficult to access for monitoring and emergency response. Repair, replacement, and installation of new devices must be evaluated throughout the life of the project subject to potential failure modes analysis (PFMA), flood performance, and other risk considerations. Increased data monitoring and analysis should be performed in conjunction with unusual loading events, such as high reservoir levels or following earthquakes. Specific devices and frequency of readings must be documented in project specific surveillance plans.

Successful risk management requires a healthy routine monitoring program, including maintenance, repair, and staff who are trained in data collection and interpretation. Data assessment must consider the anticipated design performance of the project, and whether

the actual performance is within design safety thresholds. Data anomalies in critical areas must be promptly evaluated by experienced technical staff. Evaluation may include but is not limited to verification readings, verification of calibration and collection methods, visual observation of area and instrument for damage or distress, and comparison with available redundant instrumentation.

In some cases, where data is complex and is relied upon for life safety risk reduction decisions, it may be appropriate to utilize independent expert consultants to review instrumentation data analyses and help validate conclusions.

The design and construction of new projects as well as the rehabilitation, dam safety modifications, and normal maintenance of older projects present opportunities for planning instrumentation systems for the future engineering analyses of structural performance. Careful attention and detail must be incorporated into the planning of instrumentation systems and programs to ensure that the appropriate potential failure modes are adequately monitored. Once the parameters that are critical to satisfactory performance are determined by the design, appropriate instrument devices are selected to provide the engineering measurements to the magnitude and precision, and response time necessary to measure the parameters and evaluate project performance.

Additional guidance is provided in Chapter 14 of the *FERC Engineering Guidelines*.

The following questions should be asked and answered in developing potential failure mode-specific monitoring plans:

- For each PFM what would be an indicator of this PFM actually occurring?
  - (You want to catch it at the earliest possible opportunity so action can be taken.)
- Where would I look for signs?
- What would I use to help me detect it?

The potential failure mode pathway should be evaluated from the initiation location to the breach location to determine possible locations for detection that the potential failure mode is active or to monitor the conditions that might initiate the potential failure mode.

In evaluating existing instrumentation in support of evaluating potential failure modes, the following questions should be asked and answered:

- Does existing instrumentation and monitoring plan adequately capture this PFM?
  - Right location?
  - Right equipment?
  - Right frequency of reading?
- If not, what type of instrumentation and where would it be helpful to detect PFM?

Keeping in mind the following:

- Existing instruments might not be in the location to monitor/detect PFM.
- Existing instruments might not be installed at the correct depth to monitor/detect PFM.
- There might not be enough or correct spacing of instruments to monitor/detect PFM.
- Existing instruments might not be currently measured at proper timing or frequency to monitor/detect PFM.

Increased surveillance and monitoring, to include more frequent readings, may be required when operating under Interim Risk Reduction Measures (IRRM) or during critical dam safety events such as high or surcharge pool or near record pool. The owner must document when this increased surveillance and monitoring is to be invoked in the project specific surveillance plan. Those instruments that are critical for monitoring during the increased surveillance and monitoring periods are to be documented in an addendum to the project specific surveillance or monitoring plan.

## **4.5 RISK COMMUNICATION**

### **4.5.1 Key Elements**

Risk communication activities including dam safety inspections, risk analyses, DSRC, risk reduction measures, and other key actions must take an integrated approach. The goal is to include the elements of communication throughout the dam safety risk management activities. Key elements include (USACE, 2014):

1. The importance of communicating project benefits and risk during each step of the dam safety risk management process to include the DSRC.
2. The more consistent inclusion of potential actions for the public and others in information releases.
3. The coordination and the identification of the shared responsibilities among the licensee and other entities with responsibilities for communication of flood risk and dam safety.

### **4.5.2 Dam Safety Risk Communication Definition**

Risk communication is the open, multi-dimensional exchange of information. This information includes characterization of the risk (incremental and non-breach), uncertainty in the risk analysis, the life safety impacts, other benefits and costs (monetary and non-monetary) and the actions that should be taken (USACE, 2014).

Risk communication is a fundamental part of the risk framework and is integrated into the risk analysis, assessment and management steps and ensures that the decision makers, other stakeholders and affected parties understand and appreciate the process of risk and in doing so can be fully engaged in and responsible for risk management. It must begin early and continue throughout the risk management process, including the dissemination of information of any adverse impacts of the risk reduction actions and how those impacts can be mitigated, and is essential to risk-informed management. Public education is included under the umbrella of risk communication.

### **4.5.3 Dam Safety Risk Communication Philosophy**

Risk communication is a foundational element in a successful dam safety program.

Licensees should have the philosophy that they will ensure communication regarding potential inundation hazard, consequences, and solutions are open, transparent and understandable to the public. Licensee should document and routinely report the risk communications and management decisions to the FERC.

Communicating risk to the public is the responsibility of the licensee<sup>1</sup>. An open, interactive and ongoing dialogue is critical. Communicating risk is as important as assessing and managing risk. Today's risk communication goes beyond just communicating technical information—it includes recognition of important cultural values and ideas that affect decisions. Social context and culture can influence the beliefs and action for all parties—technical and non-technical. Communicating the ongoing residual risks associated with the most robust dam is as important an activity as is communicating any change to risk because of a change in the dam's status. Research has shown that communicating recommended actions to the public is an effective way to change behavior. In emergency situations communicating the immediate hazard is important and, in most cases, local authorities will be communicating about the imminent danger.

#### **4.5.4 Risk Communication Principles**

A number of principles apply to risk communication. These principles are (FEMA, 2015):

- Enhance communication with the public, internally within dam owning and regulating organizations, and Emergency Management Agencies (EMAs). Risk communication provides many benefits, including improving the chances that dam safety decisions will be supported within and outside of the organization, better preparing the organization and the public for taking action in the event of an emergency, and instilling confidence in the dam safety office of an organization.
- Emergency Action Plans identify emergency situations that may develop at a given dam and establish protocols for reacting to the emergency. The advance planning inherent in these plans, and the familiarity of local officials and the public with the plans, will save valuable time during an emergency. Emergency Action Plans and communication with the public are important and integral aspects of reducing risk to life.
- Communications should be open and transparent. This will help instill confidence in the organization and better prepare the organization and the public for responding to an emergency.
- Dams present both a benefit and a risk to the public. When dam safety risks are presented, the public may focus on the negative aspects of the dam and not realize

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<sup>1</sup> For those projects in which the licensee is not the owner of the dam and where some other entity, organization, or individual is responsible for the notification or activation of the project's EAP, the licensee shall coordinate with that entity, organization, or individual in communicating the risks from the licensee's facilities.

the offsetting benefits that the dam provides. When describing dam safety issues at a given dam, the presenter should focus on the benefits as well as the risks posed by the infrastructure.

- Integrate risk communications early in the process of responding to dam safety issues. This is beneficial because by including individuals in the process and giving them the opportunity to provide input and, possibly, influence decisions, they are more likely to accept the decisions being made. Provide context for risk communications (i.e., compare with other risks). This is especially important for the public who may have trouble identifying the significance of dam safety risks.
- Focus communications on actions that individuals/organizations need to take. This is important because an effective dam safety program and effective risk reduction actions involve a number of organizations and individuals: those that monitor and maintain dams, those that evaluate and make decisions regarding the safety of dams, and those that react and respond to emergencies at dams. Risk estimates are inherently uncertain, with the nature and the amount of uncertainty varying from dam to dam. It is important to acknowledge the uncertainty and put it into the proper context. The following aspects of uncertainty in risk estimates and the dam safety case should be discussed:
  - What is certain
  - What is likely, but not certain
  - What is possible, but not likely

#### **4.5.5 Types of Communication**

There are essentially two types of dam safety risk communication:

1. Long term communication - lending itself more to information and actions that foster involvement in decision making and to public education, and
2. Warnings or hazard communication of an immediate or imminent danger.

#### **4.5.6 Levels of Communication**

Communication is important in all aspects of dam safety within a licensee's organization, with emergency management officials, with FERC, with the public, and with other local, state, and federal agencies. However, communication about the work associated with risk is particularly important because of the fears, sentiments, perceptions, and emotions surrounding the word *risk* and the use of *risk analysis* in engineering. Thus, it is important to understand and have a good plan for communicating risk, including:

1. What information is available at a given dam related to potential failure modes and how the information is considered in a risk analysis?
2. How risk will be considered by an organization?
3. What are the results of the risk analyses?
4. What decisions were reached and what risk remains?

This communication can help create an awareness of potential dam safety issues and help all parties gain a greater understanding. Creating an understanding of risk and dam safety issues is important for those who have varying degrees of connections to the dam and the associated potential impacts. These diverse groups have a variety of backgrounds, experience, and sophistication. Communication plans and strategies should be developed for:

- Internal to a licensee's organization
- External stakeholders
- The public

#### **4.5.6.1 Internal Communication**

There are at least four levels at which communication garnered from risk studies and resulting decisions needs to take place within an organization. These include:

1. Communication with employees at the dam or project site.
2. Communication at the local level of the organization, where the responsibility for managing the operation and maintenance, as well as the routine visual surveillance and instrumental monitoring for the suite of dams associated with one or more projects typically resides.
3. Communication at the technical level, where traditional engineering and geologic studies and investigations are performed, where risk analyses and risk assessments are carried out, and where independent staff check and review studies, analyses, and risk analysis results.
4. Communication at the senior management/decision making level, where funding is secured and decisions are made regarding dam safety actions and risk management decisions on program priorities.

##### **4.5.6.1.1 Dam Site and Project Site Personnel**

The dam tenders, inspectors, staff performing visual inspections and taking readings of seepage and instruments, and plant operators responsible for gate operations provide a valuable source of information relative to risk analyses and need to be included. Dam operators often have detailed information and understanding of the dam history, past performance issues, and a good perspective on perceived changes at the dam. It is important to include them in risk analysis activities to benefit from their knowledge of the dam. In addition, it is very important for them to gain an understanding of potential failure modes at the dam, specific locations at the dam where potential failure modes might develop, and the initiating mechanisms for the potential failure modes. This will allow them to more effectively monitor the dam. Likewise, the results of risk analyses and the decisions and rationale used in risk assessment and risk management need to be provided to these personnel so that they have a full understanding of the outcome of the risk process.

#### **4.5.6.1.2 Local Level**

Supervision and management of the operation of a number of projects and dams are usually the responsibility of a local office within a dam safety organization. These offices have the responsibility to staff for routine operation and maintenance of the projects and dams under their purview, as well as for inspection and monitoring of the dams. In addition, they are often responsible for implementing structural and nonstructural actions which may be specified as the outcome of the risk-informed decision analyses. Often, these local offices cover a number of facilities and manage a staff that must distribute its time between several sites. Local office personnel, as appropriate, also need to be consulted and included in risk analyses relative to failure modes and dam performance, either because they have previously been assigned to dams under their purview and have an intimate historic knowledge and/or they have a broader perspective by virtue of being associated with all the projects and dams under their responsibility. With respect to communicating the findings from the risk analyses, and the decisions from risk assessment and risk management, the local office is typically the key intermediary between the desired objectives of the organization's dam safety office and the field site that will be affected by the outcomes.

#### **4.5.6.1.3 Technical Level**

Detailed communications are required among the technical staff (including consultants and contractors) performing the basic analytical studies and evaluations, the persons performing the risk analyses, and the staff performing the risk studies who will be reviewing studies, analysis reports, and risk analysis reports and making their assessments on specific dams and dam safety issue evaluations. The reports prepared by each previous study level will need to include sufficient detail so that the primary reviewers (as well as analysts in future years) can understand assumptions made, detailed results of studies, analyses and risk analyses, and the technical basis for overall findings.

Further, these results may be called for at any future stage in the process (e.g., risk management, stakeholder review, etc.); thus, good documentation is essential. Briefings are typically performed for technical staff on the results of studies, risk analyses, the overall findings, and the dam safety case for proposed actions. Briefings may also be performed for consultant review boards, which provide an independent review of studies and findings. At this level, the communication will be the most technically demanding.

#### **4.5.6.1.4 Decision Making Level**

Decision makers need to have a general understanding of the potential failure modes at a dam, the results of studies and analyses performed, the risk analysis results, and the dam safety case. Decision makers have the responsibility for formally accepting dam safety actions and must be convinced that the proposed actions are warranted and appropriate. Summary technical information is typically presented in briefings for decision makers, and the detail needs to be sufficient to support the key findings and dam safety case. Individuals who have the responsibility for setting priorities within an organization will also need to understand the basis and urgency of dam safety actions at a given dam. This is needed to prioritize actions across an entire inventory.

#### **4.5.6.2 Communications with Stakeholders**

Risk communication with stakeholders and owners is important in order to be successful. Risk communication and stakeholder participation should ensure that:

1. Responsible and affected stakeholders will be partners and be afforded the opportunity to participate in decisions that affect them, and
2. Communications regarding potential inundation hazard, consequences, and shared solutions will be open, transparent, and understandable.

It may be helpful to include individuals from stakeholder organizations as observers in the risk analysis, especially in the risk assessment meetings. This will allow those individuals to gain a better understanding of the basis of the risk analysis estimates, the subsequent findings, and the rationale on which a decision is made. They will typically be interested in the rationale behind proposed dam safety and will want to ensure that the chosen actions are appropriate and efficient. It will also be helpful to explain the overall dam safety process used and explain the risk guidelines that were used in the risk assessment. Funding partners may enlist consultants to review reports, attend briefings, and interact with technical staff. Detailed technical reports and briefings may need to be provided for consultants.

There may be multiple levels of stakeholders that will be impacted by risks at a given dam or that could be impacted by the risk at another dam upstream or downstream of the

given dam. Impacts may be related to new or updated risk estimates at a given dam or may be related to a change in operations (or expected releases for a given magnitude flood). These potential impacts may need to be shared with dam or facility operators, owners, or the regulators who oversee the facilities.

Local emergency management authorities are key stakeholders in dam risk management. Effective communication of dam risks with emergency management authorities responsible for responses and evacuation actions is essential. Effective risk communication should provide timely and best available information to facilitate the development of response plans and risk mitigation strategies.

Because risk assessments may influence other local, state, or federal agencies, it is imperative that coordination with these respective agencies be accomplished close to the time that the information is provided to the public. This may include the National Weather Service, U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Fish and Wildlife Service, the National Resources Conservation Service, as well as other agencies.

If activities impact or affect tribal land, coordination with the local tribes should also be accomplished.

#### **4.5.6.3 Communications with Organizations and the Public**

Communications should also be provided proactively for organizations and the public that will be, could be, or consider themselves impacted by a dam failure or by dam safety actions that will restrict or modify the operations at the dam. These communications should be initiated at the planning or investigation stage to prevent erroneous information and rumors from developing. Such presentations need to be appropriately technical, conveying the technical information in a manner that conveys the key issues and concerns at the dam, the potential impacts of a dam failure, the proposed actions to address the issues/concerns, and the impacts of these actions on organizations and the public. In addition, the presentation needs to convey the costs and schedule for the dam safety actions.

The diverse audience that attends the public and stakeholder meetings may include persons who can fully comprehend the technical content being presented. Therefore, a definite way to alienate the audience is to presume they are incapable of understanding the work that is planned or has been done. Information should be presented in a manner that is easy to understand but not condescending to the audience. While recognizing this, the presentation should avoid the use of technical jargon and unnecessary detail. Technical staff should be available to answer detailed technical questions from individuals with technical backgrounds that may attend the briefing.

Organizations may have security concerns related to information that is presented in these general briefings or public meetings, and the presentations may have to be adjusted to take this into account. Security concerns will vary with individual dams, and security protocols will vary within each dam owner's organization. Each licensee will need to establish their own guidelines on the type of information and the level of detail that are appropriate for public briefings. Decisions on the level of information to share should balance legitimate security concerns with the benefits of creating a public awareness of potential dam safety issues.

When a situation exists that requires the development of IRRM, it becomes even more critical for public communication.

#### **4.5.7 Communication Planning**

Issuing warnings or hazard/emergency communications is performed by responsible local officials—the mayor, city council, police, fire or emergency management official, and is, therefore, under their direction. Generally, the EAP for a project will identify applicable emergency response officials. Long term communication activities can support the hazard or emergency communication activities by building an awareness of the possible hazard and educating people about possible actions in the event, for instance, what to pack when evacuating, evacuation routes or where shelters are. The guidance provided herein deals more with communication over the long term, and communication planning will include steps to foster better-informed and educated stakeholders.

##### **4.5.7.1 Communication Planning Scope and Elements**

For each step of the risk management process within the dam safety program, it is important that communication planning include elements related to public education, risk communication and any appropriate stakeholder involvement. Research has shown that the most effective plans have these characteristics:

- They are ongoing (not a singular or set of individual acts);
- They use multiple channels of communication to reach the audiences and do not employ a one-size-fits-all strategy (using experts, partnerships with other organizations, various media and events);
- They make full use of a range of communication modes (written materials, television and print media, special events, social media);
- They have effective messages (clear, consistent, posing the problem and solutions, explicit about the potential events, losses, and actions that should be taken, incremental and ongoing);

- They use “windows of opportunity” such as a near miss in a near-by community or a gathering of experts to lead a discussion on a related issue; and
- They have an evaluation component to determine whether the program is successful and where improvements can be made.

Communication plans should include the information shown in Table 4-3.

Communication planning is a management function, accomplished among numerous staff elements.

Table 4-3. Communication Plan Elements (from USACE, 2014)

| Plan Elements          | Element Content   |
|------------------------|---|
| Purpose                | Directly related to the reasons for disseminating and gathering information.  |
| Background and Issues  | Lays out the situation and the issues.  |
| Audience               | Identifies the specific organizations and individuals in the responsible, affected and interested groups with regard to this project.   |
| Messages               | Most important points for the audiences to know including the benefits and services provided by the project, the potential issues and recommended actions by the residents.   |
| Strategy               | How will you achieve the purpose—what methods and communication channels will you use?  |
| Activities and Tactics | What planned activities will support your strategy?   |
| Products               | What products will you develop to provide information. A minimum requirement of a fact paper, talking points and frequently asked questions will provide you with the basic documents to ensure consistent communication. |
| Evaluation             | How will you know the plan’s purpose has been achieved?   |

Social media sites have played an integral role in keeping communities apprised during flooding and other emergency situations as well as on current events. Licensees are encouraged to use social media platforms and tools safely and responsibly to enhance credibility and increase transparency. Social media provides the ability to share information while allowing the public the opportunity to provide comment, ask questions and discuss topics.

For security reasons, numerical risk results, aggregate lists of dams with the assigned DSRC, and inventory ranking **should not be released to the public**. Regional and project specific information may be shared with stakeholders, adjacent and potentially impacted dam owners, emergency responders and Congressional interests, designated as CEII.

Research has shown that many people are not as concerned about the “perceived risk” or “event probability” – just about what they should be doing. However, in projects where

the public and other stakeholders are looked to for input on the decisions, knowing and understanding specifics about the risk is important.

There are basically three challenges that must be addressed (USACE, 2014):

1. **Knowledge.** The audience needs to understand the technical information surrounding the risk assessment. To meet the knowledge challenge, the technical information will have to be presented in a variety of ways.
  - Information materials (pamphlets, fact sheets, and publically releasable reports)
  - Visual representations of risk (graphics, such as simple diagrams, pie charts and conceptual drawings),
  - Face-to-face communication (presentations with vivid projected graphics and handouts),
  - Stakeholder participation (small group discussions with facilitators who are knowledgeable about the risk), and
  - Technology assisted communication (websites and interactive models of risk).
2. **Process.** The audiences need to feel involved in the risk management process. To meet the process challenges, the audience will have to be included in how the risk is being managed. The audience may be involved in helping to develop the ways the decisions will be made, making the decision or even implementing.
3. **Communication Skills.** The audience and those who are communicating the risk need to be able to communicate effectively. To meet the communication skills challenge, those who are communicating must have and react to continual feedback regarding how the information is received and may need to meet with smaller groups or even more often.

Research shows that the kinds of information many people want is related to the actions they should take. Table 4-4 provides examples of target audiences and desired behavior changes. These example types of behavior changes should be considered in communication planning, purpose, and documents.

Table 4-4. Behavioral Change (from USACE, 2014)

| <b>Target Audience</b>                   | <b>Behavior Change Desired (Examples only)</b>   | <b>Information &amp; Tools (Examples only)</b>   |
|--|--|--|
| Homeowners                               | Buy flood insurance on elevate/flood proof home  | National Flood Insurance Program Information; height of potential flooding; information on FEMA assistance with flood proofing; calculator of household damage at various depths of flooding |
|  | Elevate/flood proof home   | Information on FEMA assistance, technical specifications, articulation of financial benefits, calculator of damage with x feet of water  |
| Individuals living in an inundation area | Develop emergency plan   | Examples of emergency plans; height of potential flooding; evacuation routes; checklists for what to take and timeline   |
|  | Evacuate when instructed   | Marked evacuation routes, e-mail alerts, checklists for what to take, articulation of consequences of staying  |
| State and local governments              | Develop and maintain robust emergency action programs  | Information regarding number of people at risk, estimates of damage to critical infrastructure, economic impacts   |
| Developers, realtors, homebuilders       | Promote flood proofing in new construction and renovation  | Long term benefits to clients and customers and the sustainability of the community as a whole   |
| Media                                    | Educate and inform public about dam safety issues  | Info about compliance, educate public about potential consequences of dam failure  |
| School Children                          | Increase geographical understanding of students benefitting from dams, awareness of benefits and risks, encourage parents to know how to evacuate and practice (similar to fire) | Education programs, field trips, incorporate into history and geography curriculum   |
| Insurance                                | Provide financial incentives to those who take steps to mitigate damage through raising buildings, flood proofing and emergency plans  | Mitigation measures that can be provided to customers.   |

#### 4.5.7.2 Dam Safety Communication Fact Sheet

Licensees are strongly encouraged to compile a publicly releasable dam safety fact sheet that provides updated information about the project at each stage within the dam safety

risk management process. This fact sheet should address the incremental and non-breach risk posed by the dam and should graphically display inundation information. Fact sheets should be revised and redistributed as evaluations advance through dam safety risk management process. See Appendix 4C for an example fact sheet used by the U.S. Army Corps of Engineers.

A critical component of risk communication is the non-breach risk, or the dam operating as intended, but the risk that remains from spillway flow without breach or from the dam overtopping without a breach. It is very important for licensees to understand and consider the "non-breach" risk as it applies to normal operations. In most cases, normal operation during high-runoff periods causes the most public concern. The high-runoff periods which result in high river stages downstream of projects may involve high project releases, but are still within the range of normal operations. In some cases, residents/businesses have encroached on the floodway downstream of the project over the years and are under the misperception that downstream flooding would be eliminated, rather than reduced, by the operation of the dam. Incremental unregulated runoff, which is the flow entering the river downstream of the project from tributaries, can be a major contributor to the resultant flow and stages observed at locations downstream of a project. Downstream users need to gain and maintain awareness that each project has a detailed reservoir operations plan and these plans are followed closely as release decisions are made. Most dams are authorized to serve multiple purposes (e.g. flood risk management, hydropower, navigation, environmental compliance, water supply, recreation) and the plan must reflect that.

## 4.6 REFERENCES

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**APPENDIX 4A**

**DAM SAFETY RISK CLASSIFICATION (DSRC) BACKGROUND AND  
EXAMPLES**



## DSRC BACKGROUND AND EXAMPLES

The FERC Dam Safety Risk Classification (DSRC) is intended to provide consistent and systematic guidelines for appropriate actions to address the dam safety issues and deficiencies based on the results of risk analyses and assessments. FERC-regulated dams are placed into DSRC classes informed by their incremental risk considered as the combination of life or economic consequences with likelihood of failure. Consequences of the dam failure considered are lives lost, economic, environmental, and other impacts. Dams are reclassified as new dam safety 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.

The structure and make-up of the DSRC table is very similar to that of the USACE Dam Safety Action Classification (DSAC) and Bureau of Reclamation Dam Safety Priority Rating (DSPR), both of which resulted from the need to formally recognize different levels and urgencies of actions that are commensurate with the different safety status. These actions range from immediate recognition of an urgent and compelling situation requiring extraordinary action through to normal operations and dam safety activities.

Five classes of action are provided to portray the range of actions that are necessary for Licensees to take in executing their dam safety responsibilities. Dams are assigned a DSRC informed by the likelihood of failure initiation or incremental risk.

*NOTE: Many of the examples in this appendix are taken from USACE, Safety of Dams, Policy and Procedures, ER 1110-2-1156, Appendix G, Background Information on the USACE Dam Safety Action Classification System, dated 31 March 2014.*

**DSRC 1 – Very High Urgency of Action.** DSRC I is for those dams where progression toward failure is confirmed to be taking place under normal operations and the dam is almost certain to fail under normal operations within a within a few years without intervention; or the incremental risk – combination of life or economic consequences with likelihood of failure – is very high. This level of life-risk is unacceptable except in extraordinary circumstances.

A summary of the potential actions to be considered and pursued for this class of dams are:

- Take immediate action to avoid failure.
- Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public.

- Implement interim risk reduction measures, including operational restrictions, and ensure that the emergency action plan is current and functionally tested for the initiating event.
- Conduct heightened monitoring and evaluation.
- Expedite investigations to support development of the basis for remediation using all resources and funding necessary.
- Initiate intensive management and situation reports.

Examples of DSRC I dams include:

- **Dam A.** Dam A is experiencing internal erosion of the embankment into the foundation and abutment due to seepage under normal pool elevations, 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 internal erosion through the foundation and abutment and through the embankment along the conduit during all pool elevations which may rapidly progress to breaching of the dam. 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 internal erosion of the embankment material. The left abutment is composed of cohesionless granular glacial deposits and has experienced significant seepage during normal pool events. The project has had several test fillings and additional 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.

- Dam C. The most likely potential failure mode is internal erosion of the embankment material into the foundation and abutments. 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 percent 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.

**DSRC 2 – High Urgency of Action.** DSRC II is for dams where failure could begin during normal operations or be initiated by an event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public safety; or the incremental risk – combination of life or economic consequences with likelihood of failure – is high. This level of life-risk is unacceptable except in extraordinary circumstances.

Potential actions to be considered and pursued for this class of dams are:

- Communicate findings to local, state, Federal, Tribal officials, and the public.
- Implement interim risk reduction measures, including operational restrictions as warranted, and ensure that the emergency action plan is current and functionally tested for the initiating event.
- Conduct heightened monitoring and evaluation.
- Expedite confirmation of classification.
- Give very high priority for investigations to provide the basis to support remediation.

Examples of DSRC II dams include:

- Dam D. The most likely potential failure mode is breaching of the dam by concentrated erosion of the embankment material through cracks in the core caused by significant displacements of the upstream shell during an Operating Basis Earthquake (OBE) or greater earthquake. 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 and will quickly progress to breach of the remaining dam embankment. 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 potential failure mode is backward erosion piping in the foundation. Deficiencies in the design and construction techniques contribute to internal erosion at moderately high pools – annual exceedance probabilities of 0.05 to 0.01. 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. It is possible that seepage through the lift joints in the concrete section may be entering embankment materials.
- Dam G Dam is overtopped by several feet at 80 percent 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 though the failure mode is driven by a near PMF event.

**DSRC 3 – Moderate Urgency of Action.** DSRC III dams have issues where the incremental risk – combination of life, economic, or environmental consequences with likelihood of failure – is moderate. This level of life-risk is unacceptable except in unusual circumstances.

Potential actions to be considered and pursued for this class of dams are:

- Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public.
- Implement interim risk reduction measures, including operational restrictions as warranted, and ensure that the emergency action plan is current and functionally tested for the initiating event.
- Conduct heightened monitoring and evaluation.
- Prioritize investigations to provide the basis to support remediation as informed by consequences and other factors.

Examples of DSRC dams include:

- Dam H. The most likely potential failure mode is backward erosion piping through 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. 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. The dam is estimated to be overtopped by several feet by the probable maximum flood and the embankment is expected to be breached by erosion under this loading condition. The volume of water behind this dam at the higher pool elevations would create low to moderate loss of life consequences.
- 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. The assessment 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.

**DSRC 4 - Low Urgency of Action.** DSRC IV dams are inadequate with low incremental risk such that the incremental risk – combination of life, economic, or environmental consequences with a likelihood of failure – is low and the dam may not meet all *FERC Engineering Guidelines*. This level of life-risk is in the range of tolerability, but the dam may not meet ALARP or all *FERC Engineering Guidelines*.

Potential actions to be considered and pursued for this class of dams are:

- Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public.
- Conduct elevated monitoring and evaluation. When the assigned DSRC for a dam is changed from a 1, 2, or 3 to a 4 (I, II, III, or IV) the licensee will review the available risk assessment information, (such as potential failures modes, associated loads on the dam, performance of the dam, and related consequences) to identify the appropriate level of monitoring and evaluation above the routine level. The level of monitoring must be such that it will provide the licensee with an adequate level of awareness and lead time to take any actions needed if there is indication of deteriorating performance of the dam.
- Give normal priority to investigations to validate classification, but do not plan for interim risk reduction measures at this time.

Examples of DSRC IV dams include:

- Dam J. The embankment has a potentially preferential seepage path along the top of the outlet conduit and may result in internal erosion 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 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 extreme events. 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 *FERC Engineering 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.

**DSRC V – Normal Urgency of Action.** DSRC V is for dams where the incremental risk - combination life, economic, or environmental consequences with likelihood of failure – is very low and the dam meets ALARP and all *FERC Engineering Guidelines*. This level of life-safety risk is tolerable.

Potential actions include continuing routine dam safety activities and normal operations, maintenance, monitoring, and evaluation.

An example of a DSRC V dam includes:

- Dam L meets the requirements for hydrologic capacity for passing the most current inflow design flood (IDF), there are no known internal erosion issues, 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. 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 incremental risk indicates that the risk is tolerable for all design loads and the dam is “safe.” Normal operations require due diligence by the licensee to perform the requisite monitoring, evaluation, maintenance, and training to actively manage the inherent incremental risk associated with any dam with the goal to keep the incremental risk at or below the that which is considered tolerable for the respective dam.



**APPENDIX 4B**

**INTERIM RISK REDUCTION MANAGEMENT PLAN REVIEW CHECKLIST**



## INTERIM RISK REDUCTION MANAGEMENT PLAN REVIEW CHECKLIST

1. Overall Project Description and Purposes. Make sure the description includes a brief summary of construction and operational history including remediation and past and current problems. A summary of instrumentation would be good as well (needs to be in appendix). This helps provide sufficient background for evaluating the validity of the potential failure modes and how they relate to the history of the dam.
2. Overview of Identified “Credible and Significant” Potential Failure Modes. Include an overview of all credible and significant potential failure modes from most recent PFMA. If a facilitated PFMA has not been done, it should be identified as an IRRM and completed as soon as practical.
3. General Consequences Associated with Each Identified Potential Failure Mode. Estimates for each potential failure mode should be included. Consequences should include at least a qualitative estimate of consequence.
4. Structural and Nonstructural IRRM Alternatives. Alternatives considered to reduce the likelihood of failure and/or consequences associated with the failure modes (reservoir pool restrictions and modification of reservoir regulation plan must always be included as an option that is addressed).

Reservoir Restrictions. If a reservoir restriction or pool deviation has been ruled out, very specific reasons should be included as to why.

Non-Structural IRRM. Non-structural measures such as increased monitoring and surveillance, stockpiling materials, help to reduce likelihood of failure by early detection and ability to intervene should an incident occur. Non-structural measures can also be testing of EAP for better notification and evacuation, updated EAP inundation mapping, etc. that all reduce potential life loss.

Structural IRRM. These measures typically improve the system response which will reduce the likelihood of failure.

For each considered IRRM, a detailed explanation of how the measure reduces system loading, uncertainty in the load, improves the system response, or reduces the estimated consequences.

5. Discussion of Likelihood of Failure and Consequences. A general discussion of how predicted reduction in risk (the likelihood of failure and associated consequences) impact on project purposes, environmental impacts, and economic impact to region associated with potential IRRM, both positive and negative is

provided. This will help reviewers discern if the cost of the IRRM is clearly warranted based on its estimated risk reduction.

NOTE. Analysis does not reduce risk – just reduces the uncertainty associated with the risk estimate.

Has NEPA coordination been started and continued throughout the process?

6. Recommendations and Risk-Informed Basis for IRRM to be Implemented. Each basis for action should include an estimate of the risk reduction from the IRRM implementation. Address potential for reduction in likelihood of failure and consequences along with the estimated cost and impacts on other aspects of the project (possibly environmental, recreation, flood reduction, ability to execute). A table of this information by IRRM should be included as a summary.
7. Schedules for Implementation of IRRM Recommendations. Verify the IRRM's have been prioritized and consider the expediency of reducing overall risk. Prioritization must consider the expediency of implementing the IRRM. Resources, capability, execution time, and the time to complete the dam remediation must all be considered when prioritizing IRRM's. For example, a warning system IRRM may take 2 years to design, coordinate, and construct while performing a table top exercise with the local emergency managers can be done in the next 2 months. Clearly one is more expedient than the other. IRRM's that can be implemented quickly should be given high priority particularly those that impact the ability to warn and help evacuate the public including increased monitoring and surveillance.
8. Estimate of Benefits for IRRM (DSRC I Dams). Include the proposed schedules for conducting a risk-based assessment to estimate the benefits and costs for incremental evaluation of IRRM. This is primarily for DSRC I dams where significant and urgent risk reduction is necessary.
9. Updated EAP. The IRRMP should include updating the EAP to reflect site specific risks, and include emergency exercises for DSRC I, II, and III dams conducted in manners that are appropriate for the risk involved. Specifically it should include the local emergency managers for DSRC I, II, and III dams.
10. Communication Plan (Internal and External). Verify communication plan is in place and a way of addressing the questions and requests of the media, stakeholders, and public is in place. Check the schedule for media training based the DSRC, and discuss how the plan will be updated as the study progresses.

**APPENDIX 4C**

**EXAMPLE DAM SAFETY FACT SHEET**



## EXAMPLE DAM SAFETY FACT SHEET

Dam Safety Fact Sheet. Licensees are strongly encouraged to prepare a Dam Safety Fact Sheet, for public release, at the completion of any risk analysis performed on a dam in support of their dam safety risk management activities. The fact sheet should contain an inundation map. This is a map showing the predicted extent of inundation from controlled or uncontrolled reservoir releases for a pre-determined event scenario or scenarios. Releases may be a result of normal reservoir operation, a result of structural failure or a result of misoperation.

Fact Sheet Template. Figures 4C-1a and 4C-1b provide an example template for the fact sheet that the USACE uses for such purposes that is releasable to the general public. Each dam owner should determine what information is appropriate to include in a public release. As an example, the USACE uses the following guidelines when preparing a dam safety fact sheet for public release:

1. The *light blue* italicized text on Figures 4C-1a and 4C-1b is to be edited to fit the specifics for each dam.
2. Add a project overview photograph. After pasting, format picture for “square” text wrapping, and set picture border to black, if necessary. Locate the picture in the upper right corner of the text for Project Location and Description, just below the banner. Limit the picture size to about 2.5 to 3 inches wide by 1.5 to 2 inches tall.
3. Project Location and Description (first paragraph): List the authorized purposes for the dam and related benefits.
4. Project Location and Description (second paragraph): Describe the main components of the project but avoid using technical terms. Provide the spillway capacity in gallons per unit of time (seconds, minutes, or hours, whichever is more meaningful) and provide the swimming pool volume-equivalent. An Olympic-sized swimming pool contains about 2.5 million liters of water or 660,430 gallons, and 1 cubic foot is equivalent to 7.48 gallons.
5. Project Location and Description (third paragraph): Describe the operation of project.
6. Benefits associated with XYZ Dam: Provide pertinent information for benefits provided by the dam. Highlight flood damages prevented by any recent major flooding.

7. Risks associated with XYZ Dam: Use the incremental risk category (low, moderate, high, or very high) that corresponds to the DSAC (DSRC) rating. Provide a very short summary of the dam safety issues that support the DSAC (DSRC) rating in general terms without providing specific location detail which could be used by an adversary. **Neither inspection reports nor numerical calculations are to be publicly released in an uncontrolled or unrestricted manner.** However, information that may help inform the public of the risk may be summarized. All DSAC 1 through 3 (DSRC I through III) dams (moderate, high, or very high risk) are required to have IRRM implemented. IRRM are not required for DSAC 4 (DSRC IV) dams, but elevated monitoring and evaluation may be performed.
8. What residents should know: List primary impact areas by city and state. Provide a map of a scale such that features of the dam and individual structures in the flood plain are not easily discerned. Include impacted downstream communities and provide flood wave arrival time and peak flood elevation in NAVD. After pasting, format picture for “square” text wrapping, and set picture border to black, if necessary. Locate the picture in the upper right corner of the text on Page 2. Limit the picture size to less than about 4 inches wide by 2.5 tall. Compress picture after sizing to reduce the file size.
9. Public Awareness (XYZ Dam Facts): Structures at risk by reservoir level are not always available. Therefore for the fact sheet may state the data is not available. Include structures at risk if the data is available.
10. For additional information: If there are multiple emergency management agencies (i.e., multiple counties or communities affected), then do not include a phone number.
11. Modify the footer with the appropriate contact, mailing address, and web address. Add the date of release.



## USACE Dam Safety Facts for *XYZ Lake Dam* (10 July 2013)

U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG®

**Project Location and Description:** *XYZ Lake Dam was designed and built by the U.S. Army Corps of Engineers (USACE) and completed in 1974. USACE operates XYZ Lake Dam for flood damage reduction, municipal and industrial water supply, water quality and recreation.*



*The main components of the project are earthen embankment section, a gated outlet works, and an ungated spillway for releases during major flood events. The ungated spillway is located on the right abutment (looking downstream) and is 210 feet wide with a crest elevation of 984.4 feet above mean sea level. The spillway can pass up to 295,181 gallons per second (9,460 cubic feet per second) or approximately half the volume of an Olympic size swimming pool each second. The earthen dam is 2,900 feet long, 178 feet high, and top of the dam is 30 feet wide. The elevation of the top of the earthen embankment is 1018.4 feet above mean sea level. The foundation is made up of clay, silt, sand, cobbles, and boulders.*

*During the fall and winter months, when excessive rainfall is likely, the lake is kept at a relatively low level (referred to as winter pool). Should heavy rains occur, surface water runoff is stored in the lake until the swollen streams and rivers below the dam recede and can handle the release of stored water without damage to lives, property or the environment. Sometimes water must be released to protect the dam's integrity even though streams and rivers may have already reached or exceeded their capacity.*

**Benefits associated with XYZ Lake Dam:** *This dam has provided \$486,000 in annual flood damage reduction since placed into service. During the YYYY flood the dam prevented inundation of YYY acres or ZZZ square miles and \$xxx in flood damages. XYZ Lake provides 92,400 acre-feet of water to a number of communities downstream of the dam. The annual water supply benefits gained from XYZ Lake amount to nearly \$22 million. Annual recreational benefits to the area are \$4.5 million.*

**Risks associated with dams in general:** Dams reduce the risk of damages and loss of life from inundation due to floods but do not eliminate this risk. Large amounts of water that could cause flooding downstream might have to be released when a flood exceeds the reservoir's storage capacity (such as during a large flood or storm event). This release could be damaging. A fully functioning dam could be overtopped when a very rare or infrequent, large flood comes along. Or, a dam could breach because of a deficiency, which raises the risk of property damage and life loss even further. This means there will always be inundation risk that has to be managed. To manage these risks USACE has a routine program that inspects and monitors its dams regularly. USACE implements short and long term actions, on a prioritized basis, when unacceptable risks are found at any of its dams.

**Risk associated with XYZ Lake Dam:** Based upon the most recent risk assessment of *XYZ Lake Dam in 20XX*, USACE considers this dam to be a *high risk* dam among its more than 700 dams *because of the risk associated with spillway and/or stilling basin wall overtopping and erodability in extreme events; embankment piping along a outlet works conduit; and embankment erosion and instability from high discharge flow at the downstream toe of the dam.* (For low risk dams state the following.) USACE manages this risk by conducting routine monitoring and evaluation. (For moderate, high, and very high risk dams state the following.) USACE has implemented interim risk reduction

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ENTER ADDRESS HERE, ENTER WEB ADDRESS HERE  
FACT SHEET DATE OF RELEASE – DD/MMM/YYYY

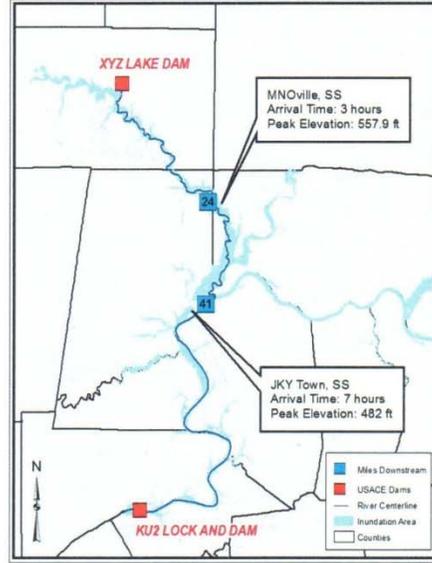
Figure 4C-1a – Example USACE Dam Safety Fact Sheet (Page 1)

measures and/or long term risk reduction measures to reduce this risk. *(List any pool restrictions that have been implemented.)*

**What residents should know:** Dams do not eliminate all inundation risk, so it is important that residents downstream from the dam are aware of the potential consequences should the dam breach; not perform as intended; or experience major spillway/outlet works flows. The *high risk* in *(list the communities immediately downstream of the dam)* XYZville, SS and the related consequences further downstream warrant increased efforts on the part of USACE, local emergency management officials and residents to heighten awareness of the potential inundation risk associated with the dam.

The primary areas impacted should the dam breach with a full reservoir during a rare flood event; or experience major spillway/outlet works flows are shown in the map. The potential for loss of life is highest *within a couple of miles of the dam with the loss of life concerns decreasing substantially beyond 60 miles downstream of the dam.*

Advanced warning of problems and events plays a major role in protecting life and property. See the map for a general indication of breach with a full reservoir during a rare flood event.



**Public Awareness:** Dams are designed to pass large amounts of water on a regular basis and this means there will always be inundation risk that has to be managed (see table below).

| Recommendations for Residents  | XYZ Lake Dam Facts  |
|--|---|
| <ul style="list-style-type: none"> <li>Living with flood risk reduction infrastructure comes with risk—know your risk.</li> <li>Living with flood risk reduction infrastructure is a shared responsibility—know your role.</li> <li>Know your risk, know your role and take action to reduce your risk.</li> <li>Listen for and follow instructions from local emergency management officials.</li> <li>Strongly consider purchasing flood insurance.</li> <li>Contact your elected local, county and state officials to make sound flood risk management decisions in your area.</li> </ul> | <p><b>Estimated consequences for a dam breach with the reservoir at top of active storage &amp; rare flood event. (Top Active Storage-Fail) / (Max. High -Fail)</b></p> <ul style="list-style-type: none"> <li>Population at risk: 12,300 / 16,900</li> <li>Structures at risk: 4,700 / No data available</li> <li>Land and property at risk: \$1.2 billion / \$1.7 billion</li> </ul> <p><b>Estimated consequences for the non-breach maximum spillway release (Max High-No Fail)</b></p> <ul style="list-style-type: none"> <li>Population at risk: 4,200</li> <li>Structures at risk: No data available</li> <li>Land and property at risk: \$194 million</li> </ul> <p>Damages prevented to date: \$15 million (1974-2005)<br/>National Inventory of Dams # SS99999</p> |

Residents should listen to and follow instructions from local authorities. For more information, please contact USACE ZDCDEF district office using the information on this fact sheet. You can also contact your local emergency management office at (###) ###-####.

For additional information about dam safety and living with dams, please visit <http://www.usace.army.mil/Missions/CivilWorks/DamSafetyProgram.aspx> and [http://www.damsafety.org/media/Documents/DownloadableDocuments/LivingWithDams\\_ASDSO2012.pdf](http://www.damsafety.org/media/Documents/DownloadableDocuments/LivingWithDams_ASDSO2012.pdf)

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Figure 4C-1b – Example USACE Dam Safety Fact Sheet (Page 2)