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Sustainment Management Systems Program

Sustainment Management System Dams Inspection Module

Department of Defense Dams Inventory and Inspection Template

James P. Allen, Stuart D. Foltz, and Matthew H. Werth

June 2018

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Sustainment Management System Dams Inspection Module

Department of Defense Dams Inventory and Inspection Template

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Under Project L9GDHG, "SMS Dam Inspection Module - WHS" OASD(EI&E)FIM

Abstract

The Department of Defense (DoD) owns over 800 dams and levees. These structures have requirements that are distinct from other asset classes, including federally required periodic inspections by qualified inspectors. The DoD Inspector General has required DoD to implement an inspection policy for these types of structures. This report documents the DoD's current inventory, processes, and systems related to dams; defines inspection requirements consistent with U.S. Army Corps of Engineers and federal processes; and proposes a framework that could be used to include dams in the DoD's sustainment management system (SMS) that is used by all service components for conducting facility inspections and assessments. The report includes a dam inspection and SMS framework with requirements to support the inspection of dams by installation or contract engineers.

The authors concluded that a data structure for dam inspections similar to the inventory catalogs of other SMS modules would assist DoD in reporting results of formal inspections, conducting intermediate and informal inspections, and providing assistance for future efforts to create condition forecasting and work planning models for dams. It is proposed that a working group be formed from members of the DoD services to elaborate on the proposed template and to formulate future requirements.

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Preface

This study was conducted for the Assistant Secretary of Defense for Energy, Installations, and Environment (ASD(EI&E)) and Facilities Investment Management (FIM) under Project L9GDHG, “SMS Dam Inspection Module – WHS.” Mr. Robert Lang is the sponsor’s technical monitor for this work.

The work was performed by the Engineering Processes Branch (CFN) of the Facilities Division (CEERD-CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. Charles Schroeder was Chief, CEERD-CFN; Mr. Donald K. Hicks was Chief, CEERD-CF; and Mr. Alan Anderson was the Technical Director for Lands and Ranges, CEERD-CZT. The Deputy Director of ERDC-CERL was Dr. Kirankumar V. Topudurti, and the Director was Dr. Lance D. Hansen.

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The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. David W. Pittman.

Unit Conversion Factors

Multiply	By	To Obtain
acre-feet	1,233.5	cubic meters
feet	0.3048	meters
inches	0.0254	meters

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1 Introduction

1.1 Background

The Department of Defense (DoD) Inspector General (IG) conducted a review of dam safety and summarized the findings in a report (DoD 2014). In that report, the DoD IG makes the following recommendations:

- Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) establish dam safety inspection policy that is in accordance with the Federal Guidelines for Dam Safety, which define inspection frequency, scope, and inspector qualifications, and outline the need to develop and maintain inspection support documentation.
- Secretaries of the Army, Navy, and Air Force, and the Commandant of the Marine Corps implement a dam safety inspection program in accordance with DoD dam safety inspection policy, after that policy is issued.

The DoD seeks to more clearly understand and maintain visibility of its dam inventory and dam conditions in order to establish the policies outlined in the above review.

This technical report begins the process of examining the feasibility and framework for a Sustainment Management System (SMS) for dams that could address some of the DoD IG recommendations. An overall SMS Enterprise is one part of the DoD's solution for managing infrastructure assets. In September 2013, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) issued a policy titled "Standardizing Facility Condition Assessments" that requires DoD components to use the SMS for conducting and documenting facility inspections; however, a current SMS tool specific to dams or other water retention facilities does not yet exist. The U. S. Army Engineer Research and Development Center - Construction Engineering Research Lab (ERDC-CERL) is designated as the SMS Technical Center of Expertise (TCX). In this role, ERDC-CERL provides assistance to DoD agencies and offices in SMS scope of work for development, implementation planning, and data management. This project will leverage the existing SMS methodology and tools and will propose a framework for apply-

ing SMS to over 800 DoD dams; as per the fiscal year (FY) 2014 real property database, the DoD owns and manages 824 dams on military installations (Army – 541; Marines – 55; Navy – 155; Air Force – 73).

1.2 Objective

The objective of this effort is to understand the current DoD inventory of dams, document current DoD processes and systems related to dams, define dam inspection requirements consistent with processes of U.S. Army Corps of Engineers (USACE) and other federal agencies, and then, propose a framework which will be used in the future to include dams in the DoD's SMS that is used throughout the service components for conducting facility inspections and assessments. The product of this effort is a dam inspection and SMS framework with requirements to support the inspection of dams by installation engineers or by contract support.

1.3 Approach

This report begins by laying a foundation of common understanding for dam safety-related laws, regulations, and existing inspection criteria of the Federal Emergency Management Agency (FEMA), including the National Inventory of Dams. The report examines the common design components and functionality of dams and the USACE Civil Works program requirements that relate to very large and complex dams. This background is then used as a lens with which to analyze the current DoD inventory and the current systems, processes, and procedures for managing dams utilized by various service components.

This report then reviews the current dam inventory, assessment, analysis, work planning, and forecasting procedures as they are within DoD. Documented system information was collected from interviews with Army, Navy, Air Force, and Marine facility management personnel. Finally, this report provides an overview of the SMS's typical methodology and then, it proposes an inspection module be created within the SMS framework to support dam inspections by DoD installation engineers. This module can help ensure that dams on DoD installations are routinely inspected by following standardized procedures and ensuring that consistent data is maintained in an easily accessible database. This report identifies appropriate items within disparate DoD systems that could be brought into the existing SMS Enterprise for a more holistic understanding and monitoring of dam facility condition.

2 Dam Safety Background

This chapter provides a brief overview of dams and their regulation and maintenance. The purpose of this chapter is to build a background for the conclusions and recommendations found in chapter 7 of this report. A general understanding of the concepts presented is needed to judge those conclusions.

The scope of this report includes both dams and their appurtenant works. Federal law—The National Dam Safety Act (U.S. Congress 2006)—defines a dam as follows:

“...any artificial barrier that has the ability to impound water, wastewater, or and liquid-borne material, for the purpose of storage or control of water...”

The design, construction, and management of levees can be quite similar to that of dams. Some levees may even fall into the definition given above, such as the case when a ‘levee’ is constructed to constrain the reservoir created by a dam. However, for the purposes of this report levees will be considered a separate type of structure. The primary difference between the two is that dams have their long axis oriented perpendicular to the normal flow of water, while levees are oriented parallel to flow. This distinction serves the interests of the sponsor of this report.

2.1 Federal regulatory authority, policy documents, and laws

The federal government’s dam safety program is authorized in Title 33 of the U.S. Code, Chapter 9, subchapter VII.¹ This law designates FEMA as the agency to coordinate federal dam safety efforts, including those of the DoD.

The principal policy document regarding dam safety is the *Federal Guidelines for Dam Safety*, also known as FEMA-93 (FEMA 2004a). This document was developed based on the input from an ad hoc committee convened in 1977, in the wake of the infamous Teton Dam failure. That committee’s report found that federal dam management practices, at that time authorized by the National Dam Inspection Program Act 1972 (U.S.

¹ <http://uscode.house.gov/view.xhtml?path=/prelim@title33/chapter9/subchapter7&edition=prelim>

Congress 1972), were inadequate. Shortly thereafter in 1979, Executive Order (EO) 12148 was enacted (1979), which created FEMA and made it responsible for coordinating all federal dam safety efforts. FEMA has since published several supporting documents regarding dam safety in addition to FEMA-93, including the following:

- FEMA 333 – Hazard Potential Classification System for Dams (FEMA 2004c)
- FEMA P-94 – Selecting and Accommodating Inflow Design Floods for Dams (FEMA 2013b)
- FEMA 64 – Emergency Action Planning for Dams (FEMA 2013a)
- FEMA 145 – Dam Safety: An Owner’s Guidance Manual (FEMA 1987)
- FEMA-65 – Earthquake Analyses and Design of Dams (FEMA 2005)
- FEMA-148 – Glossary of Terms (FEMA 2004b)

Congress subsequently amended the original National Dam Inspection Program Act several times. Below is a list of laws that amend the National Dam Inspection Program Act, according to the Association of State Dam Safety Officials (ASDSO n.d.):

- Public Law (P.L.) 99-662, Water Resources Development Act of 1986 (U.S. Congress 1986)
- P.L. 104-303, Water Resources Development Act of 1996 (U.S. Congress 1996)
- P.L. 107-310, Dam Safety and Security Act of 2002 (U.S. Congress 2002)
- P.L. 109-460, Dam Safety Act of 2006 (U.S. Congress 2006)
- P.L. 113-121, Water Resources Reform and Development Act of 2014 (U.S. Congress 2014)

While federal dams are not under state-level dam safety jurisdiction, some amount of cooperation with each state’s dam safety agency is required by law. Federal agencies are required to allow states to participate in the inspection of any dam which poses a risk to the state it resides in, and to inform the state on the construction, condition, operation, and emergency planning for such dams. Federal agencies must also notify the governor of the state in question if a hazardous condition is found in a dam that could affect the state.

2.2 Dam safety overview

The goal of dam safety is to ensure a reasonably low risk to life and property downstream. It is generally understood that risk cannot be eliminated from the dam management process, and the existence of a dam may either increase or decrease the overall risk to downstream areas. Rather than seek to eliminate risk, dam managers must seek a level of “tolerable risk,” which is “a risk within a range that society can live with so as to secure the benefits provided by the dam.” (FEMA 2015)

Safety programs may either assess risk directly, as does the USACE and Bureau of Reclamation, or rely on a standards-based approach where the standards are implicitly risk-informed. The general standard is that dams must pose a risk that is “as low as reasonably practicable” (ALARP). The concept of ALARP implicitly acknowledges that society is willing to accept some amount of risk to secure the benefits of the dam, and that monetary costs may be weighed against safety concerns.

Dams are generally required to meet two criteria related to risk—limiting life loss and limiting dam failures. Each of these criteria contribute to the overall risk analysis for a given dam and are unique to individual structures. The calculation of these values is complex and requires both technical expertise and some degree of practical assumptions.

The foremost concern is that a dam is expected to pose a minimum risk to life, and that events that threaten more lives are expected to occur less often than those that threaten fewer people. This criterion is commonly described as a maximum Average Annualized Life Loss (AALL), which is understood to be the sum of the lives expected to be lost for all potential failure modes of the dam. A typical value for an allowable AALL is 10^{-3} lives per year (USACE 2014). Note that it is only required to consider the incremental risk to life; that is, the difference in life risk posed by the failure of the dam compared to the same event had the dam’s failure not occurred.

Dams are expected to have an acceptably low overall probability of failure. This goal clearly overlaps that of limiting life loss, since all dam failures involve some potential for life loss. The intent is to provide a minimum amount of safety for people that are only rarely downstream of the dam (e.g., campers, fishers) and may therefore be undercounted in the AALL calculation. This also provides a minimum amount of reliability for the

primary function of the dam. This criterion is commonly referred to as an Annualized Failure Probability (AFP), where 10^{-4} failures per year is a common standard.

For both of these criteria, it is necessary to evaluate the probability of the loads sustained by the dam, the likely response of the dam to those loads, and the consequences of failure given those loads. The loads usually considered for the purposes of risk management are the inflow flood and earthquakes. Federally regulated dams are required to sustain loads associated with the probable maximum flood (PMF) and the maximum credible earthquake (MCE). These loads represent events that are very unlikely to occur and may be expressed explicitly by the return period of the event (e.g., a 50-year flood or a 500-year earthquake). Dams built to resist those loads therefore meet an implied minimum standard for AFP.

2.3 Hazard classifications

Dams are classified according to regulations outlined in FEMA-333, titled “Hazard Potential Classification System for Dams” (FEMA 2004c). The FEMA hazard classification describes the potential consequences of the failure of a dam, without regard to the mechanism or overall probability of failure. The hazard classification of a dam is an important factor in dam safety management, since it gauges the magnitude of the risk posed by the dam. However, frequency of failure data is also necessary to form a complete picture of the risk posed by a dam. Table 1 shows the Corps of Engineers’ definitions for the three hazard classifications.

Table 1. National Inventory of Dams (NID) hazard potential classifications (USACE 2008).

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses
High	Probably 1 or more	Yes (but not necessary for this classification)
Significant	None expected	Yes
Low	None expected	Low, and generally limited to owner’s property

Additionally, in order to be included in the NID, low hazard dams must meet one of the following criteria:

- Equal or exceed 25 feet in height and exceed 15 acre-feet in storage.
- Equal or exceed 50 acre-feet in storage and exceed 6 feet in height.

Some state dam safety programs further distinguish between high hazard classifications based on the estimated life loss associated with dam failure. For example, the State of Washington subdivides the NID high hazard potential classification into three parts, based on the population at risk during a dam failure (Washington State Department of Ecology 2007). The intent of these classifications is to aid in apportioning funding and inspection time between dams. Table 2 shows the alternate classification system in use by Washington State.

Table 2. Washington State hazard classifications
(source of data: Washington State Department of Ecology 2007).

NID Hazard Potential	Washington Hazard Classification	Population at Risk
Low	3	0
Significant	2	1–6
High	1C	7–30
High	1B	31–300
High	1A	300+

2.4 Existing inventories

DoD dams appear in at least two different databases; the real property database, and the NID. The real property database is the authoritative source for the inventory of all DoD dams. The systems used to maintain the real property database vary by service (e.g., the Headquarters Installation Information System (HQIIS) for the Army or the internet Navy Facilities Asset Data Store (iNFADS) for the Navy). The NID is maintained by the Corps of Engineers, and it is published based on information provided by dam owners. The most recent version of the NID is from 2016; USACE plans to publish an updated version every 3 years.

Generally speaking, every dam listed in the NID is also listed in the real property database, but the converse is not always true. For example, 258 dams were found in the 2016 NID which were owned by the DoD, compared to 824 found in the FY2014 real property database. This comparison implies that only 31% of the DoD inventory is captured in the NID. Most

DoD dams listed in the NID (74%) are classified as Low Hazard Potential (USACE 2016). The remaining dams are either classified as Significant (9%) or High (17%) Hazard Potential. Figure 1 shows the distribution by hazard potential of dams owned by the DoD, as reported in the 2016 NID (USACE 2016).

Figure 1. Distribution by hazard potential in NID for 258 DoD dams (USACE 2016).

2.5 Dam purposes

Dam management decisions implicitly weigh economic considerations alongside safety considerations. It is therefore important to the dam management process to know what benefits accrue from the operation of a dam. The purpose for which a dam was constructed affects the features added to its design and, to some extent, the construction method used to build the dam. In turn, the design features present in a dam affect the safety- and maintenance-related issues encountered by dam managers.

For example, dams constructed for hydroelectric power generation require electrical generation turbines and may merit a higher overall tolerance for risk compared to a dam that is purely for recreational purposes. The distribution of the uses of DoD dams reported to the NID in 2016 is shown in Figure 2. Note that some dams may be either recently reclassified or will

be in the near future, as many DoD dam owners are in the process of reassessing the need for many of the dams in the current inventory.

Figure 2. DoD dams by NID “purpose” (USACE 2016).

Because dams may be constructed for more than one purpose, the sum of the numbers presented in Figure 2 is greater than the total number of DoD dams in the NID. Note that there are 90 DoD dams listed in the 2016 NID that have more than one purpose listed.

By far the most common use of DoD dams in the NID is recreation (190 dams), followed by the closely related purpose of fish and wildlife cultivation (66 dams). Relatively few (2 dams each) are constructed for hydroelectric power generation or navigation. Based on discussions with Directorate of Public Works (DPW) and dam management personnel, many DoD dams were originally constructed to provide a water supply for the base in question, but those bases now use public utilities to supply their water. Hence, many of these DoD dams have been reclassified as either recreational or fish and wildlife dams.

2.6 Construction types

Dams are generally custom-built structures, where the exact dimensions and materials used are dependent on the characteristics of the site in question and the dam's intended purpose. Regardless of the type of construction, dams are constructed of the same two principal parts—the body, and the outlet works. The body of the dam transmits all forces exerted on the dam to the foundation. The outlet works allows water to pass from the reservoir to the downstream channel without damage to the dam's body.

Dam bodies may be constructed in a variety of types. In decreasing order of prevalence, the most common types are embankment, gravity, arch, and buttress. Gravity, arch, and buttress types of dams are typically concrete structures, but they may be made by using stone masonry or timber. Gravity and buttress types of dams use the weight of the structure and the friction between the body and its surroundings to distribute loads to the foundation. Arch dams rely on thrust from the adjacent landmasses, which are called abutments.

Embankment dams may be thought of as a special kind of gravity dam, since they also use the weight of the embankment and friction with the foundation to resist loads. However, embankment dams are constructed by using layers of compacter fill rather than concrete. The primary materials used in embankment dams are earth and rock.

The choice of dam type and construction material is primarily determined by the dam's location and intended purpose. Concrete dams of every type are more susceptible to cracking due to foundation settlements, and they are generally only used when hard foundations are present. Concrete arch dams may only be constructed where abutments with sufficient strength to resist the thrust of the arch are present at the dam site. Most often, the design of a dam is dictated by economic concerns. Hauling building materials from off-site sources is usually not practical. Thus, most dams utilize whatever material is readily available on or near the site.

Earth and rock fill dams are often constructed with multiple zones of differing materials, as shown in Figure 4. Zoned fill dams are intended to limit the amount of water seepage through the body of the dam and the possibility of internal erosion. The impervious zone may be constructed from either compacted fill or concrete. The exact composition of the dam

body may not be apparent from visual inspections of a completed dam. Detailed as-built plans are therefore an important tool for dam inspectors.

Outlet works may be subdivided into structures typically known as either spillways or (simply) as outlet works. The difference between the two is that spillways usually conduct water over the top of the body, while outlet works allow water to flow through or under the dam. Both outlet works and spillways may have features allowing for the controlled release of water.

Figure 3 shows the distribution of construction types for DoD dams in the 2016 NID. Almost all DoD dams (234 out of 258 total) use an earth embankment as the primary load resisting structure, with most of the remainder using concrete (15 of the 24 remaining; note that gravity type dams are typically concrete).

Figure 3. DoD dams by NID type (USACE 2016).

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Figure 4. Types of earth and rock embankments (U.S. Bureau of Reclamation 2007).

2.7 Required inspections

Federal law requires periodic inspections of dams owned and operated by the DoD. The requirements are presented in detail in the FEMA-93 document titled “Federal Guidelines for Dam Safety” (FEMA 2004a). Inspections performed in accordance with this document are intended to meet the requirements of the National Dam Inspection Program Act of 1972 and its subsequent amendments.

In its glossary, FEMA defines four type of inspections, as follows: formal, intermediate, informal, and special (FEMA 2004b). Formal inspections are required at least every 5 years, while special inspections are to be scheduled after any unusual event such as large floods or earthquakes. Both formal inspections and special inspections require the direction of a

licensed professional engineer. Professional engineers are usually accompanied by specialists with knowledge of the types of features present on the dam in question. Formal inspections involve a review of the design and construction of the dam as well as a detailed visual inspection of the dam itself.

Intermediate inspections are required by FEMA at least every 2 years for high hazard potential dams. Intermediate inspections are to be scheduled by “responsible engineers” in accordance with the size and importance for other hazard classifications (FEMA 2004c). Unlike formal inspections, intermediate inspections do not explicitly require a professional engineer’s supervision. However, inspectors are required to be technically qualified engineers familiar with dam safety. Intermediate inspections include a review of previous inspection records as well as a field inspection of the dam.

Informal inspections are intended to provide, as far as practicable, continuous surveillance of a dam. These inspections may be performed by any personnel suitably trained to recognize evidence of safety deficiencies, which typically include base maintenance personnel. Informal inspections are to be scheduled in accordance with the importance and condition of the dam in question, and typically only involve a visual inspection of the dam.

2.8 Rating procedures

Data collected by the NID includes a condition rating for each dam. The definitions of those ratings are set by the National Dam Safety Review Board (USACE 2008). The categories are intended to convey the severity of the deficiencies of the dam, without considering the risks associated with failure. The NID’s condition assessment rating must therefore be considered along with the hazard potential classification for prioritization purposes.

Of the 258 DoD dams reported in the 2016 NID, roughly one-quarter (24%) were not rated on this scale. Of those dams that did receive condition ratings, 20% scored “satisfactory,” 21% scored as fair, and the remaining 35% were rated as poor. No DoD dams were reported to be in unsatisfactory condition. Figure 5 shows the distribution of the condition ratings within each hazard classification for DoD dams in the 2016 NID.

Figure 5. DoD dams, condition rating by hazard potential in NID (USACE 2016).

2.9 Typical maintenance procedures

Maintenance of dams may be generally subdivided into two categories—routine and major. Major maintenance items usually involve a greater amount of engineering design and judgment in both the planning and execution of the work, as well as greater cost. Often, major repair work involves a change in the actual design of the dam. The decision making involved with these design choices are more likely to be informed by risk and long-term functional requirements than by routine maintenance concerns.

2.9.1 Routine and preventative maintenance

Routine maintenance items typically address observed deficiencies in features of a dam. Routine maintenance is more likely to be periodic in nature, and it typically results in no changes in the design of the dam. Examples of routine maintenance of embankment dams include removal of unwanted foliage, preventive maintenance of mechanical equipment associated with the dam, clearing of debris and clogging, controlling erosion, and continuous monitoring of the condition of the dam.

Figure 6 shows an example of unwanted vegetation on the slope of an earthen embankment. The roots of this type of foliage create a potential

hazard by forming channels which water can readily move through. These channels can lead to internal erosion and to eventual failure of the embankment. FEMA has published a technical manual for owners describing the impacts of plants on embankments (FEMA 2005b).

Figure 7 shows a corroded and clogged drain pipe from the inside. Drains in dam embankments are intended to prevent dangerously high water pressures from forming in the dam. High water pressures can lead to excessive seepage through the dam, along with the resulting internal erosion and instability of the embankment slopes.

Figure 6. Unwanted vegetation (Landers et al. 2015).

Figure 7. Clogged drain pipe (Ailstock et al. 2012),

Figure 8 shows erosion on an embankment, likely caused by runoff. Corrective actions include redirecting the flow or protecting the slope by one or more of many alternatives.

Figure 8. Erosion on embankment slope (Stanton et al. 2014).

2.9.2 Major repair and maintenance

Major repair usually stems from a serious safety issue that is identified through inspection of the dam. Corrective measures for these types of deficiencies can vary substantially; there may not be a single repair method for each deficiency. Consider an embankment that is observed to have excessive seepage. This situation may be addressed with grouting, if the foundation of the dam is identified as being the cause of the seepage. The problem may be solved by installing or repairing the existing drains in the embankment. The same deficiency may also be fixed by installing a filter in the embankment, which is a zone of earth intended to limit internal erosion. Seepage may also be dealt with by simply lowering the level of the reservoir (or increasing the level of the downstream area if possible) without doing anything to the dam itself.

The brief background information in this chapter generally applies to all dams. However, significant differences in complexity and risk exists between most dams owned by the DoD and those that are typically larger and higher risk civil works dams that are managed by the USACE Civil Works program. The next chapter reviews USACE civil works dams in order to draw information and practices that may apply to the feasibility and framework of a DoD dam management system.

3 USACE Civil Works for Dams

The USACE (2016) inventory of dams is similar in number to DoD but, unlike DoD dams, the USACE inventory's size, complexity, hazard potential, and economic consequences rank among the largest in the nation. In the 2016 NID, USACE reported 709 dams. Of these, 48 are low hazard, 150 significant hazard, and the remaining 501 are high hazard. Of the total of 198 low and significant hazard dams, 112 include navigation as a purpose, indicating that even if they are relatively low head and risk, many of these dams are not small or simple structures.

This chapter provides a somewhat historical look at three directions USACE has pursued during the 1990s and 2000s that may be relevant to how the DoD could manage inspection, evaluation, budgeting, and work prioritization for dam safety-related actions and expenditures.

3.1 Maintenance and repair funding

USACE not only has a large inventory of dams, but the dams themselves also tend to be relatively large and complicated. The methods developed for management of these structures are multifaceted. Each of the 39 USACE districts has primary responsibility for operating and maintaining one or more of these structures. Depending on the type and size of expenditure, nonrecurring repair and rehabilitation (R&R) will be reviewed and prioritized at the national level of USACE within the multiple offices with criteria for prioritizing R&R. The role of the offices in influencing and controlling R&R varies, depending on the type of R&R; the roles are also constantly evolving.

USACE has long relied on annual inspections, special inspections, and their most formal inspections, called Periodic Inspections, which are to be performed every 5 years (more frequently for new projects). Operations, inspections, and most repairs are funded via an operations and maintenance (O&M) budget. The O&M budget covers five business areas—navigation, flood damage reduction, hydropower, recreation, and environmental—with navigation being largest. O&M repairs are proposed within the districts and internally ranked. Divisions, Asset Management, Risk Management Center, and Headquarters may adjust rankings, thereby potentially moving some work packages in or out of the budgeted work. Larger R&R, with a minimum cost of \$5M (\$8M for inland navigation),

are funded via a separate construction budget. Those repairs require a substantially more involved major rehabilitation report which includes detailed engineering and economic analyses. The engineering aspects of those repairs are scrutinized at higher levels even more closely than the O&M work packages. For more information, see engineering pamphlet (EP) 1130-2-500 (USACE 1996).

3.2 Dam safety risk analysis

Periodic Inspections have long played an important role in dam safety inspection and assessment. They form an important historical record of condition and concerns regarding the safe performance of dams. Until recently, risk was only considered implicitly. There were standards to meet, and the expectation was that meeting those standards assured risk was adequately mitigated. A significant change to USACE practice began to develop in the late 1990s. There was an increased recognition that risk should be more formally evaluated as part of the dam safety process. An ERDC research program was initiated under the name RADS (Risk Analysis for Dam Safety). Also in the late 1990s, USACE Headquarters (HQ) funded an effort to develop an EP titled “Guidelines for Risk-based Assessment for Dam Safety,” which is now expired. These efforts did not immediately result in a risk-based approach to dam safety within USACE, but they changed how USACE considered risk. For example, one effort within RADS (Patev et al. 2005) looked at using fault tree analysis for evaluating risks associated with dam gates and their operating equipment. RMC and asset management efforts discussed in subsequent sections also look to fault trees to help assess risks and repair priorities for dam components. RADS also produced a technical report on Early Warning Systems (Foltz et al. 2003), which addresses components associated with dams that might be of interest.

3.2.1 Dam safety inspections and assessments

Current policy and practice for dam safety inspections and evaluation is documented in the newest version of engineering regulation (ER) 1110-2-1156, “Safety of Dams, Policy and Procedures” (USACE 2014). Besides documenting the Periodic Inspection requirements, it also includes other, newer additions such as the following: (a) periodic assessments, which are performed on each dam in conjunction with every second Periodic Inspection; (b) portfolio risk assessment (PRA), for looking at risks across the entire portfolio; (c) tolerable risk guidelines; (d) interim risk reduction

measures, which include lowering the pool and other measures until more permanent repairs and modifications can be completed; and (e) risk communication. These procedures are discussed further in the next section. It should be noted that implementation of these risk-based procedures requires manpower, including professional engineers with broad dam safety knowledge and experience as well as specialists with particular engineering expertise.

3.2.2 Risk Management Center

Risk-based work starting in the mid-2000s resulted in a Screening Portfolio Risk Analysis (SPRA) process that was used to evaluate relative risk of all dams in the USACE portfolio. The SPRA process resulted in ratings of A, PA, PI, and I (adequate, probably adequate, probably inadequate, and inadequate). The goal was to use a formal process to identify the dams presenting the greatest risk. This process was a significant change in how dam safety was approached. Subsequent efforts resulted in a more in-depth PRA procedure.

In a PRA, all dams in the portfolio are evaluated and ranked in terms of existing risk and the cost effectiveness of risk-reducing investments. The goal is to determine the most efficient allocation of investments in dam safety improvements for USACE dams. Identifying, analyzing, and prioritizing repair of the biggest dam safety deficiencies not only became more risk-based, it was also managed much more intensely at the national level. As a result, the Risk Management Center (RMC) was created in 2009 to perform this management activity. The USACE Institute for Water Resources (IWR) website² describes the RMC as follows:

“The Risk Management Center (RMC) is a center of expertise under the U.S. Army Corps of Engineers (Corps) Institute for Water Resources (IWR). It was established in 2009 to improve management controls over infrastructure decisions, serve as an independent advisor to senior leadership, maintain and develop risk competencies, and ensure consistency in processes, application of criteria and decision-making.

The mission of the Risk Management Center is to support Civil Works by managing and assessing risks for dams and levee systems across the

² <http://www.iwr.usace.army.mil/About/Technical-Centers/RMC-Risk-Management-Center/>

Corps, to support dam and levee safety activities throughout the Corps, and to develop policies, methods, tools, and systems to enhance those activities.”

According to ER 1110-2-1156 (USACE 2014), the RMC is responsible for the development, dissemination, and interpretation of methodology guidance for use in conducting dam safety risk assessment. Methodology guidance is developed and provided at two basic levels. A best practices manual has been developed jointly with the United States Bureau of Reclamation for the purpose of summarizing the overall philosophy, methods, and approach to risk assessment for dam safety (USACE 2012). In support of the best practices manual, a suite of toolboxes has been developed to provide specific methods and tools for performing analyses of loading, failure modes, and consequences needed to inform inputs to a risk assessment.

Figure 9 and Figure 10 outline the risk-based dam safety program that is implemented through the RMC. Table 3 outlines the five action classifications used by USACE in PRA. As illustrated in the figures, each classification entails distinctly different levels of action and urgency, depending on whether the dams are critically near failure, adequately safe, or at one of the three levels in between.

3.3 Asset management

USACE began a formal asset management effort in 2006. The goals are many, and significant efforts have been made towards realizing those goals, but much remains to be accomplished. A Computerized Maintenance Management System (CMMS) based on Maximo® software, that USACE named Facility Equipment Maintenance (FEM), was previously implemented in part of USACE and became a part of USACE Asset Management (AM). Related maintenance management efforts have been initiated within AM. AM also includes efforts in condition evaluation and budget prioritization that are more relevant to this report. Inland navigation (which includes dams) has been a higher priority within AM, but AM also applies to flood damage reduction dams. Hydropower has its own, largely independent AM effort, in part because much of their repair budget comes through Bonneville Power Authority (BPA).

Figure 9. Generalized dam safety portfolio risk management process (USACE 2014).

Figure 10. USACE Dam Safety Portfolio Risk Management Process (USACE 2014).

Table 3. USACE Dam Safety Action Classification Table (Table 3.1 in USACE 2014).

URGENCY OF ACTION (DSAC)	ACTIONS FOR DAMS IN THIS CLASS***	CHARACTERISTICS OF THIS CLASS
VERY HIGH (1)	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. Ensure the emergency action plan is current and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Expedite investigations to support remediation using all resources and funding necessary. Initiate intensive management and situation reports.	CRITICALLY NEAR FAILURE: Progression toward failure is confirmed to be taking place under normal operations. Dam is almost certain to fail under normal operations to within a few years without intervention. OR EXTREMELY HIGH INCREMENTAL RISK**: Combination of life or economic consequences with likelihood of failure is very high. USACE considers this level of life-risk to be unacceptable except in extraordinary circumstances.
HIGH (2)	Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public. Implement interim risk reduction measures, including operational restrictions as warranted. Ensure the emergency action plan is current and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Expedite confirmation of classification. Give very high priority for investigations to support the need for remediation.	FAILURE INITIATION FORESEEN: For confirmed and unconfirmed dam safety issues, failure could begin during normal operations or be initiated as the consequence of an event. The likelihood of failure from one of these occurrences, prior to remediation, is too high to assure public-safety. OR VERY HIGH INCREMENTAL RISK**: The combination of life or economic consequences with likelihood of failure is high. USACE considers this level of life-risk to be unacceptable except in extraordinary circumstances.
MODERATE (3)	Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public. Implement interim risk reduction measures, including operational restrictions as warranted. Ensure the emergency action plan is current and functionally tested for initiating event. Conduct heightened monitoring and evaluation. Prioritize investigations to support the need for remediation informed by consequences and other factors.	MODERATE TO HIGH INCREMENTAL RISK**: For confirmed and unconfirmed dam safety issues, the combination of life, economic, or environmental consequences with likelihood of failure is moderate. USACE considers this level of life-risk to be unacceptable except in unusual circumstances.
LOW (4)	Communicate findings to sponsor, local, state, Federal, Tribal officials, and the public. Conduct elevated monitoring and evaluation. Give normal priority to investigations to validate classification, but do not plan for risk reduction measures at this time.	LOW INCREMENTAL RISK**: For confirmed and unconfirmed dam safety issues, the combination of life, economic, or environmental consequences with likelihood of failure is low to very low and the dam may not meet all essential USACE guidelines. USACE considers this level of life-risk to be in the range of tolerability but the dam does not meet all essential USACE guidelines.
NORMAL (5)	Continue routine dam safety activities and normal operations, maintenance, monitoring, and evaluation.	VERY LOW INCREMENTAL RISK**: The combination of life, economic, or environmental consequences with likelihood of failure is low to very low and the dam meets all essential USACE guidelines. USACE considers this level of life-safety risk to be tolerable.
<p>*At any time for specific events a dam, from any action class, can become an emergency requiring activation of the emergency plan. ** INCREMENTAL RISK is used to inform the decision on the DSAC assignment, NON-BREACH RISK is not reflected in this table. ***DSAC 1 and 2 dams with no life loss will be referred to the appropriate business line program and are given lower priority in the dam safety program.</p>		

3.3.1 Operational Condition Assessments and Operational Risk Assessments

Much of the AM effort has been focused on the development and implementation of what are called Operational Condition Assessment (OCA) and Operational Risk Assessment (ORA). Until recently, the condition rating criteria in Figure 11 was used within the budget prioritization process for both inland navigation and flood damage reduction business areas. The rating criteria in Figure 12 has replaced this. This newer condition rating process relies on the inspector to categorize infrastructure based on knowledge of the infrastructure and using information from other preexisting inspections.

Asset management has a risk-based process for prioritizing navigation project repairs within the O&M budget. The process uses the OCA rating to estimate probability of unexpected lock closure. This is multiplied by a cost to industry based on the expected duration of the closure. In theory, the methodology is largely sound, but many of the steps need further refinement by the O&M budget team; improvements continue to be made in

the process. The ORA for flood damage reduction dams was under development in FY2017, but a completion date is undetermined.

Current AM requires that only known deficiencies be considered in the OCA ratings. At the same time, the USACE HQ Asset Management team recognized that many deficiencies are difficult to identify without dewatering and other types of costly investigations. They are working on a process to appropriately consider these unknown conditions in a risk-based prioritization process.

Figure 11. Original OCA rating criteria (USACE Budget Circular FY13 – now expired).

Figure 12. Updated OCA rating criteria (source: USACE HQ Asset Management Team).

3.4 ERDC-CERL condition indexes

The REMR (Repair, Evaluation, Maintenance and Rehabilitation) research program started in 1984 and ended in 1998 (McCleese 2000). It included seven broad research areas, and one was titled Operations Management. That research area heavily emphasized the development of condition indexes (CIs). CIs are quantitative ratings of condition that vary from entirely subjective to entirely measurement-based. The goal is to reduce

subjectivity while the quantitative rating also provides additional capabilities to look at trends and make other condition-based calculations, such as estimating failure probabilities. CIs have been developed for the following USACE civil works infrastructure components, and technical reports for each are referenced in this report, as listed below:

- Embankment dams (Andersen et al. 1999)
- Spillway systems (Chouinard et al. 2008)
- Rubble breakwaters and jetties (Oliver et al. 1998)
- Non-rubble breakwaters and jetties (Pirie et al. 2005)
- Miter lock gates (Greimann et al. 1990)
- Tainter dam and lock gates (Greimann et al. 1995)
- Tainter and butterfly valves (Greimann et al. 1994)
- Roller dam gates (Greimann et al. 1997)
- Sector gates (Greimann et al. 1993)
- Lock and dam operating equipment (Stecker et al. 1997)
- Timber dikes (Yu and Kao 1989)
- Training dikes and revetments (McKay 1998)
- Steel sheet pile structures (Greimann and Stecker 1989)
- Lock monoliths (Bullock 1989)
- Gravity dams, retaining walls, and spillways (Bullock and Foltz 1995)
- Hydropower components (USACE 1993)

There are additional technical reports on various topics related to CIs that may be of particular interest, as described below. The reports provide an introduction to numerous topics related to condition rating.

- A technical report (Foltz and McKay 2008) was prepared under funding from the program manager for AM. It includes short overviews of many of the condition indexes for various infrastructure components.
- A technical report (Uzarski et al. 2009), also prepared under funding from the program manager for AM, reports results of a targeted survey of USACE employees who were involved in inspection of Civil Works locks and dams infrastructure regarding the role of inspection and condition assessment.
- A technical report (Foltz, Howdyshell, and McKay 2001), discusses numerous ways that condition ratings can be used to help manage civil works infrastructure.

As currently designed, few CIs could be meaningfully used for condition rating of relatively small and simple DoD dams, but the CI technical reports provide a wealth of information that could be helpful in creating more useful criteria for inspecting and rating the condition of DoD dams.

The CIs vary significantly in approach and methods for rating condition. The CIs vary mainly in the extent that they rely on descriptive criteria for ratings versus using measured quantities. Some CIs (more than others) help the inspector or rater to identify deficiencies and other unsatisfactory conditions. Two of the most relevant CIs are for spillway (Chouinard et al. 2008) and embankment dams (Andersen et al. 1999). Those two CIs use rating tables that inform the inspector of types of deficiencies to look for, as described next in sections 3.4.1 and 3.4.2. As currently formulated, those two CIs give the inspector latitude in assigning a rating. That may need to be revised for use on DoD dams, however, if the intent of CIs is for engineers and technicians without dam safety expertise to perform the ratings. Also note that the CIs do not cover all components that are common to smaller dams. In particular, many components of outlet works are not covered in the CIs.

3.4.1 Spillway components - condition rating

While a small number of DoD dams have gated spillways similar to those addressed in the spillway CI (Chouinard et al. 2008), the CI also includes other subcomponents that may be relevant. More importantly, the approach taken in developing the rating tables for this CI may be useful even if the subcomponents for DoD dams are mostly different or the criteria needs to be changed to be more relevant to DoD dams. The CI also includes many operational components that are worth consideration in an SMS for DoD dams. See Table 4 for a list of the components that have rating tables.

Table 4. Spillway condition rating, component list (ERDC-CERL).

Category	Components
Operational	River flow measurement (manual or electronic) Reservoir level indicator Precipitation and temperature gauge network Snow measuring stations Weather forecasting Ice and debris management Third party data

Category	Components
	<ul style="list-style-type: none"> Gate position indicator Flow prediction model Decision process Telecommunication system Public protection and warning system Availability and mobilization (design flood) Availability and mobilization (load rejection) Operating procedures Qualification and training of operator Portable equipment for lifting gates Road Alternative means of access Local access Remote and on site controls
Electrical	<ul style="list-style-type: none"> Overhead lines Local or emergency generator Underground and encased cables (medium voltage) Power feeder cables (low voltage) Transformer Power source transfer system Ice prevention system (air bubbler) Lighting system (normal and emergency) Limit switches Ice prevention system (heating) Distribution panel Translation motor (electric) Lifting motor (electric) Motor control center or individual control panel Cam switches External resistors Inverter control system
Mechanical	<ul style="list-style-type: none"> Screw and nut (screw-type hoist) Bearings Split bushing or journal bearing Rotating shafts, supports, bearings, and couplings Gear assembly (hoist) Gear assembly (carriage) Dedicated lifting connectors Non-dedicated lifting connectors Carriage wheels Clutch Drum, sheaves, and pulleys

Category	Components
	Hoist brake Carriage brake Fan brake Wire rope and connectors Trunnion assembly Trunnion beam and anchorage Chain and sprocket assembly Hydraulic cylinder assembly Fixed wheels for vertical lift gates Roller trains
Civil/structural	Carrying tracks Lifting device structure Mobile structure to support a shared lifting device Approach and exit channel Lifting device structure (steel) Embedded parts Gate structure Stoplogs, bulkheads (steel) Bottom and side seals

Condition rating tables were developed by a panel of experts for each spillway component, and the rating tables were fully field tested through a series of inspections. Component condition is rated on a scale developed by USACE under the REMR program, as shown in Table 5. The component condition tables define both the function of a component and the component's condition, with scores ranging from excellent (100) to failed (0). Intermediate conditions are based either on quantitative data or qualitative observations on indicators of condition. For each indicator, a range of condition ratings is suggested. Observations are obtained either from an on-site inspection or examination of existing records for the spillway. For each indicator, the inspector assigns a CI value within the appropriate intermediate condition by comparing what is seen with the description. Table 6 gives an example by showing a CI rating table for transformers.

Table 5. Revised REMR scale for dam component condition rating
(Foltz, Howdyshe, and McKay 2001).

Zone	Condition Index	Condition Description	Recommended action
1	85 to 100	Excellent: No noticeable defects. Some aging or wear may be visible.	Immediate action is not required
	70 to 84	Good: Only minor deterioration or defects are evident.	
2	55 to 69	Fair: Some deterioration or defects are evident, but function is not significantly affected.	Economic analysis of repair alternatives is recommended to determine appropriate action.
	40 to 54	Marginal: Moderate deterioration. Function is still adequate.	
3	25 to 39	Poor: Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need for repair, rehabilitation, or reconstruction. Safety evaluation is recommended.
	10 to 24	Very poor: Extensive deterioration. Barely functional.	
	0 to 9	Failed: No longer functions. General failure or complete failure or a major structural component.	

Table 6. Sample transformer rating table. (Chouinard et al. 2008).

Transformer									
Function	Supply power at correct voltage level								
Excellent	Built to current codes and standards, and maintained to provide continuous service at correct voltage level.								
Failed	Cannot supply correct voltage level.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Dielectric (oil)									
Oil according to specifications							X		
Contaminated oil (presence of foreign matter, e.g.: moisture)		X	X	X	X				
Degraded oil (by arcing, aging, acidity)	X	X	X	X					
Dissolved gases	X	X	X	X					
Insulation									
Performs the function and/or passes the standard testing procedures (insulation resistance and power factor, etc.)						X	X		
Does not perform the function nor passes the standard testing procedures	X	X							
Windings									
Performs the function and/or passes the standard testing procedures (resistance and turns-ratio)						X	X		
Does not perform the function nor passes the standard testing procedures	X	X							
Cannot supply power	X								
Tank									
No leaks							X		
Inadequate oil level or oil leak	X	X	X	X	X				
Service life (based on utility standard practices)									

Transformer condition is evaluated by testing and visual inspection. The testing is performed to monitor the quality of the oil, the insulation, and the windings. The visual inspection determines the condition of the tank. Considering the wide variety of possible tests, outcomes are described qualitatively and must be evaluated by considering the recommendations of each specific manufacturer of testing devices.

The condition rating tables for spillway components are divided into four categories: (1) Civil/Structural, (2) Mechanical, (3) Electrical, and (4) Operational. This grouping of rating tables corresponds to typical fields of expertise for inspectors, and it was done to facilitate the on-site inspections. These rating tables are presented in Appendix E.

As previously stated, the CI gives the inspector guidance, but still a great deal of latitude, when assigning the rating for a particular distress or deficiency. Selection of a rating near the top, middle, or bottom of the rating category should be made according to the inspector's best judgment. The lowest CI is assigned to a component when several condition indicators are present. When a component is either not relevant to a spillway's safety functions or cannot be observed, an appropriate comment should be entered in the inspection rating table. Estes, Foltz, and McKay (2005) present an alternative method of updating condition when no recent inspection has determined a condition rating.

3.4.2 Embankment Dam condition index

The Embankment Dam CI includes condition rating tables that are similar to the spillway CI. These tables are included in Appendix F. The components in this CI are called "defense groups." The rating table would at least be a good starting point for creating rating criteria for a Dam SMS.

This CI also includes definitions for failure modes, adverse conditions, and defense groups, as shown in Table 7, Table 8, and Table 9. The CI includes a process for evaluating how important each defense group is for resisting adverse conditions, the relative likelihood that the adverse conditions will lead to the failure modes, and the relative likelihood of the failure modes occurring. In this way, the importance of each defense group on a particular dam can be considered in a systematic framework.

Table 7. Failure modes and definitions
(Andersen, Chouinard, and Foltz 1999 – REMR-OM-25).

Failure Mode	Definition
Overtopping	Water flowing over the crest of the dam resulting from an uncontrolled rise in the reservoir.
Surface Erosion	Any erosive mechanism that can compromise the integrity of the embankment surfaces or spillway and lead to breach of the dam. This erosion can be caused by wave action, spillway flow, cycles of rain and drought, wind, burrowing animals, human activities, etc.
Piping	The migration of soil particles from locations within the embankment thus creating voids. This internal erosion can be caused by high seepage velocities or inappropriately designed filters.
Mass Movement	Large volumes of embankment and/or foundation material that move along sliding surfaces. This mass movement is generally caused by the buildup of excess pore pressures. Sliding can also be initiated by liquefaction due to earthquake loadings.

Table 8. Adverse conditions for embankment dams
(Andersen, Chouinard, and Foltz 1999 – REMR-OM-25).

Adverse Condition	Definitions
Inadequate Spillway Capacity	Spillway unable to pass the design flood
Loss of Spillway by Erosion	Erosion of spillway during operation
Loss of Crest Elevation	Crest elevation lowered below design height
Loss of Surface Protection Material	Erosion and loss of surface protection material
Piping of Embankment Materials	Physical removal of embankment core or filter materials under the action of hydraulic gradients
Piping of Foundation Materials	Physical removal of foundation materials under the action of hydraulic gradients
Slide Through the Embankment (Static or Dynamic)	Mass movement of the embankment that involves only the embankment material
Slide Through the Foundation and Embankment (Static or Dynamic)	Mass movement that involves both embankment and foundation materials

Table 9. Defense groups for embankment dams
(Andersen, Chouinard, and Foltz 1999 – REMR-OM-25).

Defense Group	Purpose
Spillway Capacity	Ability to pass design flow
Spillway Erosion Control	Ability to pass flow without loss of sill
Crest Elevation	Crest elevation relative to design elevation
Surface Runoff Collection Discharge System	Capacity of collection system and ability to remove from dam without erosion
Downstream Slope Protection	Protection from erosion of slope
Upstream Slope Protection	Protection from erosion of slope
Filtering in Embankment	Prevention of the migration of fines
Pressure Control in Embankment	Maintain magnitude of pressures within design parameters
Filtering in Foundation	Prevention of the migration of fines
Pressure Control in Foundation	Maintain magnitude of pressures within design parameters

4 DoD Dam Management Process

This chapter provides a brief overview of the dam management processes currently employed by the DoD military services. The purpose of this chapter is to characterize the DoD's dam inventory, and how the military services currently handle the basic steps of the SMS process (see Chapter 5). This chapter may therefore serve as both a record of research completed for this tech report, as well as a guide for the future development of a Dam SMS.

The information for this chapter was gathered through a survey posed to dam safety personnel representing each service, along with a review of the policy documents regarding dams. A full list of questions and responses are provided in Appendix A.

At the time of this report's writing, much of what is contained in this chapter will be subject to change in the near future. All the services mentioned have provided initial responses to the aforementioned DoD IG's report (2014), and they are preparing more detailed responses, including this report. Details of the upcoming policy changes for each service are discussed in the subsequent sections of this chapter. Representatives from the services have indicated that the relevant policy documents will be updated, pending the recommendations of this report.

4.1 Army

The Army owns the largest and most diverse portfolio of dams among the armed services. The Army's inventory includes both the oldest (Mine Lake dam at West Point, constructed 1845) and the tallest (Cat Creek dam on Hawthorne Army Depot, Nevada, at 123 ft) of those DoD dams that are listed in the NID (USACE 2016). At the time of this report's writing, the Army's policy documentation is the most comprehensive among DoD services, and it implements federal standards for the management of dams.

4.1.1 Policy

The Army's dam management system is described in detail in chapter 7, section 6 of Army Regulation (AR)-420-1 document titled "Army Facilities Management" (U.S. Army 2012). Additional guidance on chapter 7 of AR-

420-1 is given in chapter 6 of DA PAM 420-1-3, “Transportation Infrastructure and Dams” (U.S. Army 2009). These documents also make explicit reference to the FEMA-93 publication (FEMA 2004a), and the related works that are listed in chapter 2 of this report.

Of special note is that both of the documents just mentioned—AR 420-1 (Ch. 7-47, sec. a) and DA PAM 420-1-3 (Ch. 6-1)—establish the minimum performance standards for dams to be in line with the host state or nation. A summary of state laws and regulations is available from the Association of State Dam Safety Officials (ASDSO 2000). The majority of the states impose no additional standards for dams, and some explicitly exempt federal dams from state regulation (e.g., South Carolina). Note that the limits of state regulatory authority have previously been investigated by USACE counsel, where it was found that states lack the authority needed to enforce standards on DoD dams.

Also of note is that the definition of a dam used in AR 420-1 is not the same as used by the NID or in current federal law. The full-text definition from AR 420-1 reads as follows (U.S. Army 2012):

“A dam is any artificial barrier, including appurtenant works, which impounds or diverts water, and which is either—

(1) Twenty-five feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier or from the lowest elevation of the outside limit of the barrier if it is not across a stream channel or watercourse, to the maximum water storage elevation.

(2) Has an impounding capacity at maximum water storage elevation of 50 acre feet or more.”

This definition is the same as the one used in the National Dam Inspection Program Act of 1972 (U.S. Congress 1972 - P.L. 92-367). However, it does *not* contain the language added by the Water Resources Development Acts of 1986 or 1996 (U.S. Congress 1986 - P.L. 99-662; U.S. Congress 1996 - P.L. 104-303). The additional language adds a requirement to report all high hazard dams, while removing the requirement to report dams under certain thresholds of size and capacity. In theory, there could be small (but high hazard) dams that are not counted by the Army’s definition, while

some very small dams may be counted by the Army but not by the NID. In practice, there are likely few dams that fall into the category between the two definitions, and a precise count of such structures is beyond the scope of this report. However, for the purposes of compatibility with the USACE guidance, this report recommends that the Army's definition be updated to match current federal law and the NID. Appendix C of this report gives the complete, updated text of the relevant section of U.S. Code (U.S.C.) Title 33, "Navigation and Navigable Waters," as well as a link to the complete text of the chapter on dam safety.

At the time of this writing, the designated dam safety program manager for the Army is Mr. Arden Dean, DAIM-ODF. Army policy names the commander of each garrison containing a dam as the designated dam safety officer and dam owner. Thus, the garrison commander is responsible for the safety of dams, as well as for funding projects to correct deficiencies. The garrison commander is required to manage dams in accordance with federal policy (i.e., FEMA-93 [FEMA 2004a]).

Note that the Army's dam policy may be subject to change in the near future, both in response to the DoD IG report (DoD 2014), the program review directed by Vice Chief of Staff of the Army, and this technical report.

4.1.2 Inventory

The real property database from Q3 of 2016 shows 302 dams in the Army's inventory, of which the vast majority (300 dams) have category code (CATCODE) 89270 (see Appendix B). The remaining 2 assets are classified as CATCODE 88111. The 2016 NID shows 219 dams in the Army inventory (USACE 2016). The discrepancy in numbers is to be expected, given that the NID discriminates based on size, capacity, and hazard classification. However, the Army real property database has an additional CATCODE 87140 titled "Dikes" that includes structures meeting the following definition (U.S. Army 2012):

An artificial barrier that impounds or diverts water away from areas or facilities to avoid damage but does not meet either of the criteria for a dam (89270). Dikes are artificial barriers that are both

(1) less than 25 feet in height from the natural bed of the stream or watercourse to the maximum water storage elevation and

(2) have an impounding capacity at maximum water storage elevation of less than 50 acre-feet. Dikes may be constructed of earth, concrete, or other materials.

It is clear that the intent of assigning different CATCODEs is to separate, within the real property database, those dams which are reportable to the NID from those that are not. The same version of the real property database counted 286 such dikes, bringing the total count of Army dams (including non-NID) to 588.

Among the dams the Army reported to the NID, a majority (51%) were used for recreational purposes. Figure 13 shows the distribution of uses for Army dams in the NID.

Figure 13. Army dams by purpose in NID (USACE 2016).

Earth fill embankments (197 dams, 84% of the NID inventory) were the most common construction type. Of the remaining dams, most were concrete-gravity (11 dams, 5%). Alone among DoD services, the Army reported 7 dams of masonry construction, 2 arch type dams, 2 stone dams, and 1 buttress type dam. Figure 14 shows the distribution of Army dams by construction type. Based on report authors' conversations with DPW personnel familiar with the Army inventory, most of the dams not counted in the NID are small, earth fill embankment type.

Figure 14. Army dams by construction type in NID (USACE 2016).

Of those dams which the Army reported to the 2016 NID, the majority (74%) were designated as low hazard. In total, the Army has 161 low hazard, 18 significant hazard, and 40 high hazard dams in the NID. Figure 15 shows the distribution, by hazard classification, of Army dams listed in the 2016 NID. Note that, by definition, the dams not counted in the NID should all be low hazard.

Figure 15. Army dams by hazard classification in NID (USACE 2016).

4.1.3 Inspection

The required periodic inspections of Army dams are carried out by either the nearest USACE District, ERDC, or private consultants. The Corps of Engineers inspects the majority of Army dams. Shaun Stanton of the Corps is currently the primary POC for Army dam inspections. Consultants are used primarily when Corps personnel are unavailable at the time of the inspection, or when the dam inspection requires special inspection techniques such as diving. Of the 15 inspection reports reviewed for the purposes of this technical report, 13 were conducted by the Corps of Engineers. The other two dams were significantly older (constructed 1878 and 1896) than the average Army dam, and they were inspected by private contractors.

Army policy requires the use of the inspection forms found in the appendix of FEMA 145 (FEMA 1987) to conduct and record maintenance inspection. All the inspection reports reviewed for this report contained those inspection forms as appendices to the formal inspection reports. The actual inspection reports followed a Corps of Engineers template, which is organized into the following three sections: Project Information, Visual Inspection, Recommendation and Cost; each report also could have attached appendices.

The last section of the inspection report (Recommendation and Cost) contains an assessment of the dam's condition. This assessment includes a description of the deficiencies observed during the inspection as well as an overall characterization of the condition of the dam in terms of the NID condition criteria. Table 10 shows the condition rating scale that appears in Army dam inspection reports.

Table 10. Condition ratings for Army dams (e.g., Landers et al. 2015).

Dam Condition Rating	Description	Equivalence	
		NID	ISR
1=Critical	Failure of the dam is imminent and requires immediate or emergency remedial action for problem resolution. Major structural, operational, and maintenance deficiencies exist under normal operating conditions. Major repair or rehabilitation is necessary to restore dam, spillway, or appurtenant works to original design or current design standards. Access should be restricted until repair/rehabilitation is performed. Repairs may need to be carried out on a very high priority basis with strong urgency.	Unsatisfactory	Red
2=Serious	A dam safety deficiency is recognized and immediate remedial action is recommended for problem resolution. Dams with such deficiencies cannot assure the safety of the dam. Among the deficiencies which could result in this rating are developing seepage problems, structural stability inadequacies, or seriously inadequate spillway capacity. Access may be restricted until problem resolution. Repairs may need to be carried out on a high priority basis with urgency.		
3=Poor	a- Defects- A dam safety deficiency is recognized for possible loading conditions. Repairs or investigations may need to be carried out with moderate urgency. b- Uncertainty- Used if uncertainties exist as to critical analysis parameters which recognize a potential dam safety deficiency. Further investigations and studies are necessary.	Poor	Amber
4=Fair	Dams with physical or operational deficiencies which do not require further significant engineering analysis. No existing dam safety deficiencies are recognized for normal loading conditions. Unusual or extreme hydrologic and/or seismic events can result in a dam safety deficiency. Increased maintenance or monitoring may be necessary. Repairs are recommended, but the priority is low.	Fair	
5=Satisfactory	Dam safety inspection did not reveal deficiencies. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines. Safe performance is expected under all anticipated loading conditions, including such events as infrequent hydrologic and/or seismic events. Dam is well maintained and supervised. No need for increased maintenance or monitoring activities. No repairs are required.	Satisfactory	Green

Roughly 30% (65) of Army dams that were reported to the NID received a condition assessment of “not rated.” Of the dams that did have a condition assessment, the majority (62% of those rated) were in “poor” condition. Only 9 dams of the 219 (4%) in the Army NID inventory were rated as “satisfactory.” Figure 16 shows the distribution of the condition ratings given to Army dams.

Figure 16. Army dams by NID condition assessment (USACE 2016).

Being listed as “Not Rated” (as are 65 Army dams) does not necessarily mean that no effort was made to rate those dams. The lack of a rating may be caused when a condition rating was generated during a formal inspection, but it was not added to the NID data set. Without a detailed analysis of every case, therefore, it is impractical to determine if any Army dams actually lack an NID condition rating. For reference, a list of NID reportable Army dams without a condition rating is provided in Appendix G.

4.1.4 Work planning and prioritization

The inspection reports for Army dams include recommendations for correcting the deficiencies noted in the reports. These recommendations include both cost estimates for the maintenance or repair project and priority ratings for each action item. Both the work cost estimates and the prioritization ratings were generated based on the inspector’s judgment and prior experience with similar projects. Personnel involved with Army inspection reports indicated that commercial resources such as RSMeans Cost Data Books³ or past work history were used to generate these type of work plans.

Inspectors commonly provide guidance on what kinds of maintenance and repair might be accomplished by base civil works, as opposed to contract

³ Cost Books are produced annually by R.S. Means of Rockland, MA, a Gordian company., which provides construction cost data, software, and services for all phases of the construction life cycle.

labor. Table 11 shows an example work plan generated for the Stilwell Lake dam (Landers et al. 2015). Note that most of the proposed maintenance and repair items were considered to be within the capabilities of the installation's DPW, so only a single item has a cost estimate associated with it.

Table 11. Example work estimate and prioritization
(reproduced from Landers et al. 2015).

Rec. Number	Recommendation Description	Priority	Estimated Cost
1	Repack upstream valve and test the outlet.	High	\$0K
2	Remove current vegetation and establish a control plan.	High	\$53K
3	Evaluate spillway and repair as necessary.	High	\$0K
4	Repair ladder.	High	\$0K
5	Repair and repaint the outlet box cover and fence railings.	Low	\$0K
6	Resurface the spillway.	Low	\$0K
7	Repair the cracks and concrete spalls.	Low	\$0K
8	Replace cover.	Low	\$0K
9	Replace with new barbed wire.	Low	\$0K

Funding for these projects is currently being provided by the installation to which the dam belongs. The installation's Commander, acting as the dam owner and safety officer, has discretion on the actual distribution of funding. Previous work items are reviewed in each report; however between formal inspections, the status of individual projects are monitored by installation personnel rather than by inspectors.

4.2 Navy

The size and scope of the Navy inventory of dams is roughly an order of magnitude smaller in number, compared to the Army. The Navy's dam management program is similar in execution to the other services, and it relies primarily on local authorities to enforce policy. Of special note is that the Marine Corps previously reported their dams through the Navy. This reporting relationship is no longer the case, as discussed in the next section. Unlike the Army and Air Force, the Navy has no planned revisions of dam safety policy that are likely to be implemented in the near future at the time of this report's publication.

4.2.1 Policy

The principal policy document for Navy dam safety is the NAVFAC Business Management System (BMS) B-10.7, titled “Dam Safety Inspections and Assessment.” At the time of this writing, the most recent update of this document was December 2016. The Naval Facilities Engineering Command (NAVFAC) is named as the centralized technical lead for dam safety.

The Dam Safety Inspections and Assessment document mentions several other sources as “resources.” Several FEMA publications including FEMA-93 and related manuals, guides, and reports are explicitly cited as parts of Navy policy. For instance, the BMS policy requires that the need for inspections be in accordance with FEMA specifications (e.g., the Federal Guidelines for Dam Safety [FEMA 2004a]). Other resource listings include the commercially available Maximo asset management system and the NAVFAC-hosted Specialized Infrastructure Data Element Reporting System (SPIDERS).

Of special note is that the Navy policy covers exclusively those dams that meet FEMA guidelines (i.e., only those dams that are reported to the NID). Dams that do not meet the FEMA criteria are the responsibility of the local installation commanding officer (ICO) or public works officer (PWO), and those dams do not have any explicit standards in the BMS policy.

At the time of this writing the Navy Dam Safety Inspection Program (NDSIP) manager is Mr. Bradley Patch, NAVFAC HQ. The Navy BMS document does not explicitly designate an owner or safety officer to individual dams. However, there are designated points of contact for each NID reportable dam. Installation commanders are responsible for maintaining inspection data and emergency action plans, as well as scheduling intermediate and special inspections.

4.2.2 Inventory

As of August 2017, the Navy iNFADS database contained 139 assets in the Facility Analysis Code (FAC) 8714, “Levees and Dikes for Grounds Drainage.” Four Navy-specific CAT codes are associated with this FAC, as follows: (1) 87125 Dyke/Dam, (2) 87126 Levee &/or Dike, (3) 16430 Levees, and (4) 87145 Dredged Spoil Handling. This report focuses on the CATCODE 87125, which contains all NID reportable dams in the Navy inventory. The iNFADS database captured 114 dams with this CATCODE.

The NID (USACE 2016) contains only 3 dams owned by the Navy; however, Corps of Engineers personnel have indicated that this is a data error that will be corrected in the future. The Navy reported 17 dams to the NID in the third quarter (Q3) 2015 update. Further, the Navy has provided the authors with a list of dams to be reported to the NID containing 19 total dams, including recent additions. For the purposes of this report, the most recent data provided by the Navy will be referred to as belonging to the 2016 NID, since it is assumed that all 19 will be added to the database when it is corrected. Compared to the iNFADS database, this leaves 95 structures unaccounted for in the NID. The discrepancy between the iNFADS and NID numbers is expected and also occurs with the Army inventory, due to differences in inventory methodology between the two databases.

Of the 19 dams the Navy reported to the NID, most are classified as recreational (13 dams). The remainder are either flood control (4 dams), water supply (1 dam), or other (1 dam). None of the Navy dams in the NID have multiple purposes associated with them. Figure 17 shows the distribution of Navy dams by purpose.

Figure 17. Navy dams in NID, by purpose (USACE 2016).

Only 8 Navy dams have a construction type listed in the NID. All 8 are classified as earth embankments. No details were found as to the construction type of the other 11 dams.

Similar to the Army inventory, the majority of the Navy dams reported to the NID are low hazard dams (12 dams, or 63%). The Navy inventory also has 4 high hazard and 2 significant hazard dams. One dam is listed as “TBD” (to be determined). This dam (named “Dam for Pond #3” in the database) is a recent addition to the inventory, which became NID-reportable after a recent renovation. It will be assigned a hazard classification after the next formal inspection, scheduled for FY2018. Figure 18 shows the distribution of hazard classifications for Navy dams.

Figure 18. Navy dams in NID, by hazard classification (USACE 2016).

4.2.3 Inspection

Navy policy permits formal inspections to be carried out by USACE, in-house labor, or contractors at the discretion of the Expeditionary Warfare Center (EXWC) NDSIP manager or the project engineer. USACE Norfolk District is the Navy’s primary point of contact for formal inspections, but various other districts have conducted inspections. For example, three inspection reports for Navy dams were obtained for purposes of this report. Of those reports, two had Norfolk District listed in the front matter. However, those two reports were actually conducted by USACE Honolulu District and Schnabel Engineering Consultants, Inc., respectively. The third report examined for this work lists only USACE Louisville District as the author.

Formal inspections are scheduled every 5 years for low hazard dams and every 3 years for high and significant hazard dams. Note that more frequent inspections for high hazard and significant hazard dams were explicitly required by earlier versions of federal law such as Water Resources Development Act 1986 (U.S. Congress 1986 - P.L. 99-662). However, subsequent amendments set the required frequency of inspections to 5 years for all dams (U.S. Congress 1996 - P.L. 104-303). The Navy's inspection schedule therefore reflects the judgment of NAVFAC engineers, while also meeting federal standards.

The outline of the inspection reports obtained from the Navy is similar to those obtained from the Army. The recommendations section of the reports includes specific maintenance and repair actions, along with "rough order of magnitude" estimates for the cost of those actions. The cost estimates are based on the inspector's knowledge of the work in question, as well as prior experience with similar work. All reports contained the same inspection forms from the FEMA-145 document (FEMA 2004a) as well as appendices.

Note that the Navy uses their own condition rating system for dams, just as the Army uses a rating system based on the Installation Status Report (ISR). However, the Navy system correlates a numerical condition index to the condition rating specified by the NID. For each condition rating, there is an equivalent condition index, along with a range of values over which inspectors may rate a dam with that condition rating. Table 12 shows the correlation between the NID and Navy condition rating scale.

Table 12. Navy condition index definitions (obtained by authors from Navy Dam Safety officer, 2017).

NID Rating	Former Rating	Equivalent CI Rating	Description
Satisfactory	Good and Satisfactory	85 (67-100)	No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.
Fair	Fair	60 (54-66)	No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action
Poor	Poor	45 (37-53)	A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary
Unsatisfactory	Serious and Critical	25 (0-36)	A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution
Not Rated			The dam has not been inspected, is not under state jurisdiction, or has been inspected but, for whatever reason, has not been rated.

The Navy also rates dams based on the Mission Dependency Index (MDI). The formulation of this index for dams is specific to the Navy, and it includes installation commander's input. Of those dams the Navy reports to the NID, some were rated as high as 100 out of 100 MDI, while others ranked as low as 11 on the same scale.

4.2.4 Work planning and prioritization

Formal inspection reports are the Navy's primary source of information for generating and prioritizing maintenance and repair work for dams. Actual prioritization decisions are the responsibility of the NDSIP Manager, per the Navy BMS policy. Navy dam safety personnel indicated that hazard classification is used as an informal prioritization metric, with high and significant hazard dams receiving priority given the same deficiency.

Key findings from the inspection are translated into recommendations for future maintenance and repair. The inspection report itself informs the relative priority of each item, and the costs associated are included by the inspectors for planning purposes. Table 13 shows the work estimate generated in the latest inspection report for Fena Dam on U.S. Naval Base Guam.

Table 13. Example work estimate (partial re-creation of Table 2: Rough Order of Magnitude [ROM] costs for Fena Dam Improvement Action Items in Dridge et al. 2013).

Action Item No.	Item Description	Approximate Quantity	ROM Cost	Remarks
1	Remove vegetation from upstream and downstream embankment	360,000 SF	\$300,000	Complete removal of tree stump and root system; see Notes 1 and 2 on Figure 7.
2	Regrade slope and grass	360,000 SF	\$250,000	As an option to facilitate future maintenance, see Notes 1 and 2 on Figure 7.
3	Remove vegetation along spillway	14,500 SR	\$150,000	Complete removal of tree stump and root masses more than 4 inches. See Note 3 on Figure 7.
4	Perform CCTV of toe drain and drainage systems	Each	\$50,000	See Note 7 on Figure 7.
5	Restore toe drain system	Each	\$400,000	If CCTV confirms toe drain is plugged.
6	Restore 4-inch force main	Each	\$100,000	See Note 8 on Figure 7.
7	Spillway retaining wall spalled and gap filling with grout or mortar	1,450 LF	\$70,000	See Note 4 on Figure 7.

Installation commanders are responsible for actually funding the maintenance and repair actions taken. Navy personnel indicated that central funding was available through the Commander of Navy Installations Command (CNIC) for formal inspections. Repair work is usually funded via Sustainment, Restoration, and/or Modernization (SRM) funds. In any case, the installation is responsible for either completing the repair work in-house or contracting the work as needed.

4.3 Air Force

The Air Force's dam safety program is currently in a state of transition between a decentralized management program to one with more central oversight and policy making. Policy execution, however, will remain decentralized. Dam safety representatives stated that central oversight has a relatively brief (approximately 10-year) history for the Air Force. The shift in policy was partially in response to the aforementioned DoD IG's report (2014), and the new policy is embodied in the upcoming facilities criteria document, as described in section 4.3.1.

The scope of the Air Force inventory is roughly equivalent to that of the Navy in terms of the number of dams and their respective hazard classifications. In general, the condition of Air Force dams is quite good compared to other services, possibly due to the close cooperation between the

Air Force, the Corps of Engineers, and Colorado State University on dam management issues. Dam safety managers did express concerns that the state of some small, low-hazard dams in the Air Force inventory may not be properly accounted for in the NID, or may not be maintained to the same standard as the inventory as a whole. These concerns will be addressed through future policy changes by the Air Force. Of special note is the Woods Reservoir, the largest reservoir owned by the DoD, which is impounded by the Elk River dam that is operated by Arnold Air Force Base.

4.3.1 Policy

Current Air Force dam safety policy is contained in Air Force Instruction (AFI) 32-1001, titled “Operations Management” (U.S. Air Force 2014). Section 10.2 of that document requires dams to be managed according to the Federal Guidelines for Dam Safety (FEMA 2004a). Operations managers are required to report on the status of dams to the Commanding Officer (CO) of the Air Force Civil Engineer Center (AFCEC) on a biennial basis. AFCEC is responsible for aggregating the data collected and making a formal report to the Corps of Engineers.

Of note is that AFI 32-1001 contains the words “Additional state or county laws may also be applicable.” This is not quite the same level of commitment that, for example, the Army has made in applying state standards for dam safety. However, it does appear that Air Force policy intends to comply with state standards wherever the local law is more conservative than federal guidelines.

Air Force policy is due for a substantial update and expansion in roughly the same timeframe as the publishing of this tech report. At the time of this writing, an Air Force Facilities Criteria (FC 3-310-09) titled “Dam Safety” is in draft form awaiting final editing.

4.3.2 Inventory

The 2016 real property inventory shows 89 dams and dikes in the Air Force’s inventory, split between three different CATCODES. The majority are in the CATCODE 841423 “Water Storage Dam” (76 dams). There are 36 Air Force dams counted in the 2016 NID. In addition, the Air Force has three other CATCODEs that may contain dams. Unlike the Army, there seems to be more latitude in assigning structures to each CATCODE, given the lack of a concrete definition for each code.

Among those dams the Air Force reported to the NID, a majority (52%) were used for recreational purposes. Compared to the other services, a larger amount of Air Force dams are used for flood control (20%). Figure 19 shows the distribution of uses for Air Force dams in the NID.

Figure 19. Air Force dams in NID, by purpose (USACE 2016).

As with the rest of the DoD inventory, the vast majority of Air Force dams are earth fill embankments (87%). Only 5 of the Air Force's dams are of a construction type other than earth (1 concrete, 3 rock fill, and 1 "other"). Figure 20 shows the distribution of Air Force dams by construction type.

Figure 20. Air Force dams in NID, by construction type (USACE 2016).

The vast majority of Air Force dams reported to the NID are classified as low hazard (78%). In total, the Air Force has 28 low hazard, 3 significant hazard, and 5 high hazard dams. Figure 21 shows the distribution of Air Force dams in the 2016 NID by hazard classification.

Figure 21. Air Force dams in NID, by hazard classification (USACE 2016).

4.3.3 Inspection

Air Force bases are free to contract out the execution of required inspections of dams. The most common source for this effort is the nearest district of the Corps of Engineers. Of the 5 inspection reports reviewed for this report, all 5 were conducted by Corps of Engineers personnel. These inspection reports are generally made to be in accordance with ER 1110-2-1156 (USACE 2014).

Air Force policy does not require the use of a specific form for periodic inspections. The format and content of the reports reviewed were set by the inspectors themselves and reflected the nature of the dam in question. Of note is that all inspection reports reviewed for Air Force dams contained survey data, which was not included in other services' inspection reports.

4.3.4 Work planning and prioritization

Air Force inspections typically include recommendations for correcting any deficiencies present at the time of the inspection. Unlike some other services' inspections, the recommendations typically do not include cost estimates for the repair items in question. Instead, recommended work items are categorized in accordance with the work item funding priority levels listed in ER 1110-2-1156, as shown in Table 14. These codes apply to non-routine maintenance and are intended to aid in budget planning

Table 14. Sample work prioritization for Air Force dams (USACE 2014).

Priority Funding Level	Code	Descriptions
CFY	1	Serious dam safety deficiency exists that needs remediation immediately. If not corrected, item has an unacceptable dam safety risk. May require operational restrictions placed on the project. Reprogramming funds is appropriate.
CFY + 1	2	Remediation should be initiated within 12 months. May require operational restrictions placed on the project. Reprogramming funds is appropriate.
CFY + 2	3	Study and remediation (as applicable) should be initiated within 24 months. The funds are currently being budgeted.
CFY + 3	4	Study and remediation (as applicable) initiated within next budget cycle or 36 months. Used for tracking and monitoring.
CFY + 4	5	Study and remediation (as applicable) initiated within next budget cycle or 48 months. Used for tracking and monitoring.

Air Force representatives indicated that hazard potential is used as an informal prioritization tool, meaning that high-risk dams are given a higher priority for repair and maintenance of deficiencies of the same magnitude than lower risk dams.

4.4 Marine Corps

The U.S. Marine Corps (USMC) owns the smallest inventory of dams among the DoD services. Only 7 dams are in the USMC inventory, including one recent addition not captured by the 2016 NID. Until the latest update of the NID, all Marine Corps dams appeared as Navy owned. The Marines now report to the NID separately from the Navy. Many of the systems and policies that apply to the Marines are similar to those used by the Navy. Rather than cover all details of the USMC dam management process, the following discussion will be limited to the highlights and differences, as compared to the Navy program.

4.4.1 Policy overview

The principle policy document covering USMC infrastructure is Marine Corps Order (MCO) 11000.5, titled “Facilities Sustainment, Restoration, and Modernization Program,” which was last updated in June 2016 (USMC 2016). This document is the authoritative policy for managing facilities, but otherwise offers no details specific to dam safety management. Further guidance is given in the Facilities Directorate memo titled “Dam Safety Inspection Guidance,” which was last updated in December 2014. Note that the Navy B-10.7 policy (NAVFAC 2016) is also mentioned as a reference in the guidance memo. The guidance memo explicitly names installation commanders as being responsible for the management of dams for each installation.

There are 7 NID-reportable dams in the USMC inventory, but only 6 dams appear in the most recent NID database (USACE 2016). Three of those dams are high hazard, while the rest are low hazard. One dam is of concrete construction and the rest are earth embankment type. One notable item is the Lake O’Neill dam on Camp Pendleton, which was constructed in 1883, making it the third oldest dam in the DoD inventory after the aforementioned Mine Lake dam (1845) and the Army’s Arsenal Power dam (1873). All USMC dams listed recreation as a purpose in the NID, and 5 of the 6 had multiple purposes listed in the 2016 NID. The other purposes included water supply (3 dams) and fire protection (3 dams).

All dams in the USMC inventory are entered into the FAC 8714 with the CATCODE 87125, which is the same designation used in the Navy. iNFADS is the Marines Corps' primary inventory system for dams. Note that the USMC also includes weirs as a separate asset type but includes them in the same CATCODE 87125 as dams.

In general, the dam safety inspection guidance implements federal guidelines. Dams are required to be formally inspected every 3 years, but the practice is to conduct inspections every 2 years. Installation commanders are responsible for establishing a periodic inspection program, as well as designating a dam safety officer for each dam. The Marines utilize USACE Norfolk district for inspections, as does the Navy. The rating criteria, including the MDI, is the same as the Navy uses.

An update of the USMC facility inspection program policy is expected to be released in September 2017. At the time of this writing, draft policy names USACE as the "primary contracting and execution agent for dam inspections." This is not a substantial change from current practice for the Marines, but the explicit designation of USACE is new to the policy revision's language.

5 Overview of the Sustainment Management System Process and Framework

5.1 Definition of a Sustainment Management System

“Sustainment” is maintenance and repair necessary to keep facilities in good working order. “Management” is a systematic approach to insure optimum return on investment. Thus, an SMS can be defined as a systematic approach to ensure maintenance and repair of facilities in a manner that maintains good working order and optimum return on investment. An SMS allows for total life-cycle management of facilities.

5.2 Advantages of Sustainment Management Systems

Several SMS modules developed by ERDC-CERL are now proven facility and investment management tools that facilitate effective practices for investment in maintenance and repair of DoD and other federal facilities. These best practices include the following (National Research Council 2012):

- Establish a framework of procedures, required information, and valuation criteria that aligns the goals, objectives, and values of individual decision-making and operating groups to achieve the organization’s overall mission.
- Provide a basis for measuring and improving outcomes of facilities investments.
- Components of the framework are understood and used by all leadership and management levels.
- Implement a systematic facilities asset management approach that allows for a broad-based understanding of the condition and functionality of their facilities portfolio, as distinct from individual projects, in relation to the overall mission.
- Integrate facility investment decisions into their organizational strategic planning process, viewing facilities as mission enablers rather than solely as costs.

SMS tools already exist for certain facility types and are listed in Table 15. More detailed information on each tool is available at <https://www.sms.erdcdren.mil/>.

Table 15. Current SMS tools developed by ERDC-CERL.

Facility Type / Asset Domain	SMS Tool Name
Pavements for airfields, roads, and parking lots	PAVER™
Buildings and associated vertical facilities	BUILDER™
Railroad tracks and associated facilities	RAILER™
Roofing systems	ROOFER™
Fuel tanks and distribution systems	FUELER™
Water and electrification infrastructure (future development to include waste water, storm water, natural gas, and thermal systems)	SMS Utilities

ERDC-CERL is currently working on an SMS Enterprise solution that will provide the DoD with holistic analysis and visibility across facility types. This future capability will allow a more comprehensive facility portfolio management and a common operating picture of installations and facilities across the SMS tool spectrum. Development of a dams SMS would enhance this enterprise capability across the DoD.

5.3 Sustainment Management System methodology

SMS programs utilize a systematic and structured methodology. The methodology includes a defined manner for inputting inventory, performing assessments, and then applying a standardized method of analysis to determine the condition and estimated remaining service life of individual components or sections within a facility. The SMS tool then prioritizes work based on user-defined policies and standards. It can also determine future work items and facility condition at specified funding and condition levels through forecasting “what if” scenarios to analyze impacts. The SMS thus allows full life-cycle management of facilities that considers the total cost of ownership in managing assets in order to proactively plan, respond, and improve asset infrastructure. Figure 22 represents the steps involved in the SMS methodology.

Figure 22. Steps in Sustainment Management System methodology (ERDC-CERL).

Inventory involves identification and categorization of real property and capital assets by breaking the inventory into manageable and observable components or sections. This breakdown often involves linking location and type of asset through a geographic information system (GIS). Assessment may involve both condition assessment and functional assessment, and it is generally accomplished through an inspection process, specific to that domain and with consistent and objective protocols, that results in a CI for the facility.

Analysis may also be referred to as “prediction” in that the remaining service life of the facility is predicted based upon the existing condition and component degradation. Work planning, also known as investment planning, generates the work requirements to develop an associated cost along with a priority across the defined inventory. Forecasting or scenario planning then allows different course of action analysis to optimize facility investments based upon user defined levels of either fixed or varied budgets or facility conditions.

5.4 Management system implementation

The various SMSs developed by ERDC-CERL each have a commonality in their framework, as outlined above, but each also has unique characteristics and history based on the specific infrastructure type. Since no widely accepted SMS currently exists for dams, it is useful to review how other facility asset types implement an SMS and to consider how an SMS’s unique characteristics might apply to an SMS for dams. Figure 23 represents SMS implementation for pavements that may be a helpful guide for linear water retention assets such as levees or dikes (Shahin 2005).

This report focuses on steps 1–5 in Figure 23 for dams, in order to propose a common inventory, assessment, and condition rating and reporting for dams across the DoD.

Figure 23. Example of pavement linear asset time sequence (Shahin 2005).

Development of deterioration models for varied types of construction, materials, climates, and other significant variables for dams or any other facility type requires extensive research and statistical analysis that is beyond the scope of this report.

Since dams usually are represented by a single category code in the DoD real property inventory, buildings may serve as a useful example in implementation procedure as well. Figure 24 and Figure 25 demonstrate how BUILDER™ sustanment management system uses the industry-standard

UNIFORMAT II hierarchy in asset management, and how the process can also be integrated with existing maintenance management systems and work order systems such as Maximo, TRIRIGA, or others.

Figure 24. Inventory-naming convention used by BUILDER sustainment management system that represents the industry-standard UNIFORMAT II hierarchy. (ERDC-CERL).

Figure 25. Overall process for building management can be integrated with existing maintenance management systems during the SMS steps (ERDC-CERL).

For dams and water retention facilities, common definitions and facility components established by and reportable to the NID and the regulations and inspection requirements of both FEMA and USACE, serve as useful industry standards for the inspection template proposed in this report.

6 Proposed SMS Module for Dams

The following chapter contains an outline of a potential SMS module for dams. The primary functions of this system are to serve as a data warehouse for DoD dams' inspection data, to aid in providing documentation of federally required inspections, and to enable better and more consistent decision making regarding maintenance and repair work. The associated inspection template aids inspectors in pushing data to the SMS in an organized manner, but it should not be construed as a replacement for any existing dam safety practices.

Six principal parts are envisioned for the inventory template for dams. These parts are defined below and then discussed in greater detail in the subsections that follow. Note that the data fields presented in this chapter are placeholders; a detailed data scheme for the SMS module is beyond the scope of this report.

- **Asset definition.** Includes all information necessary to uniquely identify a dam, including links to the real property system and NID, and any maintenance management system in use by the various DoD agencies (i.e., Maximo/FEM and TRIRIGA® software systems).
- **Component catalog.** Includes a list of unique parts of a dam, which allows a standardized way to report on the condition of dams. There are two principal parts to this catalog; a list of all components of a dam and their associated attributes, and a corresponding list of deficiency indicators associated with each component.
- **Inspection data.** Includes SMS condition ratings, comments, photographs, and recommendations generated by inspectors, each linked to a component in the inventory.
- **GIS definition.** Utilizing Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) for reporting, includes a geo-referenced map of the dam itself. It may also be useful to include inundation maps, drainage basins, or survey data.
- **Repository.** To store information not included in the four parts listed above. This information would include completed inspection reports, Emergency Action Plans (EAPs), or other related documents. An implied requirement for this repository is a metadata standard suitable for making stored documents searchable.

- **Work planning.** Includes capabilities for forecasting, work planning, and prioritization. Cost estimating and Facility Condition Index (FCI) calculation are included in work planning.

At this time, capabilities for work planning and prioritization are not envisioned as part of the next phase of work on a Dam SMS. There are multiple difficulties in completing work planning for dams. Mass concrete and embankments do not undergo deterioration like other components typically encountered with SMS infrastructure. If no deficiencies are present, they can actually improve with age. Another likely difficulty is determining parametric cost estimates. Compared to other SMS components, dams have many components that make it more difficult to estimate quantities and condition-based unit costs.

The most likely path forward for a Dam SMS software module is similar to that of the Utilities SMS module, which is being implemented directly into the Enterprise SMS. Therefore, the data warehouse scheme should be similar, if not identical to that of the Enterprise system, save for the different sources used for the dam module. At this time, there is no plan for a standalone or tablet-based application, as has been developed for other SMS modules (e.g., BUILDER, RAILER), due to a general lack of stated interest on the part of service representatives.

6.1 Asset definition

The primary purposes of the asset portion of the template is to uniquely identify each dam in the inventory. The fundamental link in this part of the proposed module is between the real property system, which will remain the authoritative source for asset management purposes, and an SMS-specific unique identification (ID) number for the asset. With these two databases thoroughly reconciled, the SMS can then link to other databases, including the NID or a CMMS (e.g., Maximo, TRIRIGA). Table 16 provides suggested data fields for the asset portion of the proposed Dam SMS module.

Table 16. Suggested data fields for the asset assignment table (ERDC-CERL).

Long Title	Short Title	Data Type
SMS unique ID	UID	Short text
Real property unique ID	RPUID	Short text
Facility Analysis Code	FAC	Short text
Category code(s)	CATCODE	Short text
National Inventory of Dams ID	NIDID	Short text
Dam name	Dam_Name	Long text
Dam owner	Owner	Long text
Dam safety officer	DSO	Long text

At the time of this writing, most of this information is already being collected and sent to USACE for purposes of updating the NID. The major item not available at this time is the link between the Real Property Unique Identification (RPUID) and the NID identification (NIDID) databases. This issue could be easily addressed during scheduled periodic inspections by simply adding the required data at the same time the inspection template is first populated. Note that this proposed data template would also accommodate dams not in the NID, should it be desired to add those to the SMS.

The asset definition part of the template may also contain foreign keys that correspond to CMMSs such as TRIRIGA or Maximo. As will be discussed in section 6.3.3, such a link may be useful to dam safety personnel should the need arise to generate and report a repair cost following a formal inspection.

Note that the NID database itself contains many data fields useful for specifying the physical dimensions of a dam. It may therefore be useful to add that data directly to the SMS. However, the authors of this report view the information stored in the NID as a separate database, not necessarily within the scope of the proposed SMS for dams. In any event, adding the entirety of the NID to the proposed SMS would represent an extra data migration between the installation and the NID. However, users may find it convenient to access and edit such data directly in a centralized database such as the SMS, rather than continue to manage a data transfer to the NID. For this reason, it may be useful to incorporate the NID data scheme

directly into the SMS and defer the decision to populate those fields to each service.

6.2 Component catalog

The purpose of the component catalog is to enable consistent inspection and condition rating methods for dam components. The intent is to provide a definitive list of all parts of a dam, such that every observation made during an inspection can be linked to a single component in the catalog.

The catalog's proposed inventory template divides all components of a dam into a maximum of four hierarchical levels (see descriptions below). The hierarchy is similar to that of the UniFormat system used to inventory building components based on function rather than material. The components listed are not a complete representation of the future inventory template, which would presumably be finalized by a working group represented by each service.

The primary purpose of the component inventory is to enable tracking the condition of a dam's components through time. Since there is no expectation that the inventory template will be used for a parametric cost estimating or a condition projection system, there should be no need to specify quantities, either for the component itself or any deficiency found.

The following four levels are proposed to be the basis for a hierarchical component categorization system.

- **Level 1: Systems.** This is the highest level of the inventory hierarchy. At this level, components are subdivided into groups that serve the same first-order goals. Only 5 systems are currently in the inventory template; Dam Body, Spillways, Outlet Works, Instrumentation, Foundations. Systems are directly linked to a unique ID representing a real property asset.
- **Level 2: System Types.** This level separates components based on construction material or design features that would affect a change in management of that component. All inventory items in this level serve the same purpose as both the Level 1 parent category and all items in the same Level 2 category.
- **Level 3: Components.** This is the primary inventory level, at which CIs are generated and rolled up to the higher levels. Items in this level serve either a single purpose or several closely interrelated purposes.

The intent is that condition ratings will be applied to features at either this level of the inventory or at Level 4, and then those ratings would be rolled up to higher levels and to the dam as a whole.

- **Level 4: Component Sections.** This level further differentiates Level 3 components by subdividing them according to material type or functional form. Components may also be directly assessed on condition at this level, and the condition ratings rolled up to higher levels.

Individual components and component sections would be further described by associated attributes. For instance, for each record of a conduit, there might be attached values for construction type (e.g., concrete, corrugated steel), size (e.g., 12," 16," 24" outside diameter [OD]), and length. Other attributes that may apply include location, database keys, or other descriptive fields.

Full implementation of a Dam SMS would require further effort to create a complete a component catalog. The intent is that CIs would be generated at Levels 3 and 4 of the inventory hierarchy, then rolled up to the systems and then to the dam itself.

6.3 Inspection data

The purpose of the inspection template is to enable inspectors to better track the condition of a dam's components throughout time. This system is aimed at inspectors conducting both formal and intermediate inspections, but the foremost use will be for intermediate inspections, where a detailed record of deficiencies generated during a formal inspection can be used as a checklist during intermediate inspections. The inspection template presented in subsections 6.3.1–6.3.3 is not intended to wholly replace existing practices, but it should enable inspectors to enter data in a way that is structured and therefore, more amenable to later analysis and tracking.

The principle feature of the inspection template is that inspection observations are linked to specific features in the SMS component catalog. Within the SMS template, inspection data is expected to be attached to the record of an individual structure and grouped together by date. Other data such as photos, drawings, or reports of special inspections are also expected to be attached to the SMS database at the inspection level. Changes in the condition of the structure could therefore be tracked throughout time at a component level.

There are three distinct sections in the inspection template; the inspection front matter, inspection observations and related condition ratings, and the resultant repair recommendations, as described below.

6.3.1 Front matter

The data collected in the front matter of an inspection serves to uniquely identify each inspection in the SMS database. It is intended that each element in the database be linked to an inspection record. The fields in this section include those for recording the names and qualifications of inspectors and the timing of inspections, in order to document that federal requirements are being met (Table 17).

Table 17. Suggested data fields for an inspection's front matter (ERDC-CERL).

Long Title	Short Title	Data Type
Inspection unique ID	Insp_ID	Short text
SMS unique ID	UID	Short text
Inspection type	Insp_Type	Short text
Inspection date	Date	Time/date
Next scheduled inspection date	Next_Insp	Time/date
Lead inspector name	Lead_Nm	Long text

More data is typically collected during a formal inspection than what is shown in Table 17, such as weather conditions present or the level of the pool at inspection time. While this information is important to the inspection process, it is less critical to the SMS than it is to the inspectors themselves. For that reason, the data collected in the front matter is limited to what is required by the SMS.

6.3.2 Component conditions

As discussed previously, the intent of the component catalog is to standardize the reporting of inspection observations. It is expected that each observation of the condition of a part of a dam is linked directly to one or more components in the SMS component catalog. A condition rating may be attached to each component in the catalog. However, it is expected that a condition rating would be applied by inspectors to components lower in the hierarchy (Levels 3 and 4) and then rolled up to higher levels via a method yet to be determined.

Table 18 shows the suggested data fields for the inception of a single component. A complete inspection report would contain similar records for each component relevant to the dam in question. Appendix D of this report shows a suggested form for inputting data into the SMS in this template, which is modeled after the FEMA-145 (FEMA 1987) inspection forms currently in use by DoD.

Table 18. Suggested data fields for individual component inspections (ERDC-CERL).

Long Title	Short Title	Data Type
Component unique ID	Comp_UID	Short text
Component code	Comp_Cd	Short Text
Condition rating	Cond_Rt	Integer
Comments	Cmts	Long text

6.3.3 Work recommendations and cost estimates

An important result of inspections conducted for the SMS is the calculation of an FCI. This metric provides a financial measure of the condition of an asset and is especially suited to comparisons across domains. Figure 26 shows the outline of the FCI calculation.

Figure 26. Facility Condition Index definition (ERDC-CERL drawing of equation in Rush 1991).

$$FCI = 100 * \left(1 - \frac{\Sigma \text{Maintenance Backlog}}{\text{Plant Replacement Value}} \right)$$

The fundamental quantity in this equation is the ratio of the maintenance backlog to the replacement value of the asset. The Plant Replacement Value (PRV) is a quantity generated and stored in the real property database. The maintenance backlog is the sum of all deferred repair work on the asset.

The proposed system would generate the numerator (i.e., the maintenance backlog) as part of the SMS inspection. In the absence of a comprehensive work planning module like other SMS modules, the simplest way to generate this sum is to use the inspector's best estimate. Most inspectors already provide some form of cost estimate for remediation of deficiencies. It is suggested that the DoD recommends a standard method for generating

and reporting repair costs. For the purposes of the development of an SMS, it is sufficient to support this repair cost reporting in whatever form it is provided by inspectors. This form may then include further refinements of costs after base personnel generate a scope of work for each project and determine the work's real cost.

6.4 GIS definition

GIS information is an important part of the Enterprise SMS data scheme. A GIS standard is required before any data can be uploaded to the Enterprise SMS. The DoD uses the SDSFIE to specify GIS data, and each service publishes their own adaptation of that standard. At the time of this writing the Army, Air Force, and the Corps of Engineers all have a dam feature class defined in their SDSFIE adaptation. However, none of these standards match that of the other services, and the Navy and Marine Corps do not include such a feature class in their adaptations.

It is suggested that a standard SDSFIE feature class be specified and adopted by each service. A standard across each service would reduce the labor required to import data into the SMS, and eliminate the possibility of data gaps due to misalignment of the data scheme. A suggested template for such a standard is the USACE SDSFIE feature class for dams.

There may be some ancillary features that are worthwhile to capture in the SMS. The most important feature would be maps of the area affected by a worst-case failure of a dam (i.e., an inundation map corresponding to a breach under PMF conditions). Such a map would be useful to inspectors, who commonly verify the hazard classification of dams. This flood map may also be useful to base master planning personnel, to avoid building new structures in the flood zone and thereby increasing the hazard classification of the dam. Note that flood maps are already an integral part of the required EAP for high and significant hazard dams, so in many cases no additional effort would be required to generate this data. The difference would lie only in the standards by which the data is reported.

6.5 File repository

The fields listed in the previous sections do not capture all data that might be collected during a dam inspection. Much of the information contained in a formal inspection report is interpretation on the part of engineers,

which does not translate well into a structured database system, as described in the previous sections of this report. Rather than attempt to capture this sort of feedback into the SMS database, it is likely more efficient to provide a method for storing completed inspection reports and other data sources, and then link them to the appropriate inspection data in the SMS. For the purposes of structuring the storage of such files, it would be best if there was a standard for attaching metadata to this type of file. Otherwise, files could be linked to the dam itself by using either NIDID or RPUID. Table 19 shows the suggested metadata to be attached to inspection files uploaded to the SMS.

Table 19. Suggested metadata fields (ERDC-CERL).

Long Title	Short Title	Data Type
Metadata unique ID	met_ID	Short text
SMS unique ID	UID	Short text
Inspection unique ID	Insp_ID	Short text

Other files that may be added to this file repository are up-to-date EAPs, as-built plans and drawings, analysis reports, specialty inspection reports, or maintenance histories. As with the NID data fields, these types of files are not strictly needed in the SMS database. However, users may find it convenient to store these file types directly in the SMS, rather than manage two separate file systems. Given that the inspection reports themselves will likely be stored in the SMS, it seems reasonable to allow for the possibility of storing other file types as well.

7 Conclusions and Recommendations

Chapter 6 laid out the framework for an SMS module for dam inspections. The general conclusion of this report is that the DoD could implement such an SMS module by using an inventory methodology similar to what is described in chapter 6, with minimal modification to the formal inspection process already in use. The inventory and inspection database created for that purpose would also provide an effective means to standardize and document other federally required inspections. A condition rating scale could be developed for these inspections, based on previous work by USACE. The remaining elements of a typical SMS (i.e., condition forecasting, work planning, and prioritization) would be absent in the initial implementation, but may be topics for future efforts.

If dams were being managed to reduce overall risk, including both the condition and the hazard classifications, it would be expected that more high-hazard potential dams would be rated as satisfactory. Instead, as was indicated by Figure 5, the condition ratings are roughly the same for each hazard class. This finding shows that managers tend to respond to the deficiencies based on the severity of the defects present, which may be an indication that managers lack the tools to make risk-informed prioritization decisions such as an SMS could provide. Given that the decision process for dam repairs is highly distributed, it is likely that repairs are prioritized against repairs for other installation infrastructure rather than severity of deficiencies across the inventory of dams. Not only are the repairs of dams not prioritized based on risk, the repairs likely aren't prioritized based on the severity of deficiencies within the dam inventory.

This report recommends that the next step in the development of an SMS module for dams would be to assemble an advisory body from the relevant DoD services. This advisory body would function similarly to the working groups created for other SMS modules (e.g., PAVER). The participants would be drawn from the same group of contacts mentioned in this report, to include the Dam Safety Officer from each service as well as representatives familiar with inspections for each service (e.g., USACE Norfolk District). The key duties of this group would be to further shape the framework as described in Chapter 6, to complete the inventory template for dams, and to advise and participate in the development of the inventory and inspection capabilities.

In addition to the SMS module described above, the research conducted for the purposes of this report revealed a few ancillary action items that DoD may consider, as presented by the sections that follow.

7.1 Scope definition and CATCODE realignment

At the time of this writing, it is unclear which dams will be added to the SMS. The presumption is that the most likely candidates are dams reportable to the NID, as these dams are subject to federal regulatory requirements and would likely benefit the most from increased attention.

However, the various services may have different ideas as to how they would manage their inventories. As a first step towards an SMS for dams, this report recommends that DoD specify the details of the scope of such a system.

It has been shown that the current CATCODE system does not align with the NID methodology. The current DoD FAC also includes structures that would not fit into any definition of a dam. It is therefore unlikely that the scope of an SMS module for dams would align with an existing FAC or CATCODE. The following list shows a few options available for defining the scope of the dams-SMS:

1. DoD can add all assets classified as dams in the current CATCODE system.
2. DoD can specify which assets are to be added to the SMS, where the scope may or may not align with the current CATCODE system or the NID.
3. DoD can realign the CATCODE and FAC designations for dams such that the real property codes align with the intended scope of the SMS.

If the first option is selected, then it should be noted that the inspection template presented in this report is likely unsuitable for some of the structures that would thus be captured in the current CATCODEs, especially for very small or low head dams. The inspections described in this report are geared more towards NID-reportable dams, and using that type of inspection may involve excessive time and effort for non-NID dams. This approach would also open the possibility of varying level of capture between the services, since CATCODES are service-specific.

The second option would be the simplest to implement, and it may be preferred if each service has its own intended scope. However, it would still be

possible that some of the structures that services chose to include would be ill suited for the inspection template, especially if services choose to greatly expand the scope beyond NID-reportable dams.

The third option would be the most challenging to implement, and it would require a policy rewrite in cooperation with real property personnel. The benefits of such a policy rewrite would include a clear indication of which assets are to be inspected via the SMS, and a more realistic assignment of sustainment funding levels to dams in the SMS, where the funding reflects the increased costs of both supporting the SMS and conducting federally required inspections. Any changes to the CATCODE system would be determined by the services themselves, but the primary feature would be an FAC or group of FACs that is strictly composed of assets that would be managed by using the SMS.

7.2 Potential policy revisions

As mentioned in section 4.2.1, the definition of a dam that is used by the Army's AR-420-1 document (U.S. Army 2012) mirrors that of an older version of federal law in which it seems clear that the intent of the policy is to enact the current federal law. Therefore, it is recommended that the Army review the current language of the Army regulation and the relevant federal law to determine if the Army language meets the intent of the law. If a change in the Army regulation's language is warranted, it is suggested that the definition used in the federal law be a template for the Army's definition. This federal definition is also used in the NID inventory methodology and thus, it would more closely match the intended SMS scope.

It is also implied that the inspection template presented would serve an identical purpose to that already in use by DoD services. In particular, the inspection forms generated by using the template would be similar to those mandated by current DoD policy (i.e., those found in FEMA-145 [FEMA 1987]). There should be no need to use both types of forms for a dam inspection. It is recommended that each service review the inspection methodology presented in this report and consider if it would be advantageous to supplant the FEMA forms in favor of inspection forms aligned with SMS methodology. Appendix D provides a sample of such a form, which was modeled after the FEMA forms to be used for field observations by inspectors during formal and intermediate inspections.

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Appendix A: Dam Safety Survey

The following questions were posed to representatives from the Army, Navy, Air Force, and Marine Corps. The survey was presented to four groups of personnel, one group each to deal with dam (1) policy, (2) inventory, (3) inspection, and (4) maintenance. Some personnel represented more than one group for their service.

Note that many of the questions posed to the four groups are somewhat redundant. In many cases, the same individual answered questions for multiple groups. For brevity, questions which were unanswered are omitted from the following lists.

Army

Two representatives responded for the Army, Mr. Arden Dean of the office of Assistant Chief of Staff for Installation Management (ACSIM [DAIM-ODF]) and Mr. Michael Andres of HQ Installation Management Command (IMCOM). The first section regarding policy making and regulation was answered by Mr. Dean, while the remaining sections were answered by Mr. Andres.

Policy makers and regulators – Arden Dean

1. What is the authoritative policy document for dams for your organization, and where can it be found?

AR 420-1, DA Pam 420-1-3

2. Who is the designated dam safety officer? Who is the primary POC for each dam?

HQDA- Arden Dean, HQIMCOM-Michael Andres, Installations DSO being collected in NID; Land Holding Commands (LHCs) being determined

3. Describe your dam management procedure to include:
 - a. Inventory management

By HQIMCOM utilizing ERDC

b. Assessment and inspection methodology and qualifications

According to appropriate FEMA guidelines

c. Method of prioritization for maintenance, repair or rehabilitation

By Senior Commander of Installations now.

In future, LHC for High/Significant Hazard Critical/Serious Condition

d. Future work planning and analysis

Senior Commander at installation

4. How does your organization incorporate risk into your dam safety process? What is an acceptable risk in terms of dams?

Determined by Senior Commander

a. For life safety? (e.g., statistical lives lost per year of operation)

None

b. For failure probability? (e.g., annualized failure probability)

Don't do it. We assume 100% failure at overtopping.

c. For property loss? (e.g., liability for downstream structures)

Have no acceptable risk assumed.

5. What criteria must be met for dam removal, or changing operating parameters (e.g., lowering the reservoir)?

Senior Commander decision

6. What IT systems are being used for dam management?

None

7. Does your agency have any current or planned research or policy revisions regarding dam management?

Policy update for AR 420-1 draft in June 2017.

8. What parts of dam safety work well, or not well enough? Are levees managed similarly?

Policy working well. Installation Commander management and execution not working well.

Don't do levees.

9. Who are the best POCs for dam inventory and inspection, or others we should talk to?

IMCOM –Michael Andres. HQDA-Arden Dean ACSIM

Inventory managers-HQIMCOM–Michael Andres

1. What is the authoritative policy document for dams for your organization, and where can it be found?

AR 420-1, DA Pam 420-1-3

2. What IT systems are being used to track dam inventory, inspection and maintenance?

None

3. Who is the designated dam safety officer? Who is the primary POC for each dam?

Michael Andres

4. How are dams added to the Real Property inventory, and how are they added to the NID? How are the two databases linked?

The two systems are not linked; garrisons add dams into the RP by initiating a DD 1354.

5. How are non-NID dams managed?

All dams are classified under the NID

6. Who actually conducts formal dam inspections, and how do you decide whether to use internal, DoD, or consultants? Who actually conducts intermediate inspections? Who maintains a list of inspectors and their qualifications?

ERDC

7. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?

ATIIP (Army Transportation Infrastructure Inspection Program) on AKO (Army Knowledge Online) site – limited access.

8. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?

The funding source is SRM, depending on the cost. DPW, Garrison Commanders, Installation Directorates Director has authority on approving funding, DPW has the responsibility to accomplish the required repairs. Dams are maintained to comply with FEMA 93 requirements or ISR of green level.

9. What parts of dam safety work well, or not well enough? Are levees managed similarly?

Inspections are working well.

10. Who is the best POC for dam inspections and maintenance, and who else should we talk to?

Me?

Inspection managers—Michael Andres

1. What is the authoritative policy document for dams for your organization, and where can it be found?
2. What IT systems are being used to track dam inventory, inspection and maintenance?
3. What method is used to generate repair costs? What method is being used to prioritize spending on maintenance and repair for dams?

Repair cost estimate is based on a rough order of magnitude developed during the inspection. SRM 1-n list.

4. What are the training and qualifications required for inspectors, and how do you track it?

Covered under annex L of AR420-1, inspector's qualifications are available on the ATIIP website.

5. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?
6. Is there an existing checklist or template for dam inspections in use? Can you provide an example of an inspection report?

Yes

7. How many man-hours are expended in a typical inspection? How does this effort break out into preparation/review/inspection/write-up? (Formal, intermediate, special?)

Depends on the size, formal inspection average time is probably 8 hours

8. To whom are the inspection reports given, and what type of follow-up occurs?

Garrison DPW; if any critical findings were identified, a memo from HQ IMCOM will be provided to the Garrison Commander.

9. What parts of dam safety work well, or not well enough? Are levees managed similarly?

EAPs are not working well.

10. Who are the best POCs for dam maintenance, and who else should we talk to?

Me?

Maintenance managers

Representatives for the Army did not respond to this portion of the questionnaire. However, the primary POC for Army dam inspections, Shaun Stanton, did provide feedback during phone conversations with the authors of this report, and that feedback is reflected in the summary of Army dam management in section 4.1.

1. What is the authoritative policy document for dams for your organization, and where can it be found?
2. What IT systems are being used to track dam inventory, inspection and maintenance?
3. Who conducts routine maintenance and repair on dams? What common problems do you encounter and how do you address them?
4. Who conducts major repair and rehabilitation (including new building and removal) on dams? What common problems do you encounter and how do you address them?
5. What method is used to generate repair costs? What method is being used to prioritize spending on maintenance and repair for dams? How do you determine what repairs are fixed with internal labor vs. external?
6. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?
7. How are non-NID dams managed, and are there issues with this management system?
8. What dam safety qualifications or training is being provided to everyday maintenance personnel?
9. What parts of dam safety work well, or not well enough? Are levees managed similarly?
10. Who are the best POCs for dam maintenance, and who else should we talk to?

Navy

The following responses related to the Navy dam safety process were collected and forwarded by Mr. Bradley Patch, NAVFAC HQ.

Policy makers and regulators

1. What is the authoritative policy document for dams for your organization, and where can it be found?

A. NAVFAC Business Management System (BMS) B-10.7 (Dam Safety Inspections and Assessment of 12 December 2016).

B. Accessed at the NAVFAC Website at:

https://hub.navfac.navy.mil/webcenter/portal/bms/B-10.7+Dam+Safety+Inspections+and+Assessment?_afLoop=91678439849082#!%40%40%3F_afLoop%3D91678439849082%26_adf.ctrl-state%3Ddvkjg44ku_159

C. Or, via the Point of Contact above. The BMS cites appropriate supporting “resources” like FEMA’s Federal Guidelines for Dam Safety.

2. Who is the designated dam safety officer? Who is the primary POC for each dam?

A. Mr. Bradley Patch, NAVFAC HQ.

B. See the NAVFAC/Navy Dam Safety POC list provided separately.

3. Describe your dam management procedure to include:

Inventory management - Dams that are reportable in the National Inventory of Dams (NID) per FEMA reporting guidelines are entered in the internet Navy Facility Assets Data Store (iNFADS). iNFADS and inventory management is under NAVFAC’s Asset Management Business Line (AMBL), who manages real property assets per the NAVFAC Real Property Inventory Procedures Manual.

Assessment and inspection methodology and qualifications - NAVFAC teams are formed with Navy and U.S. Army Corps of Engineers, Norfolk District representation, for the execution of Navy dam formal inspections.

Method of prioritization for maintenance, repair or rehabilitation of dams - Formal inspection reports contain recommendations to the installation Commanding Officer, via the command's Public Works Officer. Reports contain future work planning and analysis. The formal inspection reports recommend future formal inspection periodicity based on dam hazard classification, along with future analysis based on formal inspection findings and associated recommendations.

4. How does your organization incorporate risk into your dam safety process? What is an acceptable risk in terms of dams?

A. The aforementioned BMS includes instructions for local authorities to use FEMA risk management guidelines.

B. For life safety? (E.g. statistical lives lost per year of operation) Four Navy dams are categorized as "High" hazard per FEMA guidelines, with potential for loss of life if breached. No lives have been lost due to dam failure, therefore life safety statistical analysis is not applicable.

C. For failure probability? (e.g., annualized failure probability) The aforementioned BMS includes instructions for local authorities to use FEMA risk management guidelines.

D. For property loss? (E.g. liability for downstream structures) The aforementioned BMS includes instructions for local authorities to use FEMA risk management guidelines.

5. What criteria must be met for dam removal, or changing operating parameters (e.g., lowering the reservoir)?

Local installation commanders must recommend dam removal, and changes to operating parameters – to include lowering of the dam reservoirs. The NAVFAC Engineering and Expeditionary Warfare Center (EXWC) serves as engineering backup, and provider of dam safety and risk analysis expertise. EXWC contracts for USACE and contractor experts to develop formal inspection reports annotating risk and assessments.

6. What IT systems are being used for dam management?

Formal Navy inventory data is included in iNFADS, and dam inspection reports are deposited in the Specialized Infrastructure Data Enterprise Reporting System (SPIDERS).

7. Does your agency have any current or planned research or policy revisions regarding dam management?

Not at present.

8. What parts of dam safety work well, or not well enough? Are levees managed similarly?

A. Formal inspections work well; local installation informal inspections, not so well. iNFADS serves asset management well, though SPIDERS is under development, and is assembling data over sequential inspection schedules.

B. Not at present.

9. Who are the best POCs for dam inventory and inspection, or others we should talk to?

Our EXWC POC, Terry Clarke, and our dam safety subject matter expert (SME), Lieutenant Duffy, and our Dam Safety PM, Bradley Patch are available for dam-related discussion.

Inventory managers

1. What is the authoritative policy document for dams for your organization, and where can it be found?
 - a. NAVFAC Business Management System (BMS) B-10.7 (Dam Safety Inspections and Assessment of 12 December 2016).
 - b. Accessed at the NAVFAC Website at: https://hub.navfac.navy.mil/webcenter/portal/bms/B-10.7+Dam+Safety+Inspections+and+Assessment?_afLoop=91678439849082#!%40%40%3F_afrLoop%3D91678439849082%26_adf.ctrl-state%3Ddvkjg44ku_159
 - c. Or, via the Points of Contact aforementioned. The BMS cites appropriate supporting “resources” like FEMA’s Federal Guidelines for Dam Safety.
2. What IT systems are being used to track dam inventory, inspection and maintenance?

Inventory data is resident in iNFADS, formal dam inspection reports are being assembled within SPIDERS, and maintenance records are generally available at local installation Public Works Departments.

3. Who is the designated dam safety officer? Who is the primary POC for each dam?

A listing is being provided separately.

4. How are dams added to the Real Property inventory, and how are they added to the NID? How are the two databases linked?
 - a. For dams not in the NID, yet gaining through rehabilitation or new construction structure within FEMA guidelines for inclusion in the NID, local installations recommend inclusion, and EXWC nominates.
 - b. They are not linked.

5. How are non-NID dams managed?

By local installations at present.

6. Who actually conducts formal dam inspections, and how do you decide whether to use internal, DoD, or consultants? Who actually conducts intermediate inspections? Who maintains a list of inspectors and their qualifications?

A. EXWC coordinates and contracts for the support.

B. Local commands.

C. EXWC's dam safety POC.

7. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?

A combination of local installations and EXWC. SPIDERS is being developed to warehouse reports.

8. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?

A. Sustainment, Restoration, and/or Modernization funding would be requested of Commander, Navy Installations Command (CNIC), via the chain of command.

B. Installation commanders with reach back for engineering support by NAVFAC Headquarters, and EXWC. Significant contracting, such as military construction (MilCon) would likely be coordinated with NAVFAC's Capital Improvement Business Line (CIBL).

C. The aforementioned BMS process to result in inspection reports recommending appropriate repairs.

9. What parts of dam safety work well, or not well enough? Are levees managed similarly?

A. Formal inspections work well, local installation intermediate inspections not so well.

B. Not at present.

10. Who is the best POC for dam inspections and maintenance, and who else should we talk to?

The NAVFAC Headquarters Dam Safety PM (Mr. Patch), EXWC Dam Safety Coordinator (Mr. Clarke), and EXWC's SME (Mr. Duffy).

Inspection managers (Specific to formal inspections – centralized program)

1. What is the authoritative policy document for dams for your organization, and where can it be found?

A. BMS B-10.7 Dam Safety Inspections and Assessment. Document is found in the NAVFAC Portal web site (secure access controlled). Federal Guidelines for Dam Safety (FEMA);

B. Additional resources would be the Army's regulations (AR 420-1 Chapter 7 "Transportation Infrastructure and Dams" and ER 1110-2-1156 "Safety of Dams – Policy and Procedures")

2. What IT systems are being used to track dam inventory, inspection and maintenance?

INFADS (Internet Navy Facility Asset Data Store - inventory), SPIDERS (Specialized Infrastructure Data Enterprise Reporting System – formal inspection requirements), and Maximo™ (facility configuration and SRM requirements).

3. What method is used to generate repair costs? What method is being used to prioritize spending on maintenance and repair for dams?

The installation would be responsible for contracting and funding that if they wanted to conduct a repair. CIOFP4 provides recommendations to the local PWO (primary POC) on prioritizations.

4. What are the training and qualifications required for inspectors, and how do you track it?

The Navy Dam Safety Program Manager will be a U.S. Navy Civil Engineer Corps Officer with a Master's Degree in Ocean Engineering, will usually be a Professional Engineer, and will have completed the USACE Learning Center course "Dam Safety." A typical inspection team will comprise of a team leader, a civil engineer (hydraulic), a structural engineer, and a geotechnical engineer. Inspectors are provided by U.S. Army Corps of Engineers.

5. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?

Formal inspection group maintains prior formal inspection reports. Local dam managers (usually in Public Works) have as-built plans, applicable instrumentation readouts, informal inspection reports and formal inspection reports.

6. Is there an existing checklist or template for dam inspections in use? Can you provide an example of an inspection report?

See report sample.

7. How many man-hours (MH) are expended in a typical inspection? How does this effort break out into preparation/review/inspection/write-up? (Formal, intermediate, special?)

Formal inspection only - For Navy personnel, it is about 4 MH for preparation, 2 MH for review, 8 MH per dam for inspection and 4 MH for review of write-up. For USACE group, they average 120 MH per dam inspection total (32 MH for inspection, 40 MH for preparation, 8 MH for review, and 40 MH for write up).

8. To whom are the inspection reports given, and what type of follow-up occurs?

Formal inspection reports are given to the installation Public Works Officer. CIOFP4's follow-up is currently when we perform the next formal inspection.

9. What parts of dam safety work well, or not well enough? Are levees managed similarly?

USACE support for execution of formal inspections, specialized analyses recommendations and generation, and local activity support for ER planning, implementation of recommended maintenance, repairs and improvements.

10. Who are the best POCs for dam maintenance, and who else should we talk to?

POCs for dam maintenance are the local activity Public Works groups. Reference POC columns in attached tracking spreadsheet (Dams 87125 Status MAY 2017.xlsx).

Maintenance managers

1. What is the authoritative policy document for dams for your organization, and where can it be found?

A. BMS B-10.7 Dam Safety Inspections and Assessment. Document is found in the NAVFAC Portal web site (secure access controlled). Federal Guidelines for Dam Safety (FEMA).

B. Additional resources would be the Army's regulations (AR 420-1 Chapter 7 "Transportation Infrastructure and Dams" and ER 1110-2-1156 "Safety of Dams – Policy and Procedures")

2. What IT systems are being used to track dam inventory, inspection and maintenance?

A. INFADS (Internet Navy Facility Asset Data Store - inventory), SPIDERS (Specialized Infrastructure Data Enterprise Reporting System – formal inspection requirements), and Maximo (facility configuration and SRM requirements).

3. Who conducts routine maintenance and repair on dams? What common problems do you encounter and how do you address them?

A. Installation Public Works Departments.

B. Vegetation growth. Bush hogs and mowers.

4. Who conducts major repair and rehabilitation (including new building and removal) on dams? What common problems do you encounter and how do you address them?

A. NAVFAC Headquarters would consult with EXWC and the USACE, for estimates and recommendations, and coordinate with CNIC and local installation for a prognosis.

B. Paucity of sustainment funding.

5. What method is used to generate repair costs? What method is being used to prioritize spending on maintenance and repair for dams? How do you determine what repairs are fixed with internal labor vs. external?

A. Engineering estimates.

B. Query of local installations and EXWC, and request for funding from CNIC.

C. Gain a recommendation from installation, region, and EXWC.

6. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?

A. Sustainment Restoration and Modernization funds.

B. NAVFAC Headquarters, and Capital Improvement Business Line.

7. How are non-NID dams managed, and are there issues with this management system?

Installations manage non-NID dams, and there are generally funding issues.

8. What dam safety qualifications or training is being provided to everyday maintenance personnel?

Local installation commanders specify training and they have reach back to NAVFAC Headquarters and EXWC for advice; query to USACE for particulars.

9. What parts of dam safety work well, or not well enough? Are levees managed similarly?

(Levees) Not at present.

10. Who are the best POCs for dam maintenance, and who else should we talk to?

POCs for dam maintenance are local activity Public Works personnel. See the attached document.

A.3 Air Force

The responses given by the Air Force were in the form of a teleconference involving key dam safety personnel and the authors of this report. Below are the condensed notes from those conversations. Note that this recording of responses is different from the other services, where the services responded in their own words. The following Air Force personnel were present at this conference:

- Dr. Robert Dinan
- Mr. Robert Okwera
- Mr. Tracy Caughlin

Policy makers and regulators

1. What is the authoritative policy document for dams for your organization, and where can it be found?

Currently, installations are managing AFI-32-1001 (“Operations Management”), which has language instructing bases to provide inspections in accordance with (IAW) FEMA-93. This document will be updated when the facilities criteria for dams (FC 3-310-09) is published. This FC is “almost finished” (currently in tech editing), and should be available within 3 months.

2. Who is the designated dam safety officer? Who is the primary POC for each dam?

The aforementioned FC establishes installation dam program manager, who will be named in the NID for each dam. The dam safety program manager for the Air Force will be Robert Okwera. The Air Force is to maintain a decentralized management system, with Robert Okwera providing oversight.

Note that dams are an extra duty for installation personnel, so that some may need to be informed of their roles as dam safety officer.

3. Describe your dam management procedure to include:
 - a. Inventory management

In the past: AFCEC called on installations to provide data (usually yearly). The data was then consolidated into a report given to the NID in the format required. This process will be largely intact with the new FC, but new data structures and requirements may grow out of the FC.

- b. Assessment and inspection methodology and qualifications

Once an installation reported a dam in their inventory, AFCEC passes information on the inspection requirements for dams to the installation,

which then has the responsibility to carry out the program IAW AF policy, FEMA-93.

Bases are free to contract the execution of inspections to USACE Districts or AE firms. Information from inspections bubbles up to AFCEC either on request or for a call for data. AFCEC synthesizes this data together for USACE (NID). Inspection reports are *not* being kept on file at AFCEC, the records remain with installations.

c. Method of prioritization for maintenance, repair or rehabilitation

Bases are allowed to determine their needs at the moment. After the FC takes effect, dam projects (non-maintenance) are going to be sent up to AFCEC. AFCEC is to review those projects to see if they meet federal requirements and Air Force Policy.

An example was given from the past, where AFCEC reviewed a repair project for a dam, including the scope of work to determine if the action met the standards of AF policy.

d. Future work planning and analysis

Note that, given the low mount of dams in their inventory, few prioritization decisions typically need to be made. For example, there may only be one dam project in a given year, obviating the need for a prioritization scheme.

It was noted (by Tracy Caughlin) that there had been an effort to create a system to get visibility for many projects at once, but the system didn't get off the ground.

4. How does your organization incorporate risk into your dam safety process? What is an acceptable risk in terms of dams?
 - a. For life safety? (e.g., statistical lives lost per year of operation)
 - b. For failure probability? (e.g., annualized failure probability)
 - c. For property loss? (e.g., liability for downstream structures)

Risk isn't an explicit part of inventory/inspection process for AF. Where possible, managers look at NID hazard potential, with priority funding given to high hazard dams.

Robert Dinan noted that John Bianco had pushed for a risk informed approach for the DoD. In Dr. Dinan's opinion, this sounded like a lot of work, given the nature of the Air Force's inventory (i.e., primarily low hazard). Air Force needs to prioritize high risk dams, and is currently doing so, thus the Air Force program is at least somewhat risk informed as is.

5. What criteria must be met for dam removal, or changing operating parameters (e.g., lowering the reservoir)?

No specific criteria is currently in place, but the upcoming FC has some guidance. Still, installations will have leeway to assess their own needs and missions. Dams with EAPs may also have specific guidance for operating parameters.

6. What IT systems are being used for dam management?

Excel spreadsheets are the primary means to data storage and manipulation, including for reporting to the NID. There are no other software packages being used by the AF, although consultants/USACE personnel may have their own. GIS files *may* have dam information, but AFCEC was unaware if they exist. If they do, it would be through the real property database.

7. Does your agency have any current or planned research or policy revisions regarding dam management?

In addition to the upcoming FC, Tracy is pursuing having Corps of Engineers (or Corps through ERDC) do all inspections on Air Force dams and reported having money set aside for execution.

8. What parts of dam safety work well, or not well enough? Are levees managed similarly?

Dr. Dinan (paraphrased): Our bases with significant and high hazard do a good job in all aspects (Arnold, AF academy, JB Lakehurst/Dix). These bases partner with USACE for inspections and operation. The Air Force Academy works with Colorado State University to manage their dams. As far as low hazard dams: 90% do a good job (possibly because it's not much effort). Some don't. For example, Beale AFB "discovered" dams,

some of which were in poor condition. Managing vegetation (removing trees, etc.) seems to be a problem for many dams, and Air Force is working on better informing dam owners on the hazards associated with excessive vegetation. If levees are managed, it's being handled at an installation. Dr. Dinan noted an example of Avon Park AFR removing "dams" (ones that did not meet the NID definition) from the real property databases and reclassifying them as levees.

Tracy Caughlin: The service branch has lots of turnover, and people generally only stay at a base for a few years. The best-case scenario is that these people are operations people to begin with, but that's not always the case. Caughlin also noted there is no training program in place for people who rotate in that he is completely comfortable with. Also not aware of any levees being managed centrally.

9. Who are the best POCs for dam inventory and inspection, or others we should talk to?

Inventory managers

1. How are dams added to the Real Property inventory, and how are they added to the NID? How are the two databases linked?

Air Force does not currently link the real property database with NID. If they did, it would be in the NID spreadsheet. As far as real property: there is guidance on what should be in which CATCODE, but that's left up to bases, who have some leeway with the exact definition (ex. Avon Park AFR)

2. How are non-NID dams managed?

Left at the base level. AFCEC is only collecting NID dam info.

R. Dinan: FC addresses non-NID dams (3rd or 4th section).

3. Who actually conducts formal dam inspections, and how do you decide whether to use internal, DoD, or consultants? Who actually conducts intermediate inspections? Who maintains a list of inspectors and their qualifications?

First two answered previously. Last question: This is left to the bases, but is not maintained. All present agreed that, since 90+% of inspections were contracted out, there was little to no benefit of maintaining such a list.

4. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?

Left to bases. AFCEC has access only by request (or by annual data call).

5. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?

On funding sources: repair projects go through Installation Management Support Command (IMSC), maintenance goes through bases

There will be a repair standard with the new FC, which specifies what maintenance requirements are.

Dr. Dinan: The basic idea is to bring the dam up to 'operating condition', i.e., nearly new condition after repair.

Inspection managers

1. What method is used to generate repair costs? What method is being used to prioritize spending on maintenance and repair for dams?

Up to bases.

Prioritizations: so few projects that little prioritization is done. Hoping for an SMS that can sell the projects.

2. Is there an existing checklist or template for dam inspections in use? Can you provide an example of an inspection report?

Willing to share, but should go to bases. (Look at Arnold or Lakehurst).

Dr. Dinan: Not much formal process for low hazard. We want to start with USACE templates.

3. How many man-hours are expended in a typical inspection? How does this effort break out into preparation/review/inspection/write-up?

None present felt confident estimating this.

Maintenance managers

1. Who are the best POCs for dam maintenance, and who else should we talk to?

Barksdale AFB, Arnold AFB (has a unique inventory), Terry Clarke

A.4 Marine Corps

The primary respondent for the Marine Corps was Mr. Roger Welborn of MCICOM Facilities Directorate.

Policy makers and regulators

1. What is the authoritative policy document for dams for your organization, and where can it be found?

Four documents attached to show current status. Marines broadly use Marine Corps Order 11000.5 (attached) for overall SRM program and this includes assessments at a high level. MCI Dam Inspection Guidance provides more details for inspections and is also attached. A draft policy updating the facility inspection program is also attached and anticipated to be formally issued in next few months (attached as MCI Facility Condition Assessment Program). A classification and accounting letter for water retention and diversion structures was issued in 2014 to standardize naming and classification protocol within the Marines (also attached).

2. Who is the designated dam safety officer? Who is the primary POC for each dam?

Michael Bieryla for Marine Corps out of MCI HQ and each installation that has a dam has a designated person within the Public Works Office at the installation. The only 3 Marine installations with dams are Quantico (2 dams), Pendleton (3 dams), and Miramar (2 dams) and they currently have 7 total NDI reportable dams. All four of the individuals (MCIHQ

plus the 3 installation dam safety personnel) have gone through the dam safety training put on by USACE.

3. Describe your dam management procedure to include:

a. Inventory management

Marines do lifecycle program management, so Roger is responsible for facilities through the whole SMS process. Marines use Navy property system (NFADS) and each installation real property accountability office is responsible for inventory. The letter on accounting and classification sought to standardize naming (i.e., including the word “dam” in the formal name of the facility) as well as CATCODE guidance.

b. Assessment and inspection methodology and qualifications

They have USACE do formal inspections every two years and use Norfolk District personnel to accomplish. Installation personnel responsible for other inspections. Done according to attached policy and guidance and in line with FEMA guidelines.

c. Method of prioritization for maintenance, repair or rehabilitation

Use Mission Dependency Index (MDI) and facility condition for critical infrastructure to prioritize (all their dams are considered critical infrastructure; and also justify work as a “life, health, and safety” issue). Marines try to do recommended work from inspection within the next fiscal year. If cost is \$300K or less then local base uses their funds; if cost is greater than \$300K then part of MCICOM retained funding that is managed centrally is used for the work.

d. Future work planning and analysis:

Initial plan and scope of work done by USACE inspectors, then hire A&E firm to do actual contract plans. This is usually done through NAVFAC for most facility types, but for dams typically use USACE. Local work requirements are responsibility of the installation. Breckenridge Dam is an example of one of the Marine dams that is finishing some major work that went through this process to inspect and develop repair plans and is funded by central MCICOM funding.

4. How does your organization incorporate risk into your dam safety process? What is an acceptable risk in terms of dams?

Uses USACE methodology as they do all inspections, and in accordance with FEMA and attached policies/guidance.

5. What criteria must be met for dam removal or changing operating parameters (e.g., lowering the reservoir)?

Nothing published.

6. What IT systems are being used for dam management?

NFADS for real property inventory; Facility Integration website for program level funds; Maximo for work orders.

7. Does your agency have any current or planned research or policy revisions regarding dam management?

Only as attached update to policy.

8. What parts of dam safety work well or not well enough? Are levees managed similarly?

Policy working well. Levees are also managed by the water retention policies but don't have the formal inspection requirement. They've had aircraft facilities damaged because of levee overtopping and failures in the past so are also considered critical infrastructure, especially one at Camp Pendleton.

9. Who are the best POCs for dam inventory and inspection, or others we should talk to?

New hire identified, as both Roger Welborn and Mike Bieryla are retiring. Her name is Ileana Speer and she will start soon and go to the dam safety training, as well as being responsible for other condition assessments using PAVER/BUILDER/RAILER, etc. As additional info, Marines have a couple of non-reportable dams that were earthen dams that are usually dry, but USACE was accessing if they need added or not.

Inventory managers

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
7. Where are existing documents (e.g., as-built plans, instrumentation readouts, prior inspection reports) stored, and who has access?
8. Kept at the Public Works Office at the Installation in either the Planning or Engineering offices.
9. What funding sources are being used for maintenance and repair work on dams? Who has the authority, and who has the responsibility to carry out repairs? To what standard are dams required to be maintained?

SRM typically; also can be BRM at the base or MILCON for new or major construction.

Inspection managers

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
7. How many man-hours are expended in a typical inspection? How does this effort break out into preparation/review/inspection/write-up? (Formal, intermediate, special?)

Formal inspections by USACE typically the team spends a week at a base.
Not sure of time required for informal inspections done by base Public Works.

8. To whom are the inspection reports given, and what type of follow-up occurs?

Formal inspections given to both MCICOM HQ and the installation. Installation is responsible for follow up. Installation responsible for maintaining other inspection documents.

Maintenance managers

- 1.
- 2.
- 3.
4. Who conducts major repair and rehabilitation (including new building and removal) on dams? What common problems do you encounter and how do you address them?

Contracted out to USACE at Norfolk typically.

Appendix B: Dam-Related CATCODEs and FACs

The following table shows the real property CATCODEs related to dams for each DoD service, along with their corresponding FAC. The data gathered for this table comes from the latest available real property database for each service, as listed below:

- Army: Headquarters Installation Information System (HQIIS), Q3 FY2016
- Air Force: FY2016
- Navy and Marine Corps: iNFADS, Q3 2017

MilDep	CAT CODE	CATCODE Long Name	FAC CODE	FAC Title	Number in Inventory
Air Force	841423	WATER STORAGE DAM	8713	Grounds Drainage Dams	76
	871401	DYKE / DAM	8714	Levees and Dikes for Grounds Drainage	5
	871421	DIKES	8714	Levees and Dikes for Grounds Drainage	8
Army	16430	LEEVE	8714	Levees and Dikes for Grounds Drainage	7
	87140	DIKES	8714	Levees and Dikes for Grounds Drainage	286
	88111	DAM	8811	Dam	2
	88121	LOCK	8812	Lock	0
	88131	REVTMENTS	8813	Navigation Revetments	0
	88141	TRAINING DIKES/WING DAMS/PILE DIKES	8814	Training Dikes/Wing Dams/Pile Dikes	0
	88211	FLOOD CONTROL STRUCTURES	8821	Flood Control Structures	5
	88221	FLOOD CONTROL LEEVE/FLOODWALL	8822	Flood Control Levee/Floodwall	1
	88311	FISH FACILITIES	8831	Fish Facilities	0
	89270	DAM	8713	Grounds Drainage Dams	300
Navy*	16430	LEVEES	8714	Levees and Dikes for Grounds Drainage	16
	87125	DYKE / DAM	8714	Levees and Dikes for Grounds Drainage	114
	87126	LEEVE AND/OR DIKE	8714	Levees and Dikes for Grounds Drainage	4
	87145	DREDGED SPOIL HANDLING FACILITY	8714	Levees and Dikes for Grounds Drainage	5

* Marine Corps and Navy dams are counted together and listed as Navy dams in this table.

Appendix C: Federal Definition of a Dam

The following definition for a dam is given in 33 U.S.C., Chapter 9, Subchapter VII, Section 467. Full text is available at <http://uscode.house.gov/view.xhtml?path=/prelim@title33/chapter9/subchapter7&edition=prelim>.

(3) Dam The term “dam”—

(A) means any artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material, for the purpose of storage or control of water, that—

(i) is 25 feet or more in height from—

(I) the natural bed of the stream channel or watercourse measured at the downstream toe of the barrier; or

(II) if the barrier is not across a stream channel or watercourse, from the lowest elevation of the outside limit of the barrier;

to the maximum water storage elevation; or

(ii) has an impounding capacity for maximum storage elevation of 50 acre-feet or more; but

(B) does not include—

(i) a levee; or

(ii) a barrier described in subparagraph (A) that—

(I) is 6 feet or less in height regardless of storage capacity; or

(II) has a storage capacity at the maximum water storage elevation that is 15 acre-feet or less regardless of height;

unless the barrier, because of the location of the barrier or another physical characteristic of the barrier, is likely to pose a significant threat to human life or property if the barrier fails (as determined by the Administrator).

Appendix D: Template for Proposed Inspection Forms

The following forms are modeled after those found in FEMA-145 (FEMA 1987), which are currently being used by DoD for formal inspections. The proposed forms differ from the FEMA forms in that each observation is linked to a component of the dam, whereas the FEMA forms alternately link observations to components or specific discrepancies. The components used in the forms shown are placeholders from the proposed inventory catalog, and are subject to change based on further development.

Dam Body - Embankments		CONDITION RATING
Components	OBSERVATIONS	
Upstream Face		<input type="text"/>
Upstream Toe		<input type="text"/>
Downstream Face		<input type="text"/>
Downstream Toe		<input type="text"/>
Crest		<input type="text"/>
Abutments		<input type="text"/>
Slope Protection		<input type="text"/>
Upstream Face		<input type="text"/>
Upstream Toe		<input type="text"/>
Downstream Face		<input type="text"/>
Downstream Toe		<input type="text"/>
Crest		<input type="text"/>
Abutments		<input type="text"/>
Slope Protection		<input type="text"/>
<div> <div>HOMOGENEOUS EARTH EMBANKMENTS</div> <div>ZONED EARTH EMBANKMENTS</div> </div>		
Additional Comments:		

Dam Body - Gravity, Arch, and Buttress			CONDITION RATING
	Components	OBSERVATIONS	
GRAVITY STRUCTURES	Concrete Gravity Monolith		<input type="text"/>
	Masonry Gravity Structure		<input type="text"/>
	Timber Gravity Structure		<input type="text"/>
			<input type="text"/>
ARCHES	Concrete Arch		<input type="text"/>
	Masonry Arch		<input type="text"/>
			<input type="text"/>
BUTTRESSES	Concrete Diaphragm		<input type="text"/>
	Concrete Buttress		<input type="text"/>
			<input type="text"/>
Additional Comments:			

Spillways		CONDITION RATING
	Components	OBSERVATIONS
Controlled Spillways	Spillway Channel	<input type="text"/>
	Tainter Gates	<input type="text"/>
	Vertical Lift Gates	<input type="text"/>
	Roller Gates	<input type="text"/>
	Bascule Gates	<input type="text"/>
	Drum Gates	<input type="text"/>
	Needle Gates	<input type="text"/>
	Flap Gates	<input type="text"/>
	Slide or Sluice Gates	<input type="text"/>
	Valve	<input type="text"/>
	Trashrack	<input type="text"/>
	Erodable Channel	<input type="text"/>
	Non-erodable Channel	<input type="text"/>
GATES AND VALVES		
UNCONTROLLED SPILLWAYS		
Additional Comments:		

Outlet Works - Regulated Outlet Works		CONDITION RATING
Components	OBSERVATIONS	
Tainter Gates		<input type="text"/>
Vertical Lift Gates		<input type="text"/>
Roller Gates		<input type="text"/>
Bascule Gates		<input type="text"/>
Drum Gates		<input type="text"/>
Needle Gates		<input type="text"/>
Flap Gates		<input type="text"/>
Slide or Sluice Gates		<input type="text"/>
Valve		<input type="text"/>
Trashrack		<input type="text"/>
		<input type="text"/>
Stilling Basins		<input type="text"/>
Conduit		<input type="text"/>
		<input type="text"/>
<div> <div>GATES AND VALVES</div> <div>STILLING BASINS AND CONDUIT</div> </div>		
Additional Comments: <div></div>		

Instrumentation		CONDITION RATING
Components	OBSERVATIONS	
Peizometers		<input type="text"/>
Settlement Gauges		<input type="text"/>
Wiers		<input type="text"/>
Water Temperature Therm.		<input type="text"/>
Strain Gauges		<input type="text"/>
Water Elevation Gauges		<input type="text"/>
Seismographs		<input type="text"/>
Weather Monitoring Device		<input type="text"/>
Survey Monuments		<input type="text"/>
Inclinometers		<input type="text"/>
Crack Measuring Devices		<input type="text"/>
		<input type="text"/>
AUTOMATED DATA AQUISITION		
Additional Comments: <div style="border: 1px solid black; height: 150px; width: 100%; margin-top: 5px;"></div>		

Foundations		CONDITION RATING
Components	OBSERVATIONS	
Foundations		
FOUNDATIONS		
Additional Comments:		

Appendix E: Spillway CI, Condition Rating Tables

As stated in section 3.4.1, examples of condition rating tables are presented in this appendix.

Operational components

Table E1. River flow measurement (manual or electronic).

River Flow Measurement									
Function	Provide measurement of flow upstream from the spillway.								
Excellent	Providing data accurately and reliably including under extreme conditions and at required frequency. Adequate number (for flow monitoring) for dam safety purposes. Instrument regularly checked and calibrated.								
Failed	Not providing accurate data, not functioning.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Water Level Indicator and other measurement devices									
Providing data accurately, and reliably under extreme conditions and at required frequency. Adequate number (for flow monitoring) for dam safety. Instrument regularly checked and calibrated.							X		
Inadequate frequency of measurement				X	X				
Poorly located or calibrated and/or inadequate number for dam safety purposes. Cannot be checked manually or visually.		X	X						
Not functioning.	X								
Data acquisition device									
Recording data at required frequency, accurately and reliably.							X		
Low recording frequency but still adequate				X	X	X			
Unreliable with frequent break downs reported.		X	X						
Not accurate, not functioning	X								
Data transmission									
Transmitting data at required frequency, accurately and reliably.							X		
Transmitting data at less than required frequency					X	X			
Unreliable with frequent break downs reported.		X	X	X					
Not accurate, not functioning	X								

Comments: River flow measurements are obtained from water level measurements in rivers upstream from the reservoir. Three aspects are evaluated: 1) Accuracy of river flow measurements, 2) Record keeping of data, and 3) Data transmission to operation centers. Accuracy is defined in terms of the precision, quality, frequency of readings, and number of locations for measurements of river flows. The frequency and the number of locations for measurements are to be determined for dam safety objectives (as opposed to power generation objectives) and should be determined for each facility in consultation with personnel involved in flow forecasting. The accuracy of the measurements depends on the accuracy of the stage-discharge curves and the stability of the river cross-section. An accurate stage-flow relation has to be determined from an adequate amount of data and over the full range of expected flows. Specific inspection tables may be developed by each partner for the types of devices they use.

Table E2. Reservoir level indicator.

Reservoir level indicator									
Function	Measure reservoir level								
Excellent	Providing accurate data, redundancy and no evidence of malfunction (water level in the reservoir) for dam safety purposes. Instrument regularly checked and calibrated.								
Failed	Not providing accurate data, not functioning.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Water level indicators									
Measuring level accurately and continuously and adequate number for dam safety purposes							X		
Inadequate water level indicators to determine the influence of wind on pool level				X	X	X			
Poorly located (influenced by gate opening or difficult to read)			X	X	X				
Inadequate frequency of measurement			X	X					
No redundancy (only one gauge near the dam or spillway). Cannot be checked visually or manually.		X	X	X					
Not providing accurate data, not functioning	X								
Data acquisition device									
Recording data continuously accurately and reliably.							X		
Low recording frequency but still adequate				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								
Data transmission									
Transmitting data at required frequency, accurately and reliably.							X		
Transmitting data at less than required frequency				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								

Comments: The purpose of this system is to provide accurate measurements of the water level in the reservoir to the operators. The data should also be properly stored and transmitted to operation centers. The adequate number of measuring devices at a given facility is to be determined for dam safety objectives in consultation with personnel involved in decision-making relative to the operation of the spillway.

Table E3. Precipitation and temperature gauge network.

Precipitation and Temperature Gauge Network (For a watershed, including data acquisition and storage)									
Function	Measure rainfall on watershed								
Excellent	Providing data accurately, continuously and reliably. Adequate number according to the size of the watershed for dam safety purposes. Instrument regularly checked and calibrated.								
Failed	Not providing accurate data, not functioning, no gauge in the entire watershed								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Precipitation and Temperature gauges									
Measuring rainfall accurately continuously and reliably. Adequate number according to the size of the watershed for dam safety purposes.							X		
Not accurate data or inadequate number of rain gauges			X	X	X				
Not providing accurate data, not functioning, no gauge in service in the entire watershed	X								
Data acquisition device									
Recording data continuously accurately and reliably.							X		
Low recording frequency but still adequate				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								
Data transmission									
Transmitting data at required frequency, accurately and reliably.							X		
Transmitting data at less than required frequency				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								

Comments: The adequate number of rain gauges is to be determined by considering all other means of measuring the amount of precipitation (e.g., using Radarsat). Several items can be checked when evaluating the condition of a rain gauge (or precipitation gauge). For the purposes of the current project, it was agreed that only a generic description of potential problems would be used since there exists a wide variety of devices that can be used by the various partners. Examples, of possible inspection items for rain gauges are the level and quality of the fluid used in the rain gauge and the location of the rain gauge in the field relative to accepted standards.

Table E4. Snow measuring stations.

Snow Measuring Stations									
Function	Measure snow cover on watershed								
Excellent	Measurement of snow cover depth at an adequate number of locations with sufficient frequency for dam safety purposes.								
Failed	Not measuring snow depth cover in the watershed where applicable.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Measurement of snow cover depth at an adequate number of locations with sufficient frequency for dam safety purposes							X		
Inadequate number of snow measurement locations and/or insufficient frequency of readings			X	X	X				
Not measuring snow depth cover in the watershed where applicable	X								

Comments: The adequate number and frequency of snow depth cover measurements is determined by considering all means of estimating snow cover depth (aerial surveys, etc.).

Table E5. Weather forecasting.

Weather Forecasting									
Function	Forecast precipitation in the watershed								
Excellent	Weather forecasting system can predict major precipitation events for dam safety purposes.								
Failed	Unavailability of weather forecasting data.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Weather forecasting system can predict major precipitation. Accurate for dam safety purposes							X		
Unavailability of weather forecasting data	X								

Comments: Weather forecasting can be performed by the utility or obtained from a third party. The adequacy of forecasts for a given reservoir is a function of the response and reaction times for the project. Factors that may be considered are: frequency, availability and accuracy of forecasts. Intermediate conditions were not defined for lack of expertise in this field.

Table E6. Ice and debris management.

Ice and debris									
Function	Provide information to the operator on debris and ice conditions upstream from the spillway and manage ice and debris accumulation								
Excellent	Ice and debris monitoring and management in place.								
Failed	No ice and debris monitoring and management in place.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Ice and debris monitoring									
Ice and debris monitoring in place							X		
No ice and debris monitoring in place	X								
Ice and debris management									
Ice and debris management procedures are detailed, up-to-date, available to operators, used, and effective.							X		
Ice and debris management procedures are documented but have not been used				X	X	X			
Outdated or difficult to implement IDM		X	X						
No IDM	X								
Ice and debris control equipment									
Ice and debris control is effective							X		
Ice and debris control in place but partially effective				X	X				
Ice and debris control not effective	X								

Comments: Ice and debris monitoring is performed upstream from the spillway. Excessive debris or ice accumulation can block the spillway. Another unfavorable condition can occur when an ice jam is formed upstream from the spillway. A sudden increase in flow may occur when the ice jam is dislodged.

Table E7. Third party data.

Third Party Data									
Function	Obtain data from other river users.								
Excellent	Provide reliable data on schedule								
Failed	Unreliable data and/or with unacceptable delays. Data not provided.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Provide reliable data on schedule							X		
Unreliable data and/or with unacceptable delays	X	X	X						
Data not provided	X								

Comments: Third party data must be adequate for dam safety purposes. The table rates the accuracy of predicted flow magnitudes, as well as accuracy of predicted timing of flows received in data from 3rd parties under normal and extreme conditions. The type of information provided by third parties may include flow data and meteorological data.

Table E8. Gate position indicator.

Gate Position Indicator									
Function	Indicate the position of a spillway gate								
Excellent	Provides a true reading relative to the opened or closed position of the gate. Device regularly checked and calibrated.								
Failed	Not providing accurate data, not functioning. Gate position indicator provides a false reading (relative to the opened or closed position of the gate).								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Gate position indicator									
Provides a true reading relative to the opened or closed position of the gate. Device regularly checked and calibrated.							X		
Gate position indicator out of adjustment					X	X			
Not providing accurate data, not functioning. Gate position indicator provides a false reading (relative to the opened or closed position of the gate)	X								
Data acquisition device									
Recording data continuously accurately and reliably.							X		
Recording data intermittently but still adequate				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								
Data transmission									
Transmitting data continuously accurately and reliably.							X		
Transmitting data at less than required frequency				X	X	X			
Unreliable with frequent breakdowns reported.		X	X						
Not accurate, not functioning	X								

Comments: Gate position indicators are mainly for gates that are remotely operated. A visual gate position indicator should also be installed at a location visible from on-site controls. The gate position indicator is important both for dam safety purposes and for monitoring water flows.

Table E9. Flow prediction model.

Flow prediction model									
Function	Models the inflows and outflows of the watershed								
Excellent	Properly utilizes input data to generate accurate and timely flow predictions under normal and extreme events.								
Failed	Inaccurate non dependable or untimely predictions								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Properly utilizes input data to generate accurate and timely flow predictions under normal and extreme events						X	X		
Dependable under normal conditions, untested under extreme events			X	X	X				
Dependable under normal conditions, undependable or untimely under extreme events		X	X						
Inaccurate, undependable or untimely under normal conditions	X								

Comments: The flow prediction model describes the process by which data from rain gauges, snow measuring stations, river flow measurements, and weather forecasting are integrated in order to make inflow predictions.

Table E10. Decision process.

Decision process									
Function	Clearly defined roles, responsibilities in determining the need to open a gate.								
Excellent	Clear and current decision process that promotes appropriate and timely decisions as events warrant. Process is documented and is tested on a regular basis.								
Failed	Not clearly defined process								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Clear and current decision process that promotes appropriate and timely decisions as events warrant. Process is documented and is tested on a regular basis.							X		
Clear and current decision process. Process is documented; however it has not been tested on a regular basis				X	X	X			
Decision process in place but is not documented.		X	X						
Roles and responsibilities not defined in decision process	X								

Comments: The decision process describes the chain of command in case of emergencies as well as the flow of information from the prediction group and ultimately to operators.

Table E11. Telecommunication system.

Telecommunication system									
Function	Provide communication between decision makers and local operators								
Excellent	Dedicated system designed to operate under extreme conditions, has been tested recently. Available at all times.								
Failed	No communication								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Dedicated system designed to operate under extreme conditions, has been tested recently. Available at all times							X		
Expected to be reliable under extreme conditions, has not been tested recently. Available at all times					X	X			
Expected to be reliable under extreme conditions. System has not been tested recently.				X	X				
Vulnerable under extreme conditions.		X	X						
No Communication	X								

Comments: Telecommunication systems should be reliable. Reliability can be improved with redundancy.

Table E12. Public protection and warning system.

Telecommunication system									
Function	Provide communication between decision makers and local operators								
Excellent	Dedicated system designed to operate under extreme conditions, has been tested recently. Available at all times.								
Failed	No communication								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Dedicated system designed to operate under extreme conditions, has been tested recently. Available at all times							X		
Expected to be reliable under extreme conditions, has not been tested recently. Available at all times					X	X			
Expected to be reliable under extreme conditions. System has not been tested recently.				X	X				
Vulnerable under extreme conditions.		X	X						
No Communication	X								

Comments: Public warning systems comprise signs and horns that are sounded before the operation of the gates. The signs should be located in areas that are in full view of people that may access the zone affected during spilling operations. Horns should be loud enough to be heard at locations that will be affected during spilling operations even when spillway gates are partially open.

Table E13. Availability and mobilization (design flood).

Availability and Mobilization									
(Design flood)									
Function	Provide key personnel and resources required for operation of the spillway during the design flood.								
Excellent	Key personnel and resources can always be reached and can get to gate controls in a timely fashion.								
Failed	Key personnel or resources cannot reach gate in required time.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Availability									
Key personnel always available at the site or at the gate controls							X		
Key personnel available on call continuously						X			
On-call plan activated as needed					X	X			
Extensive up-to-date list of key personnel				X	X				
Short list of key personnel		X	X						
No or outdated list of available key personnel	X								
Mobilization (Time required to contact personnel, get the required equipment and reach gate controls)									
Mobilization not required (Personnel and resources always available at the site or at the gate remote controls)							X		
Mobilization can be achieved before reaching the critical pool level						X			
Mobilization can be achieved before reaching the maximum pool level (above the critical pool level)			X	X	X				
Mobilization cannot be achieved before reaching the maximum pool level	X	X							

Comments: The mobilization of personnel and resources describes the plan that has been put in place to respond to an emergency during a design flood event. Various levels of mobilization plans have been identified. The most complete plan requires that key personnel be always on site during design flood events. At the very least, an up-to-date list of key personnel should be made available to operators. At many sites several operators are required during periods of emergencies, especially for on-site operation of gates. Technical support personnel should be always ready to respond to emergencies relative to faulty equipment (civil, mechanical and electrical). Ideally, key personnel should be on call during emergency periods. Key personnel are those required for gate operation and troubleshooting.

Table E14. Availability and mobilization (load rejection).

Availability and Mobilization									
(Load rejection)									
Function	Provide key personnel and resources required for operation of the spillway during load rejection.								
Excellent	Key personnel and resources can always be reached and can get to gate controls in a timely fashion.								
Failed	Key personnel or resources cannot reach gate in required time.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Availability									
Key personnel always available at the site or at the gate controls							X		
Key personnel available on call continuously						X			
On-call plan activated as needed					X	X			
Extensive up-to-date list of key personnel				X	X				
Short list of key personnel		X	X						
No or outdated list of available key personnel	X								
Mobilization (Time required to contact personnel, get the required equipment and reach gate controls)									
Mobilization not required (Personnel and resources always available at the site or at the gate remote controls)							X		
Mobilization can be achieved before reaching the critical pool level						X			
Mobilization can be achieved before reaching the maximum pool level (above the critical pool level)		X	X						
Mobilization cannot be achieved before reaching the maximum pool level	X								

Comments: The mobilization of personnel and resources describes the plan that has been put in place to respond to an emergency during load rejection. Various levels of mobilization plans have been identified. The most complete plan requires that key personnel be always on site. At the very least, an up-to-date list of key personnel should be made available to operators. At many sites several operators are required during periods of emergencies, especially for on-site operation of gates. Technical support personnel should be always ready to respond to emergencies relative to faulty equipment (civil, mechanical and electrical). Ideally, key personnel should be on call during emergency periods. Key personnel are those required for gate operation and troubleshooting.

Table E15. Operating procedures.

Operating procedures									
Function	Provide detailed instructions for the proper operation of the gates.								
Excellent	Operating procedures are detailed, up-to-date and available to operators								
Failed	No operating procedures								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Standard operating procedures (covers normal and emergency situations) (SOP)									
Standard operating procedures are detailed, up-to-date, available to operators and tested.							X		
Standard operating procedures have not been fully tested.				X	X	X			
Outdated or difficult to implement standard operating procedures		X	X						
SOP do not cover emergency situations (fire, dam break, earthquake, flood exceeding spillway capacity)		X	X						
No standard operating procedures	X								
Autonomous operating procedures (covers normal and emergency situations) (AOP)									
AOP are detailed, up-to-date and available to operators and tested.							X		
AOP have not been fully tested				X	X	X			
Outdated or difficult to implement AOP		X	X						
AOP do not cover emergency situations (fire, dam break, earthquake, flood exceeding spillway capacity)		X	X						
No AOP	X								

Comments: The operating procedures describe the procedures followed by the operator that cover all aspects of the normal operation of the spillway (including opening sequences where applicable). Extreme event operating procedures provide guidance to operators during extreme events even if they are not able to communicate with the outside world. Extreme events include flood events, earthquakes, ice storms, etc.

SOP: Provide detailed instructions for spillway operation, including:

Communication protocols

Gate opening protocols (public warning, operational sequence, etc.)

AOP: Provide detailed instructions for autonomous spillway operation.

They allow operators to act independently in the event of communication breakdown and include specific local decision protocols.

Table E16. Qualification and training of operator.

Qualification and training of operator									
Function	To insure that operators are qualified to operate the gates								
Excellent	Personnel are trained and practiced in the operation of the gates and are familiar with the site and standard operating procedures.								
Failed	Personnel are untrained, unpracticed and unfamiliar with the site and the standard operating procedures.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Personnel are trained and practiced in the operation of the gates and are familiar with the site and the standard operating procedures.							X		
Personnel are trained but unpracticed with the operation of the gates.					X	X			
Personnel are unfamiliar with standard operating procedures.				X	X				
Personnel are unfamiliar with the site			X	X					
Personnel are untrained and unpracticed with the operation of the gates.		X	X						
Personnel are untrained, unpracticed and unfamiliar with site and the standard operating procedures.	X								

Comments: Operators should be trained in every aspect of the operation of the spillway and should perform simulated operations on a regular basis. The latter includes the operation of the gates with the emergency generator.

Table E17. Portable equipment for lifting gates.

Portable equipment for lifting gates									
Function	Portable equipment that is required for operating the gates								
Excellent	Portable equipment is kept in good working order and is readily available								
Failed	Portable equipment can not be provided within the required time for operating the gate								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Portable equipment is kept in good working order and is readily available							X		
Portable equipment is readily available but condition is unknown				X	X				
Portable equipment must be rented		X	X						
Portable equipment can not be provided within the required time for operating the gate	X								

Comments: Some spillways can only be operated on site and require that specialized equipment be available for opening or closing operations. The ideal situation is that the equipment is always available on site.

Table E18. Road access.

Road									
Function	To provide access to the site.								
Excellent	Travel by road is possible under adverse conditions without significant delay								
Failed	Road not available under adverse conditions or seasonally.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Travel by road is possible under adverse conditions without significant delays							X		
Travel by road is possible under adverse conditions but distance to site is a hindrance				X	X	X			
Roadways or bridges known to be vulnerable to slides, erosion, flooding, etc. but alternate road available			X	X	X				
Roadways or bridges known to be vulnerable to slides, erosion, flooding, etc. with no alternate road		X	X						
Road not available under adverse conditions or seasonally	X								

Comments: Roads are the main means of access for personnel and equipment. Road access to the spillway should be possible during extreme conditions. Accessibility to the site by road should be assessed by considering the vulnerability of the road to flooding and landslides under extreme conditions during all seasons (snow removal may be an important consideration for northern isolated sites).

Table E19. Alternate means of access.

Alternate means of access									
Function	To provide access to the site in lieu of road access if required.								
Excellent	Alternate means of travel allowing access within required time under adverse conditions and recently tested								
Failed	Alternate means of access frequently not available								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Alternate means of travel allowing access within required time under adverse conditions and recently tested							X		
Helicopter or plane									
Company owned/leased helicopter or plane dedicated to operational staff and adequate landing area at site				X	X				
Helicopter or plane on call or shared and adequate landing area at site			X						
Landing site for helicopter or plane but no current use agreement		X							
No landing site	X								
Boat access									
Accessible by company boat on the waterway and dedicated to operational staff					X				
Accessible with boats available locally				X					
Accessible by company owned boat not near site			X						
No safe docking area available under flood conditions	X								
Ground access by specialized vehicles (ATV, snowmobile, etc.)									
Ground route accessible with specialized company vehicles and dedicated to operational staff				X	X				
Ground route accessible with specialized vehicles available locally			X	X					
Alternate means of access frequently not available.	X								

Comments: Alternate means of access includes all means other than roads. Examples of alternate means of access are access by boat from upstream launching points, helipads and landing strips.

Table E20. Local access.

Local access									
Function	Provide access to gate controls								
Excellent	Access is possible during adverse conditions.								
Failed	Access impracticable during adverse conditions. Access is not structurally sound.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Pedestrian access									
Access is possible during adverse conditions							X		
Access is possible during adverse conditions but minor repairs are required. Excessive debris present.				X	X	X			
Access is possible during adverse conditions but is hazardous		X	X						
Access impracticable during adverse conditions. Access is not structurally sound	X								
Keys and locks									
Operators have the required keys to access all secured areas and equipment and locks are well maintained and identified							X		
Locks are not well maintained				X	X				
Operator does not have access to a full set of well-identified keys.	X								

Comments: Pedestrian access includes all the walkways, catwalks and ladders that are used to reach the controls of the spillway gates once onsite. Operators should have access to a full set of keys at all times. On most projects, critical components and controls are locked to prevent vandalism or unauthorized operation of the spillway.

Table E21. Remote and onsite controls.

Remote and on site controls									
Function	Operate gate and equipment								
Excellent	Clearly labeled and properly maintained. Properly located and lighted.								
Failed	Improperly labeled controls. Improperly located or lighted.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Clearly labeled and properly maintained. Properly located and lighted.							X		
Correctly labeled but improperly located controls				X	X				
Controls or devices require excessive effort to be activated			X	X					
Gate or gate position indicator not located in the line of sight of the operator (visual or remote camera)		X	X	X					
Improperly labeled controls. Improperly located or lighted	X								

Comments: Controls should be properly labeled, located, and maintained. Ideally, controls should be located such that the operator is always in full view of the gates and gate position indicators as they are being operated.

Other systems

Specific items that are not common to all participants in the project have been identified and will be developed by each partner separately.

Electrical components

Table E22. Overhead lines.

Medium Voltage Overhead Lines									
Function	Supply power to the spillway.								
Excellent	Built to current codes and standards, and maintained to provide continuous service and assure that proper clearances are maintained.								
Failed	Loss of power.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Vegetation control									
Line is free of vegetation						X	X		
Some vegetation encroachment (< 10 feet)			X	X	X				
Poor vegetation control (< 3 feet)	X	X							
Lightning protection									
Protection according to codes and standards						X	X		
Inadequate lightning protection but not exposed			X	X	X				
Damaged or inadequate lightning protection and exposed	X	X							
Poles, supports and accessories (insulators, conductors)									
No visual damage						X	X		
Damaged poles, supports, and accessories	X	X	X						

Comments: Medium overhead lines that are used as a power source for the spillway may be lines that connect the powerhouse to the spillway and can also be External Power Source lines. Overhead lines are vulnerable to climatic loads such as wind and ice loads. Overhead lines may also be exposed to lightning strikes. An examination of repair records can be very useful in establishing the condition and vulnerability of a line.

Table E23. Local or emergency generator.

Local or Emergency Generator									
Function	Supply power directly to the spillway								
Excellent	Provides nominal power at the correct frequency and voltage. Able to assume required load within specified time parameters and provide continuous service.								
Failed	Will not start. Rejects load. Unable to obtain nominal frequency and/or voltage to lift the gate. Unable to heat gate if required								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional tests for alternator and engine (Tests performed periodically under load conditions and to be verified during inspections)									
Frequency and voltage									
Frequency and voltage within nominal values						X	X		
Frequency or voltage do not meet nominal values but can still operate the gates		X	X	X					
Frequency or voltage do not permit gate operation	X								
Eng. Temp. and oil pressure									
Engine temperature and oil pressure within nominal values						X	X		
Engine temperature or oil pressure outside nominal values		X	X	X					
Extreme temperature (low or high) or no pressure	X								
Starting sequence									
Starting sequence successful at first trial						X	X		
Starting sequence successful within three trials			X	X					
Does not start within three trials	X								
Noise and vibration									
Engine runs without excessive vibrations or noise						X	X		
Engine runs with increasing vibrations or noise over time				X	X				
Functional test									
Functional test performed according to standards							X		
No periodic functional test		X							
Fuel									
Fuel according to specifications							X		
No fuel registry on site			X	X	X				
Contaminated or old fuel		X	X	X					
No fuel	X								
Batteries									
Sized and maintained for specified load						X	X		
Battery in service longer than its rated service life				X	X				
Improper electrolyte		X	X						
Battery discharged or faulty cells	X								
Battery charger									
Maintains battery charge at specified level						X	X		
Does not maintain battery charge at specified level	X	X							

(Table is continued on next page.)

Continuation of table E23.

Alternator									
Insulation resistance within specifications						X	X		
Decreasing trend in insulation resistance with time but still within specifications			X	X	X				
Insulation resistance outside specifications	X	X							
Lubrication system									
Oil is within specifications (quality and level)						X	X		
Contaminated or oil outside of specifications but at correct level			X	X	X				
Clogged filter			X	X					
Low oil level due to leaks or excessive consumption		X							
No oil or excessive viscosity	X								
Cooling system									
Fluid is within specifications (quality and level)						X	X		
Contaminated fluid or significant leak			X	X	X				
No fluid, or no fluid (or air) circulation	X								
Intake and exhaust system									
Unobstructed air intake and exhaust system with filter in place						X	X		
Inadequate filter or no filter				X	X				
Partly clogged air filter or reduced circulation or exhaust defect		X	X						
Blocked air intake or exhaust system	X								

Comments: The emergency generator is a critical component of the spillway. The evaluation of the generator is made relative to all the major components of the generator as well as from a series of functional tests.

Table E24. Underground and encased cables (medium voltage).

Underground and Encased Cables (medium voltage)									
Function	Supply power to the spillway								
Excellent	Built to current codes and standards, and maintained to provide continuous service.								
Failed	Loss of power								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Insulation									
Performs the function and/or passes the standard testing procedures						X	X		
Does not perform the function nor passes the Standard Testing Procedures	X	X							
Terminations									
Adequate connection						X	X		
Loose connection		X	X	X					
Discoloration		X	X						
Cannot supply power	X								

Comments: The condition of underground or encased cables is performed by tests on the insulation and by a visual inspection of the terminations. The results from the tests on the insulation are only described in a qualitative way since there are numerous alternative procedures for performing insulation tests. The rating in any particular case has to be done by considering guidelines from the manufacturers of each testing device. The visual inspection of the cables is usually limited to the state of the termination and for signs of overheating.

Table E25. Power feeder cables (low voltage).

Power feeder cables (low voltage)								
Function	Supply power to gate operating equipment							
Excellent	Built to current codes and standards, and maintained to provide continuous service.							
Failed	Loss of power.							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
Insulation								Comments
Performs the function and/or passes the Standard Testing Procedures						X	X	
Does not perform the function nor passes the Standard Testing Procedures	X	X						
Terminations								
Adequate connection						X	X	
Loose connection		X	X	X				
Discoloration		X	X					
Cannot supply power	X							

Comments: The condition of power feeder cables is performed by tests on the insulation and by a visual inspection of the terminations. The results from the tests on the insulation are only described in a qualitative way since there are numerous alternative procedures for performing insulation tests. The rating in any particular case has to be done by considering guidelines from the manufacturers of each testing device. The visual inspection of the cables is usually limited to the state of the termination and for signs of overheating.

Table E26. Transformer.

Transformer								
Function	Supply power at correct voltage level							
Excellent	Built to current codes and standards, and maintained to provide continuous service at correct voltage level.							
Failed	Cannot supply correct voltage level.							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
Dielectric (oil)								Comments
Oil according to specifications							X	
Contaminated oil (presence of foreign matter, e.g.: moisture)		X	X	X	X			
Degraded oil (by arcing, aging, acidity)	X	X	X	X				
Dissolved gases	X	X	X	X				
Insulation								
Performs the function and/or passes the standard testing procedures (insulation resistance and power factor, etc.)						X	X	
Does not perform the function nor passes the standard testing procedures	X	X						
Windings								
Performs the function and/or passes the standard testing procedures (resistance and turns-ratio)						X	X	
Does not perform the function nor passes the standard testing procedures	X	X						
Cannot supply power	X							
Tank								
No leaks							X	
Inadequate oil level or oil leak	X	X	X	X	X			
Service life (based on utility standard practices)								

Comments: The evaluation of the condition of a transformer is done by performing tests and by performing a visual inspection. The visual inspection is performed to determine the condition of the tank while tests are performed to control the quality of the oil, the state of the insulation and of the windings. Considering the wide variety of possible tests, outcomes are described qualitatively and must be evaluated by considering the recommendations of each specific manufacturer of testing devices.

Table E27. Power source transfer system.

Power source transfer system									
Function	To transfer from normal source to alternate source and return								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test (transfer switch)									
Successful							X		
Failed	X								
Functional test (Manual transfer device)									
Successful							X		
Failed	X								

Comments: A functional test is performed for evaluating the condition of the power source transfer system. The system is considered to be in either an excellent condition or failed condition. No intermediate state has been defined.

Table E28. Ice prevention system (air bubbler).

Ice prevention system (air bubbler)									
Function	To keep gates ice free								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Upstream gate surfaces maintained ice free							X		
Upstream ice accumulation prevents operation of the gate	X								

Comments: Air bubblers can be used to prevent the formation of ice on the upstream face of the gates. A functional test is performed for evaluating the condition of the air bubbler. The system is considered to be either in an excellent condition or failed condition. No intermediate state has been defined.

Table E29. Lighting system (normal and emergency).

Lighting system (normal and emergency)									
Function	Provide appropriate illumination to assure safe spillway operation								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Safe level of lighting is provided							X		
Insufficient or impaired lighting (dirty, burned out or missing bulbs)		X	X	X	X				
Lighting system inoperable	X								

Comments: The lighting system is to allow for the safe access and operation of the spillway under any conditions.

Table E30. Limit switches.

Limit switches									
Function	To permit operation only within specified range								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Operated successfully or passed simulated test							X		
Failed	X								

Comments: A functional test is performed for evaluating the condition of limit switches. The system is considered to be in either an excellent condition or failed condition. No intermediate state has been defined.

Table E31. Ice prevention system (heating).

Limit switches									
Function	To permit operation only within specified range								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Operated successfully or passed simulated test							X		
Failed	X								

Comments: A functional test is performed for evaluating the condition of the ice prevention system. The system is considered to be in either an excellent condition or failed condition. No intermediate state has been defined.

Table E32. Distribution panel.

Distribution panel									
Function	To provide power to lighting, heaters, fans, monitoring instrumentation, etc.								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Successful							X		
Failed	X								
Visual inspection									
No visible problems							X		
General condition		X	X	X	X	X			
Damaged or missing locks			X	X	X				
Loose connections			X	X					
Presence of moisture or corrosion		X	X	X					
Damaged seals		X	X	X					
Cabinet heating									
Operational							X		
Non operational		X	X	X					

Comments: The main method for the evaluation of the condition of a distribution panel is a functional test. The functional test is complemented by a visual inspection to determine if there is some undesirable conditions such as the presence of moisture, loose connections, damaged seals, and damaged or missing locks. A statement relative to the general condition has been included to capture conditions that are not covered in the table. Cabinet heating is an important element in distribution panels to eliminate moisture that can penetrate inside the panel.

Table E33. Translation motor (electric).

<u>Distribution panel</u>									
Function	To provide power to lighting, heaters, fans, monitoring instrumentation, etc.								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Successful							X		
Failed	X								
Visual inspection									
No visible problems							X		
General condition		X	X	X	X	X			
Damaged or missing locks			X	X	X				
Loose connections			X	X					
Presence of moisture or corrosion		X	X	X					
Damaged seals		X	X	X					
Cabinet heating									
Operational							X		
Non operational		X	X	X					

Comments: The translation motor is used to move a shared lifting device. The evaluation of the motor is done by a combination of functional tests, measurement, and visual inspections.

Table E34. Lifting motor (electric).

Lifting Motor (electric)									
Function	Transforms electric power into mechanical power								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service								
	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Indicator	1	2	3	4	5	6	7	S	
Insulation									
Performs the function and/or passes the standard testing procedures (insulation resistance)						X	X		
Does not perform the function nor passes the standard testing procedures	X	X							
Apparent Temperature									
Normal temperature range						X	X		
Overheating			X	X					
Overloading									
Current and voltage within name plate specifications						X	X		
Excessive current at rated voltage		X	X	X					
Fault trip	X								
Impaired ventilation (open motor)									
Normal ventilation							X		
Impaired ventilation(open motor)		X	X	X					
Bearings and bushings									
Adequate, appropriate lubrication						X	X		
Inadequate lubrication		X	X	X					
No rotation due to seizing	X								
Noise and vibrations									
Motor runs without excessive noise or vibrations						X	X		
Motor runs with increasing noise or vibrations over time				X	X				

Comments: The lifting motor is used to lift the gate into position. The evaluation of the lifting motor is done by a combination of functional tests, measurement, and visual inspections. Tests and measurements are performed to evaluate the condition of the insulation and to determine if the motor is overloaded. Overloading cannot always be considered as an adequate indicator of the state of the motor since overloading can occur due to excessive friction. When testing is done under load, the inspector should observe the gate for noise and vibrations that could be indicative of excessive friction. The visual inspection of the motor is done to determine qualitatively if the motor overheats under load (which could be indicative of overloading). The visual inspection also includes a determination relative to the level of noise and vibration and the lubrication of bearings.

Table E35. Motor control center or individual control panel.

Motor Control Center or Individual Control Panel									
Function	Provide power to the motor								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service								
	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
Indicator	1	2	3	4	5	6	7	S	
Functional test (transfer switch)									
Successful							X		
Failed	X								
Visual inspection									
No visual distress present							X		
Damaged or missing locks			X	X	X				
Loose connections			X	X					
Audible noise			X	X					
Discolored or pitted contacts		X	X	X					
Presence of moisture or corrosion		X	X	X					
Damaged seals		X	X	X					
Cabinet heating									
Operational							X		
Not operational		X	X	X					

Table E36. Cam switches.

Cam switches									
Function	To commutate the resistances in the rotor circuit of wound-rotor motor								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 – 9	10 – 24	25 – 39	40 – 54	55 – 69	70 – 84	85 – 100	Score	Comments
	1	2	3	4	5	6	7	S	
Functional test									
Controls the speed and torque of the motor and permits reverse direction							X		
Does not control the motor as expected		X	X						
Fails to control the motor	X								
Overheating or arcing									
No overheating or arcing							X		
Improperly adjusted contacts (misalignment and/or inadequate pressure)		X	X	X					
Dirty or burned contacts		X							

Comments: Cam switches are evaluated through a functional test. A visual inspection can be performed to determine if the contacts are well aligned, if the pressure is adequate, and if the contacts are dirty or burned.

Table E37. External resistors.

External resistors									
Function	Add or remove resistance in the circuit of the rotor (wound-rotor motor)								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Permits full control of the speed and torque of the motor							X		
Fail to adequately control the motor (missing or faulty resistor)		X							
No response from the motor	X								

Comments: External resistors are evaluated through a functional test.

Table E38. Inverter control system.

Inverter control system (includes the rectifier system)									
Function	Permits variable frequency control of the translation or lifting motor								
Excellent	Built to applicable codes and standards, and maintained to provide the expected service.								
Failed	Cannot provide expected service.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional test									
Provide controlled variable speed and torque of the motor							X		
Fails to operate the motor	X								

Comments: The condition of the inverter control system is determined from a functional test.

Mechanical components

Table E39. Screw and nut (screw-type hoist).

Screw and Nut (Screw-type hoist)								
Function	Transfer shaft rotation into gate movement							
Excellent	No warping, no wear, geometry according to specifications, uncontaminated grease.							
Failed	Warped enough to jam the mechanism, broken, split, missing threads, enough surface damage/corrosion to cause excessive friction							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
No warping, no wear, geometry according to specifications, uncontaminated grease.							X	
Surface Contaminants on grease or slight warping on screw with some damage or wear to threads of nut					X	X		
Inappropriate lubrication			X	X	X			
Excessive friction/noise, vibration and jumping, presence of metal shavings		X	X					
Warped enough to jam the mechanism; broken, split, missing threads; enough surface damage/corrosion to cause excessive friction	X							

Table E40. Bearings.

Bearings (Radial, thrust, power screw assembly)								
Function	Provide low friction support to rotating parts							
Excellent	Well lubricated and without abnormal noise or vibration, no excessive play							
Failed	Does not provide support to the moving parts and accessories (wheels or gears). Does not allow free movement.							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
Normal noise or vibration, runs well							X	
Abnormal noise or vibration but still runs					X	X		
Abnormal noise or vibration with no lubrication or blockage of grease lines but still runs			X	X				
Abnormal noise or vibration with no lubrication or blockage of grease lines and cracked housing but still runs		X	X					
Seizing between pin/shaft and bushing. Rotation of pin in yoke/lug.	X	X						

Table E41. Split bushing or journal bearing.

Split Bushing or journal bearing								
Function	Provide low friction support to rotating parts							
Excellent	Well lubricated and runs without noise, no excessive play							
Failed	Moving parts seized or excessive friction.							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
Well lubricated and runs without noise, no excessive play							X	
Noise with lubrication with some wear				X	X	X		
Noise without lubrication, vibration or cracked housing, but still running		X	X					
Moving parts seized or excessive friction.	X							

Table E42. Rotating shafts, supports, bearings, and couplings.

Rotating Shafts, Support Bearings and Couplings								
Function	Transfer torque							
Excellent	No corrosion, minor surface rust, no dent, straight, no crack							
Failed	Broken or severely bent or misaligned so that it cannot rotate							
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score
Corrosion								Comments
No corrosion							X	
Corrosion but no section loss						X		
Measurable section loss			X	X	X			
Severe pitting		X	X					
Warping or Misalignment								
No warping						X	X	
Slight warping or misalignment that does not affect the motor load				X	X			
Warping or misalignment that increases the motor load / lockout order		X	X					
Warping or misalignment that prevents movement	X							
Cracking								
No cracks							X	
Crack known to be non critical (after evaluation)				X	X			
New crack or growth in existing crack		X	X					
Split or broken shaft/couplings	X							
Missing bolts or components								
No missing bolts, distortion, or gap							X	
Missing bolts or distortion or gap	X	X	X					

Table E43. Gear assembly (hoist).

Gear assembly (exposed or encased) including associated bushing and bearing (hoist)									
Function	Provide speed reduction for hoist mechanism								
Excellent	Shafts and Gears well aligned, well lubricated (no contamination, correct type of lubricant, stable level), no parts missing, no surface defects, no pitting. No excessive noise, jump or vibration.								
Failed	Gear can not transmit torque or motion								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Noise, jump and vibration									
No excessive noise, jump, or vibration						X	X		
Any one of excessive noise, jump, or vibration		X	X	X	X				
Tooth wear, contact, and breakage									
No wear with full contact and properly meshed							X		
Minor wear					X	X			
Significant part of contact surface of teeth missing due to breakage or wear, or misalignment		X	X	X					
Teeth missing preventing rotation	X								
Anchor (fastener to shaft, key or pin) movement or deterioration									
Fastener in place and undamaged							X		
Key or pin is cracked		X	X						
Gear slipping on shaft	X								
Bearing or bushing wear									
Normal noise, runs smoothly						X	X		
Excessive noise or cracked housing, but still running		X	X						
Jammed	X								
Lubricant									
Well lubricated, no contamination, correct type of lubricant, correct level or complete coverage of grease							X		
Presence of contaminants, low level of oil, or change in oil condition or color (encased)				X	X	X			
Inadequate coverage of lubricant		X	X	X					
Presence of contaminants that could jam the gear (includes ice formation)		X	X						
Presence of contaminants that jams the gear	X								

Table E44. Gear assembly (carriage)

<u>Gear assembly (exposed or encased) including associated bushing and bearing (carriage)</u>									
Function	Provide gear reduction for translation mechanism								
Excellent	Shafts and Gears well aligned, well lubricated (no contamination, correct type of lubricant, stable level), no parts missing, no surface defects, no pitting. No excessive noise, jump or vibration.								
Failed	Gear can not transmit torque or motion								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Noise, jump and vibration									
No excessive noise, jump, or vibration							X		
Any one of excessive noise, jump, or vibration		X	X	X	X				
Tooth wear, contact, and breakage									
No wear with full contact and properly meshed							X		
Minor wear					X	X			
Significant part of contact surface of teeth missing due to breakage or wear, or misalignment		X	X	X					
Teeth missing preventing rotation	X								
Anchor (fastener to shaft, key or pin) movement or deterioration									
Fastener in place and undamaged							X		
Key or pin is cracked		X	X						
Gear slipping on shaft	X								
Bearing or bushing wear									
Normal noise, runs smoothly						X	X		
Excessive noise or cracked housing, but still running		X	X						
Jammed	X								
Lubricant									
Well lubricated, no contamination, correct type of lubricant, correct level or complete coverage of grease							X		
Presence of contaminants, low level of oil, or change in oil condition or color (encased)				X	X	X			
Inadequate coverage of lubricant		X	X	X					
Presence of contaminants that could jam the gear (includes ice formation)		X	X						
Presence of contaminants that jams the gear	X								

Table E45. Dedicated lifting connectors

<u>Dedicated lifting connectors (Pins, lugs, clevises, and chain connectors)</u>									
Function	Connect gate to lifting mechanism								
Excellent	No cracks, no deformation, no corrosion, pin in place								
Failed	Cracked or cannot sustain load								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
No cracks, no deformation, no corrosion							X		
Bent, distorted or severely corroded elements				X	X				
Cracked elements	X	X	X						
Missing parts	X								

Table E46. Non-dedicated lifting connectors.

Non-dedicated lifting connectors (Pins and dogging pins, lugs to the gate)									
Function	Connect gate to lifting mechanism								
Excellent	No cracks, no irregularity, no bending, pin well set with uniform bearing								
Failed	Broken or not in place or unable to insert								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Undamaged and correctly aligned							X		
Misalignment, damaged, bent, or severely corroded but pin can be inserted		X	X	X	X				
Misalignment, cracked, damaged, bent, or severely corroded and pin cannot be inserted or missing pin	X								

Table E47. Carriage wheels.

Carriage wheels (mobile lifting hoist)									
Function	Allow travel of mobile lifting hoist								
Excellent	Roundness within tolerances, minimal rusting, freely rotating, no cracks, well aligned, correctly lubricated								
Failed	At least one wheel not rolling or cracked or damage preventing translation								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Roundness within tolerances, well aligned, minimal rusting, no cracks, correctly lubricated.							X		
Out of round or misalignment or damage on wheel not preventing translation. Vibrations, jerkiness or uneven speed			X	X	X				
At least one wheel not rolling or cracked or damage preventing translation	X								

Table E48. Clutch.

Clutch									
Function	To engage or disengage shaft at will								
Excellent	No slipping while engaged and can be disengaged at will								
Failed	Impossible to transmit torque, cannot be engaged or disengaged.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
No slipping while engaged and can be disengaged at will							X		
Minor slippage that still permits the power to be transmitted				X	X	X			
Major slippage that still permits the power to be transmitted but speed is reduced or overheating of plates		X	X						
Impossible to transmit torque, cannot be engaged or disengaged.	X								

Table E49. Drum, sheaves, and pulleys.

Drum, sheaves and pulleys									
Function	To transfer load to wire ropes								
Excellent	No visible wear, no abnormal noise, freely rotating								
Failed	Broken flange that cannot retain wire rope. Seized pulley								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Visible or measurable wear									
No visible wear, no abnormal noise, freely rotating							X		
Localized indentations, scratches				X	X	X			
Damage or wear that may cause a slip or misalignment, or abnormal noise, or vibration of wire rope		X	X	X	X				
Broken flange that cannot retain wire rope, or seized pulley	X								
Corrosion									
Failure of paint system, spots of surface rust, no section loss						X	X		
Surface scale present, no significant or measurable section loss				X	X				
Significant or measurable section loss		X	X						
Holes, complete section loss	X								
Groove wear (sheaves and drums)									
No wear							X		
Uneven groove				X	X				
Metal missing at the bottom of the groove		X	X						
Wire rope clamps or anchors									
Proper contact and solidly fastened							X		
Loose connection or damaged clamp		X	X						
Missing clamp or anchor	X								

Table E50. Hoist brake.

Hoist Brake									
Function	To arrest motion of gate and hold gate in any position								
Excellent	Can arrest motion at any position, not seized								
Failed	Cannot arrest motion at any position, seizing of brake								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Can arrest motion at any position, not seized							X		
Limited slippage without impacting operation; no slip but vibration				X	X	X			
Limited slippage that impacts operation		X	X						
Continuous slippage, seizing of brake	X								

Table E51. Carriage brake.

Carriage Brake									
Function	To arrest motion of carriage at will								
Excellent	Can arrest motion at any position, not seized								
Failed	Cannot arrest motion at any position, seizing of brake								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Can arrest motion at any position, not seized							X		
Limited slippage without impacting operation; no slip but vibration				X	X	X			
Limited slippage that impacts operation		X	X						
Continuous slippage, seizing of brake	X								

Table E52. Fan brake.

Fan Brake									
Function	To limit the speed of descent of a gate in absence of power supply								
Excellent	Clean, unobstructed airways, louvers well-aligned and secured, gate closes at the specified speed.								
Failed	Exceeds the specified closing speed of the gate								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Clean, unobstructed airways, . louvers well-aligned and secured, gate closes at the specified speed							X		
Obstructed airways, unsecured louvers or damaged impeller		X	X	X	X	X			
Gate closes too fast	X								

Table E53. Wire rope and connectors.

Wire rope and connectors									
Function	Transmit lifting force to the gate								
Excellent	No broken wires, can bend easily on a sheave or drum, well lubricated, no corrosion								
Failed	Six or more broken wires, bird caging, or reduction in wire diameter > 10%								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
	1	2	3	4	5	6	7	S	
Kinking									
No kinking							X		
Minor, kinking of a wire				X	X				
Major, kinking of one or more strand	X	X	X						
Corrosion									
No corrosion, well lubricated							X		
No surface grease			X	X					
Carbon steel wire rope or connectors below the water line, and not inspected, or corrosion		X	X						
Reduction in wire diameter>10%	X								
Outer wire wear, or breakage									
No outer wire wear, or breakage							X		
Nicks or surface gouges (round ropes)		X	X						
Nicks or surface gouges (flat ropes)		X	X						
Six or more broken wires within a lay	X								
Bird caging	X								
Corrosion									
Even tension							X		
Uneven tension not preventing opening			X	X	X				
Uneven tension preventing opening	X								

Table E54. Trunnion assembly.

Trunnion Assembly									
Function	Allow rotation of the radial gate								
Excellent	Well lubricated and without abnormal noise or vibration, no excessive play or friction								
Failed	Does not rotate or excessive friction during gate operation								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Functional Test									
Runs well with head. Frequently and uniformly lubricated, free rotation between pin and journal and/or thrust bearing. Well-aligned pins.							X		
Normal noise or vibration, Runs well in dry conditions without head. Free rotation between pin and journal and/or thrust bearing. Well-aligned pins						X			
Abnormal noise or vibration or no lubrication or blockage of grease lines or cracked housing but still running		X	X	X					
Seizing between pin/shaft and bushing. Rotation of pin in yoke/lug.	X	X	X						
Pin lateral displacement in trunnion	X	X							
Lubrication									
Well lubricated							X		
No lubrication or lubrication condition unknown			X	X	X				
Corrosion									
External corrosion on the assembly						X			
Corrosion preventing the removal of the cover plate				X	X				

Table E55. Trunnion beam and anchorage.

Trunnion beam and anchorage									
Function	To provide structural support of trunnion assembly								
Excellent	No cracks, no discoloring, no corrosion, no displacement, no deformation, no loose or missing anchor bolts, no concrete spalling								
Failed	Loss of support								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
No cracks, no discoloring, no corrosion, no displacement, no deformation, no loose or missing anchor bolts, no concrete spalling							X		
Corrosion of the anchorage and bolts				X	X				
Excessive displacement of the anchorage (if data is available)			X	X	X				
Excessive deflection of anchor beam (if data is available)			X	X	X				
External post-tension rods corrosion			X	X	X				
Diagonal shear cracks in concrete trunnion beam		X	X	X					
Loss of support	X								

Table E56. Chain and sprocket assembly.

Chain and sprocket assembly									
Function	To transmit lifting force to gate								
Excellent	No wear/play, well aligned, no corrosion, free movement of the pins, well lubricated, no deformations of the links or sprocket, no missing retention clips, no missing chain guides								
Failed	Missing pin, link, or cracked link or severely damaged sprocket								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
No wear/play, well aligned, no corrosion, free movement of the pins, well lubricated, no deformations of the links or sprocket, no missing retention clips, no missing chain guides							X		
Corrosion visible on surface of chain				X	X	X			
Operates but not well lubricated				X	X	X			
Noise, jumping, or vibration		X	X	X	X				
Kinking, not impacting operation			X	X					
Links do not lay flat on the chain rack under self-weight				X					
Links must be forced to rotate over the sprocket		X	X						
Corrosion limiting rotation of links		X	X						
Kinking limiting operation	X	X							
Improper meshing of chain and sprocket	X	X							
Missing pin, link, or cracked link or severely damaged sprocket.	X								

Table E57. Hydraulic cylinder assembly.

Hydraulic cylinder assembly									
Function	To provide lifting force to gate								
Excellent	No leak in the hydraulic system. Operates properly along full stroke within specifications.								
Failed	No pressure buildup or no movement at release pressure								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
No leak in the hydraulic system. Operates properly along full stroke within specifications.							X		
Loss of pressure controllable by motor			X	X	X				
Corrosion/pitting of rod			X	X					
Oil leakage		X	X	X					
Insufficient pressure buildup or no movement at release pressure	X								

Table E58. Fixed wheels for vertical lift gates.

Fixed wheels for vertical lift gates									
Function	Reduce friction when operating gates								
Excellent	Roundness within tolerances, minimal rusting, freely rotating, no cracks, well aligned, correctly lubricated.								
Failed	Enough wheels do not rotate preventing lifting of gate. Enough friction to prevent lifting or closing								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Roundness within tolerances, minimal rusting and pitting, freely rotating, no cracks, well aligned, correctly lubricated.							X		
Vibrations, jerkiness, uneven motion not preventing lifting or closing of gate			X	X	X				
Seized or damaged wheel or bearing not preventing lifting or closing of gate		X	X	X					
Enough friction to prevent lifting or closing of the gate.	X								

Table E59. Roller trains.

Roller trains									
Function	Reduce friction when operating gates								
Excellent	Roundness within tolerances, minimal rusting, freely rotating, no cracks, well aligned. Casings undamaged and follow gate movement.								
Failed	Jammed rollers prevent lifting of gate. Broken cable. Debris block rollers. Casing severely damaged or missing rollers.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Roundness within tolerances, minimal rusting, freely rotating, no cracks, well aligned. Casings undamaged and follow gate movement.							X		
Vibrations, jerkiness.				X	X	X			
Uneven motion not preventing lifting or closing of gate			X	X	X				
Jammed or damaged roller not preventing lifting or closing of gate		X	X						
Jammed rollers prevent lifting of gate. Broken cable. Debris block rollers. Casing severely damaged or missing rollers.	X								

Civil/structural components

Table E60. Carrying tracks.

Carrying Tracks									
Function	Provides support for, and the means to displace the lifting structure to access all the gates of the spillway.								
Excellent	Alignment according to specification, no missing parts or sections.								
Failed	Visible or measured misalignment, section missing that prevents the carriage from moving or lifting.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Alignment, elevation, spacing (gauge)									
According to specifications							X		
Out of specification but no noticeable wear of track, crane can still lift gate and travel (without noise and vibration)					X	X			
Out of specification but no noticeable wear of track, crane can still lift gate and travel (with noise and vibration)				X					
Out of specification with noticeable wear of track can still lift gate and move freely			X						
Enough misalignment, so that crane may not/cannot lift gate or move freely	X	X							
Anchor									
Present							X		
1 - 2 consecutive missing, damaged or loose anchor			X	X	X				
More than 2 missing, damaged, or loose consecutive anchor	X	X	X						
Missing sections									
None							X		
At least one gate cannot be opened	X	X	X						

Table E61. Lifting device structure.

Lifting Device Structure (concrete)									
Function	To provide support for hoisting device (and carrying tracks for mobile hoisting device)								
Excellent	Comprehensive structural inspection has been performed. All critical structural members fully accessible for inspection. No member deformations, no cracks, no exposed rebars, no concrete spalling or erosion. No loss of bearing support. No misalignment according to specifications.								
Failed	Inability to correctly position or operate the lifting device or the lifting structure. Extensive deterioration, visible member deformations. Loss of concrete section.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Support for lifting structure or hoisting mechanism									
No misalignment in a dedicated hoisting mechanism							X		
Displacement and deterioration of the structure causing misalignment in a hoisting mechanism with no effect on lifting						X			
Displacement and deterioration of the structure causing misalignment in a hoisting mechanism with abnormal noise and vibration				X	X				
Displacement and deterioration of the structure causing misalignment in a hoisting mechanism with motor overload		X	X						
Displacement and deterioration of the structure causing misalignment in a hoisting mechanism that cannot be lifted	X								

Table E62. Mobile structure to support a shared lifting device.

Mobile structure to support a shared lifting device (including gantry crane)									
Function	Provide structural support for the hoisting device								
Excellent	Comprehensive structural inspection has been performed. All critical structural members fully accessible for inspection. No visible cracks, no visible member deformation, no corrosion, no missing bolts or members, no visible misalignment.								
Failed	Visible deformations, missing parts, or cracks of a load-carrying member. Corrosion resulting in the loss of more than 20% of the cross-section of critical structural member. Missing bolts or cracked welds on a fracture-critical member or connection (a non-redundant tensile member or connection whose loss would result in the collapse of the structure)								
Indicator	0 -- 9 1	10 -- 24 2	25 -- 39 3	40 -- 54 4	55 -- 69 5	70 -- 84 6	85 -- 100 7	Score S	Comments
Displacement and deterioration									
No misalignment in the hoisting mechanism							X		
Displacement and deterioration of the structure causing visible or measurable misalignment in a shared lifting device with no effect on lifting						X			
Displacement and deterioration of the structure causing visible or measurable misalignment in a shared lifting device with excessive noise and vibration				X	X				
Displacement and deterioration of the structure causing visible or measurable misalignment in a shared lifting device with motor overload		X	X						
Displacement and deterioration of the structure causing visible or measurable misalignment in a dedicated hoisting mechanism that cannot be lifted	X								
Anchor bolts									
Corrosion on nuts and bolts				X	X	X			
Cracks in the concrete around the bolt and or missing concrete around the bolt		X	X						
At least one missing bolt or nut	X								
Cracks									
No cracks							X		
Crack in compression member	X	X	X	X					
Crack in tension members, web plate, or tension or compression connections (missing or cracked weld, splices, bolts and rivet heads)	X	X							
Crack in a fracture critical member	X								
Distortion									
No distortion							X		
Distortion in tension members and braces				X	X				
Compression members and braces, web, and bolts	X	X	X						
Corrosion (Compression and tension members and flanges)									
Intact coating							X		
Loss of coating, surface scaling					X	X			
Visible loss of section (< 20%)			X	X					
Loss of section > 20%	X	X							
Missing or loose parts									
No missing of loose parts									
Missing bolts or rivet heads in a connection < 10%			X	X					
Missing bolt or rivet head in a stiffener or a brace of main	X	X	X	X					
Missing bolts or rivet heads in a connection > 10%	X	X							
Missing welds	X								

Table E63. Approach and exit channel.

Approach and exit channel									
(Upstream and downstream apron including base of pier / stilling basin/exit channel)									
Function	Protect the downstream and upstream portion of the spillway channel from erosion associated with the flow of water during discharge. Provide unobstructed passage to the flow of water.								
Excellent	No cavitation damage or erosion. No sedimentation upstream. No obstructions downstream.								
Failed	Major erosion at foot of spillway at the foundation level compromising the stability of the dam. Obstructions to the flow of water from sedimentation or downstream blockage.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Loss of concrete due to cracking, erosion, cavitation (Apron and stilling basin)									
No loss							X		
Depth < 4"					X	X			
4" to 6" or exposure of rebar				X					
> 6" up to 30% of as-built cross-section		X	X						
> 30% of as-built cross-section design load and no structural evaluation	X								
Loss of concrete due to cracking, erosion, cavitation (In pier and/or base)									
No loss							X		
Minor (<2")					X	X			
Exposure of rebar			X	X					
Undermine rebar	X	X							
Scour of foundation material (caused by full opening of gates), scours and potential scour of sidewalls and bottom of spillway channel									
No loss of foundation material							X		
Loss or potential loss of material without undermining of dam (including never used)				X	X	X			
Loss or potential loss of material with undermining of dam (including never used)	X	X	X						
Upstream sedimentation									
None							X		
Minor						X			
Important	X	X	X	X	X				
Downstream blockage									
None							X		
Minor						X			
Important	X	X	X	X	X				

Table E64. Lifting device structure (steel).

Lifting device structure (steel)									
Function	Provide structural support for the hoisting device (and carrying tracks for mobile hoisting device)								
Excellent	Comprehensive structural inspection has been performed. All critical structural members fully accessible for inspection. No visible cracks, no visible member deformation, no corrosion, no missing bolts or members, no visible misalignment.								
Failed	Visible deformations, missing parts, or cracks of a load-carrying member. Corrosion resulting in the loss of more than 20% of the cross-section of critical structural member. Missing bolts or cracked welds on a fracture critical member or connection (a non-redundant tensile member or connection whose loss would result in the collapse of the structure).								
Indicator	0 -- 9 1	10 -- 24 2	25 -- 39 3	40 -- 54 4	55 -- 69 5	70 -- 84 6	85 -- 100 7	Score S	Comments
Displacement and deterioration									
No misalignment in a dedicated hoisting mechanism							X		
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with no effect on lifting						X			
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with excessive noise and vibration				X	X				
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with motor overload		X	X						
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism that cannot be lifted	X								
Anchor bolts									
No corrosion							X		
Corrosion on nuts and bolts				X	X	X			
Cracks in the concrete around the bolt and/or missing concrete around the bolt		X	X						
At least one missing bolt or nut	X								
Cracks									
No cracks							X		
Crack in compression member	X	X	X	X					
Crack in tension members, web plate, or tension or compression connections (missing or cracked weld, splices, bolts and rivet heads)	X	X							
Crack in a fracture critical member	X								
Distortion									
No distortion							X		
Distortion in tension members and braces				X	X				
Distortion in compression members and braces, web, and bolts	X	X	X						
Corrosion (Compression and tension members and flanges)									
Intact coating							X		
Loss of coating, surface scaling					X	X			
Visible loss of section (< 20%)			X	X					
Loss of section > 20%	X	X							
Missing or loose parts									
No missing or loose parts							X		
Missing bolts or rivet heads in a connection < 10%			X	X					
Stiffener of brace of main member	X	X	X	X					
Missing bolts or rivet heads in a connection > 10%	X	X							
Missing welds	X								

Table E65. Embedded parts.

Embedded Parts (including sill)									
Function	To provide external support and bearing surfaces to the gate and seals. i. Embedded sill plate ii. Roller path and sealing surfaces iii. Lateral guides								
Excellent	Gate has been dewatered for inspection or observations in accordance with specified schedule. - No misalignment, warping or distortion - Working heating elements - No visible surface defects (pitting, cracking, wearing, punctures, dents, missing sections) - Full structural support - No surface contaminants (crustaceans) - Gate has been tested under load and lifts with appropriate load and velocity - Warping that could bind the gate in place								
Failed	- Heating elements not working - Loss of structural support under the roller pads - Enough displacement of the structural support that could bind the gate in place - Enough displacement of the structural support under seismic loading that could damage the gate - Localized pitting or puncturing under the roller path (1/8" or greater) - Puncturing of the embedded part outside of the roller path								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Gate lifting effort									
Gate lifts under load without overloading hoist at rated speed							X		
Gate lifts under load with hoist overload		X	X	X					
Gate does not lift	X								
Geometrical alignment of roller path									
With measurement meeting specifications							X		
No Visual warping or no known displacement of supports in the absence of measurements				X	X	X			
Measurements that do not meet specifications	X	X	X	X	X				
Visual warping or known displacement of supports in absence of measurements	X	X	X						
Corrosion (confined to roller track path)									
Light surface scaling					X	X			
Pitting < 1/8" deep			X	X					
Pitting > 1/8" deep	X	X							
Roller track wear									
No wear							X		
< 10% of thickness				X	X	X			
> 10% of thickness	X	X	X						
Corrosion (Rest of embedded part - excluding roller track)									
Failure of paint system, spots of surface rust, no section loss						X	X		
< 30% loss of cross-section [locally]					X	X			
> 30% loss of cross-section [locally]		X	X	X					
Puncture or holes	X	X							

Table E66. Gate structure.

Gate Structure									
Function	Supporting structure To hold the skinplate in place and transfer water load to wheels or trunnion. Skin plate Provide lateral support to girders, retain water, water tightness								
Excellent	Gate has been dewatered for inspection or observations in accordance with specified schedule. Gate has been tested under design load and lifts and closes according to specifications. - No visual warping or member deformation - No loss of paint - No visible surface defects on members or - connections (pitting, cracking, wearing, puncture, missing sections) - No fractured or missing welds - No missing bolts or members								
Failed	Warping or member deformation that could bind or overload the gate. Corrosion resulting in the loss of more than 20% of the cross-section. Missing bolts or cracked welds on a fracture critical member or connection (a non-redundant tensile member or connection whose loss would result in the collapse of the structure).								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Loading history									
Operated under design load and positive structural evaluation							X		
Operated under design load but no structural evaluation			X	X	X	X			
Operated under design load but negative structural evaluation	X	X	X						
Never been operated under design load but positive structural evaluation					X	X			
Never been operated under design load and no structural evaluation		X	X	X					
Never been operated under design load and negative structural evaluation	X	X							
Cracks									
No Cracks							X		
Cracks in skin plate if due to impact (tear)				X	X				
Cracks in compression member or fatigue crack in skin plate	X	X	X	X					
Cracks in tension members, web plate, or tension or compression connections (missing or cracked weld, splices, bolts and rivet heads)	X	X							
Crack in a fracture critical member	X								
Distortion									
No Distortion							X		
Distortion in tension members and braces, skin plate				X	X				
Distortion in compression members and braces, web, bolts, and pins	X	X	X						
Corrosion (skin plate)									
Failure of coating and/or surface scaling present						X	X		
Visible loss of section (< 30%)			X	X					
Holes, > 30% section loss	X	X							
Corrosion (Compression and tension members and flanges)									
Intact coating							X		
Loss of coating, surface scaling					X	X			
Visible loss of section (< 20%)			X	X					
Loss of section > 20%	X	X							
Missing or loose parts									
No missing or loose parts							X		
Missing bolts or rivet heads in a connection < 10%			X	X					
Missing or loose part in a plate stiffener (bracing behind skin plate, skin plate stiffeners)			X	X					

Table E67. Stoplogs, bulkheads (steel).

Stoplogs, bulkheads (steel)									
Function	Provide closure for dewatering inspection, maintenance, and rehabilitation of gates and possible emergency closure. Used as a gate.								
Excellent	Comprehensive structural inspection has been performed. All critical structural members fully accessible for inspection. No visible cracks, no visible member deformation, no corrosion, no missing bolts or members, no visible misalignment. No loss of paint. Adequate sealing for safe working conditions downstream								
Failed	Visible deformations, missing part, or crack of a load-carrying member. Warping/member deformation that could bind the bulkhead in place. Corrosion resulting in the loss of more than 20% of the cross-section. Missing bolts or cracked weld on a fracture critical member or connection (a non-redundant tensile member or connection whose loss would result in the collapse of the structure). Cannot be lowered or raised into position. Does not provide sufficient water tightness.								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Previously installed successfully and a positive structural evaluation							X		
Previously installed successfully and no structural evaluation			X	X	X	X			
Cracks									
No cracks							X		
Crack in skin plate if due to impact (tear)				X	X				
Crack in compression member or fatigue crack in skin plate	X	X	X	X					
Crack in tension members, web plate, or tension or compression connections (missing or cracked weld, splices, bolts and rivet heads)	X	X							
Crack in a fracture critical member	X								
Distortion									
No distortion							X		
Distortion in tension members and braces, skin plate				X	X	X			
Distortion in compression members and braces, web, bolts, and pins	X	X	X						
Corrosion (skin plate)									
No corrosion							X		
Failure of coating and/or surface scaling present					X	X			
Visible loss of section (< 30%)			X	X					
Holes, > 30% section loss	X	X							
Corrosion (Compression and tension members and flanges)									
Intact coating							X		
Loss of coating, surface scaling					X	X			
Visible loss of section (< 20%)			X	X					
Loss of section > 20%	X	X							
Missing or loose parts									
No missing or loose parts							X		
Missing bolts or rivet heads in a connection < 10%			X	X					
Plate stiffener (bracing behind skin plate, skin plate stiffeners)			X	X					
Stiffener or brace of main member	X	X	X	X					
Missing bolts or rivet heads in a connection > 10%	X	X							
Missing welds	X								

Table E68. Bottom and side seals.

Bottom and Side Seals									
Function	Prevent leaks on the sides and at the bottom of the gate.								
Excellent	No leak								
Failed	Blowout of seal								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Leaks									
No leaks							X		
Leak not causing ice buildup, nor deterring maintenance or inspection, nor causing erosion.				X	X	X			
Leak deterring maintenance or inspection, or causing erosion, or causes ice buildup	X	X	X	X					

Appendix F: Embankment Dam CI Condition Rating Tables

Table F1 through F10 list the indicators and condition definitions for each of the defense groups and are presented in their respective section. For each of the indicators, a range in possible CI values is given by Xs for each indicator. The task of the dam inspector is to look for the appropriate indicators related to each of the defense groups and to assign a corresponding condition. The assigned condition must be in agreement with the condition definition and ranges given in the REMR CI Scale (Table F1). When several indicators are present, the lowest CI from the group is used. Where there are multiple occurrences of the same indicator, there is a corresponding tendency for the CI to be in the lower end of the range. In the case where no indicators of distress are present, but there is a known defect, a CI is assigned to the defense group in the suggested range following the REMR CI Scale. Examples of known defects for pressure control in the foundation could be: a leaking diaphragm cutoff wall, an upstream blanket that does not extend far enough upstream, or a toe drain filter that does not meet present filter criteria.

Spillway capacity defense group

Ideal and failed condition definitions for the spillway capacity defense group are based on the spillway's ability to handle design flows. Three indicators can be used to assess the condition of the spillway capacity defense group: (1) a visual assessment of the percent loss of cross-sectional area, (2) whether or not the spillway has sufficient design capacity, and (3) a known defect. An example of a known defect would be a known tendency for instability in the channel slopes. If the spillway is on the Headquarters USACE Dam Safety Assurance priority list for a capacity problem, then it is given a condition of zero. Table F1 presents the applicable ranges for these three indicators.

Table F1. Condition definition for the spillway capacity defense group.

Spillway Capacity Defense Group							
Ideal Condition	To be able to pass the design flow.						
Failed Condition	Enough blockage so that the dam may be overtopped or the spillway does not meet current criteria.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
% loss of cross-sectional area							
• 0-10 %						X	X
• 10-25 %				X	X		
• 25-100 %	X	X	X				
Will overtop with observed blockage CI = 0							
Design spillway capacity lower than the current design flood CI = 0 ^(a)							
Known Defects (with no indicator of distress)						X	X

(a) CI = 0 for Corps of Engineers dam on Dam Safety Assurance List for inadequate capacity.

Example of known defect is the tendency for instability in the channel slopes.

Spillway erosion defense group

Ideal and failed condition definitions for the spillway erosion defense group are based on the ability of the spillway to pass flow without loss of the sill and/or reservoir. Erodibility refers to erosion of spillway material (sill and/or foundation material) during a discharge. In extreme cases, the sill will erode and threaten the integrity of the spillway and/or dam and the project's ability to fulfill its original purpose (retain design pool). Two indicators can be used to assess the condition of the spillway erosion defense group. These indicators are: (1) evidence of erosion (including internal erosion beneath the spillway); and (2) whether or not there is a known defect. An example of a known defect would be the presence of highly erodible material in the spillway. For a Corps of Engineers dam, if the spillway is on the HQ DSA priority list for an erodibility deficiency, then it is given a condition of zero. Table F2 presents the applicable ranges for these two indicators.

Table F2. Condition definition for the spillway erosion defense group.

Spillway Erosion Defense Group							
Ideal Condition	To be able to pass design flow without the loss of the sill.						
Failed Condition	Sill and/or reservoir would be lost due to erosion.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Erosion ^(a)							
• none or minor erosion (damage can be repaired with project personnel)					X	X	X
• significant erosion (still intact but damage extensive enough that repairs must be made by contract)		X	7.2.1.1 X	X			
• critical erosion (sill lost) ^(b)	X						
Known defect (with no indicators of distress)					X	X	X

(a) This can include internal erosion of material beneath the spillway.

(b) CI = 0 for Corps of Engineers dam on Dam Safety Assurance List for erodibility.

An example of a known defect is highly erodible material beneath the sill.

Crest elevation defense group

Ideal and failed condition definitions for the crest elevation defense group are based on the design elevations for the crest. There are two indicators that are used to assess condition for the crest elevation. These are: (1) the percentage of the freeboard remaining and (2) whether or not there is a known defect. An example of a known defect would be poor compaction in the core around an instrumentation riser that could lead to excessive settlement of core material. Table F3 shows the possible condition ranges for these two indicators.

Table F3. Condition definition for the crest elevation.

Crest Elevation Defense Group (decrease due to settlement)							
Ideal Condition	Crest at or above design elevation.						
Failed Condition	Crest below surcharge pool.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Percent of freeboard remaining							
• 75 to 100 %						X	X
• 0 to 75%	X	X	X				
Known defect (no indicators of distress)						X	X

Examples of known defects:

- Poor compaction around an instrumentation riser in the core
- Poor compaction adjacent to a concrete structure.

Surface runoff collection/discharge system

Ideal and failed condition definitions for the surface runoff collection/discharge system are based on the capacity of the collection systems, the types of protective materials, and the existing grades. Four indicators can be used to determine the condition of the surface runoff collection and discharge system: (1) depth of erosion below surface protection, (2) capacity of collection lines, (3) existing surface grades, and (4) known defects (such as erodible materials in collection and discharge ditches or inadequate grade of drains). Table F4 shows each of these indicators and allowable ranges for the assignment of condition.

Table F4. Condition definition for the surface runoff collection/discharge system.

Surface Runoff Collection/Discharge System							
Ideal Condition	Capacity of the collection systems, protective materials, and existing grades are sufficient to convey storm drainage away from the dam without erosion.						
Failed Condition	Capacity of the collection systems, protective materials, and existing grades are insufficient to convey storm drainage away from the dam without erosion.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Depth of erosion below protection							
• 0 to 1 ft						X	X
• 1 to 3 ft			X	X	X		
• greater than 3 ft	X	X	X				
Capacity of collection lines							
• no backup							X
• infrequent backup				X	X	X	
• frequent backup	X	X	X				
Surface grades							
• no ponding							X
• infrequent ponding				X	X	X	
• frequent ponding	X	X	X				
Known defect (no indicators of distress)						X	X

Examples of known defects:

- Erodible materials in trenches and ditches
- Inadequate grade of drains.

Downstream Slope Protection

The defense group for downstream slope protection is applicable to earthen embankment dams with grass cover. The ideal and failed conditions are based on visual evidence of loss of grass cover or the existence of erosion gullies. Three indicators can be used to determine the condition of the downstream slope protection: (1) the presence and depth of ruts and gullies, (2) the observed loss of surface protection material, and (3) known defects such as highly erodible materials. Table F5 shows these indicators with corresponding condition ranges.

Table F5. Condition definition for downstream slope protection (applicable to earthen dams with primarily grass cover).

Downstream Slope Protection							
Ideal Condition	No noticeable erosion resulting in changes in design geometry						
Failed Condition	Existence of deep (3 to 4 ft) ruts/gullies and/or 50% loss in surface protection						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Ruts and gullies (erosion into protected soil) ^(a)							
• 0 to 1 ft deep						X	X
• 1 to 3 ft			X	X	X		
• greater than 3 ft	X	X	X				
Loss of surface protection material							
• 0% to 10 %					X	X	X
• 10% to 25%			X	X	X		
• 25% to 50%		X	X				
• greater than 50%	X						
Known defect (no indicators of distress) ^(b)						X	X

(a) Use lower end of the scale for multiple occurrences.

(b) Example of known defect: erodible downstream material.

Upstream slope protection

Ideal and failed condition definitions for upstream slope protection are based on observable erosion, deterioration/removal of the slope protection, and exposure of bedding material. Four indicators can be used to assess the condition of the upstream slope protection: (1) observed loss of slope protection material, (2) degradation/breakdown of slope protection material, (3) removal of bedding or protected material, and (4) known defects such as improperly sized stone protection for reservoir fetch and storm conditions. Table F6 shows these indicators with corresponding ranges.

Table F6. Condition definition for the upstream slope protection.

Upstream Slope Protection							
Ideal Condition	No noticeable erosion or deterioration resulting in changes in design geometry.						
Failed Condition	Removal of slope protection resulting in extensive exposure of bedding or protected material.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Loss of slope protection material							
• no noticeable erosion or deterioration							X
• isolated or minor loss or movement of outer layer material				X	X	X	
• significant loss or movement of outer layer material		X	X				
• extensive loss of outer layer material and/or exposure of bedding material	X						
Degradation/breakdown of slope protection							
• isolated/minor					X	X	
• moderate			X	X			
• extensive/major		X					
Removal of bedding or protected material without the loss of outer slope protection							
• isolated/minor					X	X	
• moderate			X	X			
• extensive/major		X					
Known defect (no indicators of distress)						X	X

Example of known defect: Improperly sized stone protection for reservoir fetch and storm conditions.

Filtering in embankment

The ideal and failed conditions for filtering in the embankment are based on prevention of internal erosion (piping) of embankment materials. Three indicators are used to assess the condition of the defense group that filters the flow in the embankment: (1) the existence of turbid flows, (2) the existence of sinkholes or depressions, and (3) the existence of known defects such as segregation of the filter materials or improperly designed filter/drainage system. While recognizing that hydrostatic pressures have an impact upon piping considerations, it is believed that those considerations are adequately treated in “Pressure Control in Embankment” and in the determination of relative importance factors for the defense groups (see Table 3.7). The condition of the filtering group is generally very difficult to determine. Note that, with any known defect in the embankment filtering system, the condition can never be 100 even in the absence of any

evidence of the migration of fines. Table F7 summarizes these indicators and the corresponding ranges.

Table F7. Condition definition for filtering in embankment.

Filtering in Embankment							
Ideal Condition	No migration of fines with a designed filtering system.						
Failed Condition	Persistent migration of fines.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Turbid flows							
• no evidence							X
• evidence of prior occurrence			X	X	X		
• actively occurring	X	X					
Sinkholes / depressions	X	X	X	X			
Known defects (no indicators of distress)			X	X	X	X	

Examples of known defects:

- Pipeable material without a designed filter system.
- Improperly designed internal filter/drainage system in embankment.

Pressure control in embankment

The ideal and failed conditions for the pressure control group in the embankment are based upon projected magnitudes of pore pressures in relationship to design values and calculated factors of safety against slope instability. Seven indicators are used to assess the condition of the pressure control group in the embankment: (1) piezometric levels at or below design levels, (2) piezometric levels above design levels, (3) uncontrolled seepage, (4) changes in controlled seepage, (5) differential movement in the embankment, (6) computed factors of safety from slope stability analyses compared to required minimum factors of safety, and (7) known defects (such as improperly designed drains). Although indicators (3) and (4) might suggest a developing piping problem, they are considered within the pressure control system. Table F8 presents these indicators and the corresponding ranges that can be used by inspectors to assign condition.

Table F8. Condition definition for pressure control in embankment.

Pressure Control in Embankment							
Ideal Condition	Magnitude of pressures within design parameters projected at design pool.						
Failed Condition	Pressures sufficient to result in $FS < 1$ at design pool for mass movement.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Piezometric levels at or below design levels ^(a)							
• constant						X	X
• increasing				X	X	X	X
Piezometric levels above design level ^(a)							
• constant		X	X	X	X		
• increasing	X	X	X				
Uncontrolled seepage							
• changes in surface vegetation					X	X	X
• soft/wet areas				X	X	X	
• constant flow			X	X	X		
• increasing flow	X	X	X				
Change in controlled seepage		X	X	X	X	X	
Differential movement (e.g., cracking, shallow slides, bulging, between fixed and floating structures)							
• minor / localized			X	X	X	X	
• major / extensive	X	X	X				
F.S. mass movement							
• $F.S. \geq \text{Design } F.S.$ ^(b)							X
• $1.0 < F.S. \leq \text{Design } F.S.$ ^(b)		X	X	X	X	X	
• $F.S. < 1.0$	X						
Known defect (no indicators of distress)						X	X

(a) Projected in relationship to design pools.

(b) Required design minimum factor of safety.

Example of known defect:

- Improperly designed drains.

Filtering in foundation

The ideal and failed conditions for filtering in the foundation are the same as those for “Filtering in embankment” and are based on the prevention of internal erosion (piping) of foundation materials. Three indicators are used to assess the condition of the defense group that filters flow in the

foundation: (1) the existence of turbid flows, (2) the existence of sinkholes or surface depressions, and (3) the presence of known defects such as segregation of filter materials or improperly designed filter/drainage system. While recognizing that hydrostatic pressures have an impact upon piping, it is believed that those considerations are adequately treated in “Pressure Control in Foundation” and through the relative importance determinations for the defense groups. Table F9 summarizes these indicators and the corresponding ranges that can be assigned by the onsite inspector. The condition of the filtering group is generally very difficult to determine. Note that if pipeable material is present without a designed filtering system, the condition can never be 100, even in the absence of any evidence of the migration of fines.

Table F9. Condition definition for filtering in foundation.

Filtering in Foundation							
Ideal Condition	No migration of fines with a designed filtering system.						
Failed Condition	Persistent migration of fines.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Turbid flows							
• no evidence							X
• evidence of prior occurrence			X	X	X		
• actively occurring	X	X					
Sinkholes / depressions	X	X	X	X			
Known defect (no indicators of distress)			X	X	X	X	

Examples of known defects:

- Segregation of the filter materials
- Improperly designed internal filter/drainage system in foundation.

Pressure control in foundation

The ideal and failed conditions for the pressure control group in the foundation are the same as those for “Pressure Control in Embankment” and are based on projected magnitudes of pore pressures in relationship to design values and calculated factors of safety against slope instability. Seven indicators are used to assess the condition of the pressure control group in the foundation: (1) projected piezometric levels at or below design levels,

(2) projected piezometric levels above design levels, (3) uncontrolled seepage, (4) changes in controlled seepage, (5) differential movement in the embankment, (6) computed factors of safety from slope stability analyses compared to required minimum factors of safety, and (7) known defects such as an improperly designed pressure relief system, a defective cutoff wall, inadequate upstream impervious blanket, etc. Although indicators (3) and (4) might suggest a developing piping problem, they are considered within the pressure control system. Table F10 presents these indicators and the corresponding ranges that can be used by inspectors to assign condition.

Table F10. Condition definition for pressure control in foundation.

Pressure Control in Foundation							
Ideal Condition	Magnitude of pressures within design parameters projected at design pool.						
Failed Condition	Pressures sufficient to result in FS < 1 at design pool for mass movement.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
Piezometric levels at or below design level ^(a)							
• Constant						X	X
• Increasing				X	X	X	X
Piezometric levels above design level ^(a)							
• Constant		X	X	X	X		
• Increasing	X	X	X				
Uncontrolled seepage							
• changes in surface vegetation					X	X	X
• soft/wet areas				X	X	X	
• constant flow			X	X	X		
• increasing flow	X	X	X				
Change in controlled seepage		X	X	X	X	X	
Differential movement (e.g., cracking, shallow slides, bulging)							
• minor / localized			X	X	X	X	
• major / extensive	X	X	X				
F.S. mass movement							
• F.S. ≥ Design F.S. ^(b)							X
• 1.0 < F.S. ≤ Design F.S. ^(b)		X	X	X	X	X	

Pressure Control in Foundation							
Ideal Condition	Magnitude of pressures within design parameters projected at design pool.						
Failed Condition	Pressures sufficient to result in FS < 1 at design pool for mass movement.						
Indicators	0-9	10-24	25-39	40-54	55-69	70-84	85-100
• F.S. < 1.0	X						
Known defect (no indicators of distress)						X	X

(a) Projected in relationship to design pools.

(b) Required design minimum factor of safety (static or dynamic).

Examples of known defects:

- improperly designed pressure relief system
- inadequate cutoff
- inadequate upstream impervious blanket
- reduced capacity of relief wells

Appendix G: Army Dams “Not Rated” in 2016 NID

The following Army-owned dams appear in the 2016 NID, where the field CONDITIONASSESSMENT was coded as “NOT RATED.”

DAM_NAME	NIDID	OWNER_NAME	HAZARD	CONDITIONASSESSMENT	CONDITIONASSESSMENTDATE	CONDITIONASSESSMENTDETAIL
GREEN LEAF LAKE	OK20992	CAMP GRUBER	S	NOT RATED	04/01/2006	
LANES CURVE POND	OK20993	CAMP GRUBER	L	NOT RATED	05/01/2002	
OKNONAME 101020	OK20996	CAMP GRUBER	L	NOT RATED	05/01/2002	
WPA POND	OK20997	CAMP GRUBER	L	NOT RATED	05/01/2002	
PUMPKIN CENTER POND	OK20995	CAMP GRUBER	L	NOT RATED	05/01/2002	MEETS APPLICABLE TOLERABLE RISK CRITERIA
OVERHILLS NO. 1	NC00013	FORT BRAGG	L	NOT RATED	05/04/2012	
TOMMEHETON LAKE	VA05313	FORT PICKETT	L	NOT RATED	09/11/1995	
BIRCHIN LAKE	VA13511	FORT PICKETT	L	NOT RATED	09/11/1995	
BUTTERWOOD LOWER	VA13510	FORT PICKETT	L	NOT RATED	09/09/1995	NOT UNDER STATE JURISDICTION
VPI	VA13508	FORT PICKETT	L	NOT RATED	09/14/1995	
TACTICAL BRIDGE	VA13525	FORT PICKETT	L	NOT RATED	09/14/1995	
ROSE CREEK	NV10102	HAWTHORNE ARMY DEPOT	S	NOT RATED	12/03/2009	
UPPER DERBY	CO01285	ROCKY MOUNTAIN ARSENAL	S	NOT RATED	07/01/1983	
LADORA	CO01286	ROCKY MOUNTAIN ARSENAL	S	NOT RATED	07/01/2005	DAM HAS NOT BEEN INSPECTED
PERSHING LAKE	TX02350	FORT HOOD	H	NOT RATED	10/14/2012	
NOLAN LAKE	TX02349	FORT HOOD	H	NOT RATED	10/14/2012	
HEINER LAKE	TX04648	FORT HOOD	L	NOT RATED	10/14/2012	DAM HAS NOT BEEN INSPECTED
AIRFIELD LAKE	TX02347	FORT HOOD	H	NOT RATED	10/14/2012	
43C	TX10116	FORT HOOD	L	NOT RATED	10/14/2012	
BIRDBATH LAKE	TX04560	FORT HOOD	L	NOT RATED	10/14/2012	DAM HAS NOT BEEN INSPECTED
COPPERAS COVE 2	TX04645	FORT HOOD	L	NOT RATED	10/14/2012	DAM HAS NOT BEEN INSPECTED
HENRY LAKE	TX04647	FORT HOOD	L	NOT RATED	10/14/2012	DAM HAS NOT BEEN INSPECTED
41C	TX10122	FORT HOOD	L	NOT RATED	10/14/2012	
41D	TX10123	FORT HOOD	L	NOT RATED	10/14/2012	
44H	TX10114	FORT HOOD	L	NOT RATED	10/14/2012	
STARNES 1	TX10131	FORT HOOD	L	NOT RATED	10/14/2012	
46F	TX10102	FORT HOOD	L	NOT RATED	10/14/2012	
46E	TX10103	FORT HOOD	L	NOT RATED	10/14/2012	
WEEMS POND	GA01714	FORT BENNING	L	NOT RATED	12/10/2012	
KINGS POND	GA01710	FORT BENNING	S	NOT RATED	10/13/2010	
LOWER TWIN LAKE	SC00231	FORT JACKSON	H	NOT RATED	08/24/2013	
WESTON LAKE	SC00233	FORT JACKSON	H	NOT RATED	08/27/2013	
UPPER LEGION LAKE	SC00229	FORT JACKSON	L	NOT RATED	08/26/2013	DAM HAS NOT BEEN INSPECTED
SEMMES LAKE	SC00225	FORT JACKSON	S	NOT RATED	08/23/2013	
UPPER DAVIS POND	SC00227	FORT JACKSON	L	NOT RATED	08/25/2013	OTHER
DUPRE POND	SC00228	FORT JACKSON	L	NOT RATED	08/21/2013	
YELLOW LAKE	AR01557	PINE BLUFF ARSENAL	L	NOT RATED	11/04/2009	
SMITH LAKE	NC01129	FORT BRAGG	H	NOT RATED	11/01/2011	OTHER
SIMMONS FIELDS LAKE	NC01127	FORT BRAGG	H	NOT RATED	11/01/2011	
TEXAS POND	NC01128	FORT BRAGG	H	NOT RATED	11/01/2011	OTHER
MCKELLARS LAKE (LOWER)	NC00029	FORT BRAGG	L	NOT RATED	11/01/2011	
KIEST LAKE	NC00025	FORT BRAGG	H	NOT RATED	11/01/2011	
YOUNG'S LAKE	NC00090	FORT BRAGG	H	NOT RATED	11/01/2011	
OAT HILL	CA10125	FORT HUNTER LIGGETT	L	NOT RATED	08/04/2015	
KYLE LAKE	TN16108	FORT CAMPBELL	L	NOT RATED	09/17/2013	DAM HAS NOT BEEN INSPECTED
LAKE TAAL "FLETCHERS FORK"	TN12502	FORT CAMPBELL	H	NOT RATED	09/17/2013	DAM HAS NOT BEEN INSPECTED
FORT PICKETT RESERVOIR	VA13501	FORT PICKETT	S	NOT RATED	06/07/1995	
PENN S POND	MO30976	FORT LEONARD WOOD	L	NOT RATED	06/09/2010	
SMOOTS POND	VA03303	FORT A P HILL	L	NOT RATED	09/20/2010	
EWIS	VA03305	FORT A P HILL	L	NOT RATED	09/20/2010	
HERNS POND	VA03336	FORT A P HILL	L	NOT RATED	09/20/2010	
JOHN TOWNSEND	CO01292	FORT CARSON	L	NOT RATED	07/24/2012	DAM HAS NOT BEEN INSPECTED
OLD TIMBERS LAKE	IN03021	JEFFERSON PROVING GROUND	H	NOT RATED	11/16/2004	
BRUSH CREEK RESERVOIR	IN00013	CAMP ATTERBURY	H	NOT RATED	08/12/2013	
LOWER DERBY	CO01902	ROCKY MOUNTAIN ARSENAL	S	NOT RATED	07/01/2005	
WEYANTS POND	NY00766	WEST POINT	L	NOT RATED	06/23/2015	
LAKE GEORGENA	NY13198	WEST POINT	L	NOT RATED	06/23/2015	
MINE LAKE	NY00767	WEST POINT	L	NOT RATED	06/23/2015	
LOWER CRAGSTON LAKE	NY13539	WEST POINT	H	NOT RATED	06/23/2015	
WILKINS POND	NY10100	WEST POINT	L	NOT RATED	06/23/2015	
DELAFIELD POND	NY16206	WEST POINT	H	NOT RATED	06/23/2015	
MOLINE POWER	IL01089	ROCK ISLAND ARSENAL	L	NOT RATED	10/31/2012	
EAST SILVER	WI82307	FORT MCCOY	L	NOT RATED	06/26/2012	
WEST SILVER	WI82304	FORT MCCOY	L	NOT RATED	07/01/2012	
SQUAW LAKE	WI82302	FORT MCCOY	S	NOT RATED	06/28/2012	MEETS APPLICABLE TOLERABLE RISK CRITERIA

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14. ABSTRACT The Department of Defense (DoD) owns over 800 dams and levees. These structures have requirements that are distinct from other asset classes, including federally required periodic inspections by qualified inspectors. The DoD Inspector General has required DoD to implement an inspection policy for these types of structures. This report documents the DoD's current inventory, processes, and systems related to dams; defines inspection requirements consistent with U.S. Army Corps of Engineers and federal processes; and proposes a framework that could be used to include dams in the DoD's sustainment management system (SMS) that is used by all service components for conducting facility inspections and assessments. The report includes a dam inspection and SMS framework with requirements to support the inspection of dams by installation or contract engineers. The authors concluded that a data structure for dam inspections similar to the inventory catalogs of other SMS modules would assist DoD in re-reporting results of formal inspections, conducting intermediate and in-formal inspections, and providing assistance for future efforts to create condition forecasting and work planning models for dams. It is proposed that a working group be formed from members of the DoD services to elaborate on the proposed template and to formulate future requirements.					
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