

# Engineer Guidelines

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**Prepared and Distributed by:**

**Georgia Department of Natural Resources  
Environmental Protection Division  
Watershed Protection Branch  
Safe Dams Program**

## Preface

The Safe Dams Program developed the first set of engineering guidelines in 1998. The guidelines help the dam owner understand the permitting process. These guidelines also provide design engineers with a better understanding of the requirements for designing a Category I dam in Georgia.

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Environmental Protection Division  
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# GUIDELINES FOR PERMITTING A CATEGORY I DAM

## Introduction

These engineering guidelines have been prepared by the Georgia Safe Dams Program to provide guidance to the program staff and engineers involved in the design of dams in Georgia. The guidelines are intended to provide procedures and criteria for the engineering review and design of dams. Since each project requires site-specific considerations, these guidelines should not be viewed as a step-by-step manual on the design, permitting, repair and/or construction of a Category I dam project. The intent of this document is to outline the process required to obtain such a permit and to address general design criteria. By standardizing the permitting process, these guidelines should help reduce the time necessary for review and approval.

The guidelines cover the majority of situations that arise in the design and modification of dams. However, special cases may require deviation from the guidelines. When such cases arise, program staff and design engineers must determine the applicability of alternate criteria or procedures based upon their experience and must exercise sound engineering judgment. Potential deviations should be discussed with program staff as soon as possible. Since every dam is unique, technical judgment is required in all analytical studies.

These guidelines are not a substitute for good engineering judgment, nor are the procedures recommended herein intended to be applied rigidly in place of other appropriate analytical solutions to engineering problems. Program staff and design engineers should keep in mind that the engineering profession is not limited to a single solution to each problem and that effective and safe dams are the desired end.

## Overview of Guidelines

Included in these guidelines is an overview of the permitting process each dam owner will need to complete to take a project from the conceptual stage, through classification, exploration of environmental and cultural impacts, preliminary and final design, preparation of construction plans and specifications, dam construction, monitoring and maintenance of the completed project.

Subsequent sections of this document will address the technical guidelines the design consultant will need to consider in preparation of the permit submittal package and the general criteria expected for the construction documents and monitoring of the construction phase. While the information in these sections is fairly detailed, each project will require specific considerations and may result in additional requirements as deemed necessary by the owner, the design consultant or the permitting agency.

Information included:

Section 1.	Permitting Process
Section 2.	Dam Breach Modeling Protocol
Section 3.	Visual Inspection Reports
Section 4.	Geotechnical Evaluations
Section 5.	Hydrology and Hydraulics
Section 6.	Plans and Specifications
Section 7.	Construction Monitoring
Section 8.	Operation and Maintenance
Section 9.	Emergency Action Plans

# 1. PERMITTING PROCESS

## 1.1 Project Description and Dam Classification

### 1.1.1 Introduction

Anyone planning to construct or modify a dam in the State of Georgia should contact the SDP and provide a description of the proposed project. Engineers from the SDP will assist the project owner in determining if the proposed project will require a permit from the Environmental Protection Division (EPD). If a permit is required for the proposed project, it will be necessary for the project owner to obtain the services of a qualified design engineer and submit the design documentation to the SDP for review.

### 1.1.2 Project Description

In order for the SDP to perform a preliminary evaluation of the project, the owner must submit basic information about the project. The owner should contact the SDP for the appropriate form to submit this information. Specific information to be provided should include the following:

1.1.2.1 Ownership - The name, address and phone number of the owner(s) of the dam must be provided. If the dam will be operated by someone other than the owner, his or her name, address and phone number must also be submitted.

1.1.2.2 Location Map - This should be a copy of the appropriate 7.5 minute United States Geologic Survey (USGS) quadrangle map indicating the exact site location, or an aerial photograph or photos available from the internet.

1.1.2.3 Proposed Dam Section Geometry - Provide the proposed elevations (above mean sea level) of the top of dam and the normal pool of the impoundment. Also provide the vertical distance from the downstream toe of the dam to the top of dam (height of dam).

1.1.2.4 Impoundment Information - Provide the surface area of the proposed impoundment at both normal pool and top of dam elevations. Provide the volume of the proposed impoundment at both normal pool and top of dam elevations.

1.1.2.5 Downstream Information - The owner should describe any specific areas downstream of the proposed dam where someone might be flooded in case of a dam failure.

### 1.1.3 Dam Classification

The classification of a dam is determined by evaluating the potential for loss of life in case of improper operation or failure. Based on the potential for loss of life in the event of improper operation or failure, a dam is classified as Category I or Category II. If a structure is not 25 feet in height and the maximum storage volume is not

greater than 100 acre-feet, then it is exempt from regulation under the Georgia Safe Dams Act because it is not a dam by definition. Structures that exceed these values are classified as follows:

1.1.3.1 Category I - Improper operation or failure would result in a probable loss of human life. The GA Safe Dams Act (Act) requires permits for these projects.

1.1.3.2 Category II - Improper operation or failure would not be expected to result in a probable loss of human life. The Act does not require permits for these projects.

#### 1.1.4. Dam Subclassification

Category I dams must be designed to pass a specific design storm. The design storm to be used is based on the subclassification of the dam. The subclassification is determined based on the height of the dam and the volume of storage at maximum pool in the impoundment.

1.1.4.1 Small Dam - This is a dam that impounds more than 100 acre-feet but not more than 500 acre-feet and is not more than 25 feet in height. The design storm is 25% Probable Maximum Precipitation (PMP).

1.1.4.2 Medium Dam - This is a dam that impounds more than 500 acre-feet but not more than 1,000 acre-feet, or has a height exceeding 25 feet but not exceeding 35 feet. The design storm is 33.3% PMP.

1.1.4.3 Large Dam - This is a dam that impounds more than 1,000 acre-feet but not more than 50,000 acre-feet or has a height exceeding 35 feet but not exceeding 100 feet. The design storm is 50% PMP.

1.1.4.4 Very Large Dam - This is a dam that impounds more than 50,000 acre-feet or has a height exceeding 100 feet. The design storm is 100% PMP.

#### 1.1.5 Exemptions

The following structures are exempt from meeting the requirements of the Georgia Safe Dams Act:

1.1.5.1 Any dam owned and operated by the United States government.

1.1.5.2 Any dam that comes under the licensing authority of the Federal Energy Regulatory Commission.

1.1.5.3 Structures constructed as part of surface mining operations in accordance with a plan that has been approved by the Environmental Protection Division (EPD) pursuant to the Georgia Surface Mining Act.

1.1.5.4 Any structure that is not greater than six feet in height regardless of storage volume or any structure that impounds less than 15 acre-feet regardless of height.

1.1.5.5 Any structure that is not 25 feet in height and impounds less than 100 acre-feet.

1.1.5.6 Any Category II dam.

## **1.2 Engineer's Role**

The primary role of the qualified design engineer is to provide professional leadership in the planning, design, and construction of a dam. The engineer must clearly determine the owner's project objectives and thoroughly evaluate the proposed dam site to determine the site's potential for an effective design and construction of a dam. The engineer must ensure that all environmental concerns are appropriately addressed and required permits obtained in a timely manner. The design engineer must be involved in the construction of the dam to ensure that the dam is constructed in accordance with the approved design. Once the dam has been constructed, the engineer must certify in writing that the dam was constructed as designed. The engineer must have overall responsibility for the planning, design, and monitoring of construction of the dam.

1.2.1 The Rules for Dam Safety were modified in 1998 to include the definition of an Engineer of Record. The revised Rules became effective October 20, 1998. The definition of an "Engineer of Record" is as follows:

An individual who:

1. Is a licensed engineer registered with the State of Georgia; and
2. Is competent and has relevant experience in areas related to dam investigation, inspection, design, and construction for the type of dam being investigated, inspected, designed, or constructed; and
3. Understands adverse dam incidents, failures, and the potential causes and consequences of dam failures; and
4. Will have responsible charge for the design of a new Category I dam or repair of an existing Category I dam; and
5. Has substantiated their qualifications to the Georgia Safe Dams Program prior to their engagement by an Owner/Operator of an existing or proposed Category I dam.

A committee was then formed to develop parameters outlining the minimum criteria for adequate experience to be an Engineer of Record (EOR). It was determined that an individual should have at least seven years of experience working with dams that are at least 20 feet tall or store at least 50 acre-feet of water.

The Safe Dams Program will maintain a list of current Engineers of Record. The designation is broken down into two categories. Those are Geotechnical and Civil/Hydraulics and Hydrology. Any engineer wishing to become an Engineer of Record should contact the Safe Dams Program for information on the process.

Anyone building or rehabilitating a Category I dam will need an Engineer of Record on the design team. The Engineer of Record can either be the geotechnical engineer or the civil engineer, or both. The Engineer of Record should have responsible charge for the project.

The Engineer of Record designation is not a certification of the competence of the engineer. Owners are encouraged to seek information and proposals from at least three engineers to ensure they are retaining the best qualified engineer for their particular project. Owners should also ensure they are evaluating comparable proposals from the engineers.

### **1.3 Safe Dams Program's Role**

The Georgia Safe Dams Act of 1978 as amended requires the EPD to develop and maintain an inventory of dams, to classify them, and to ensure compliance on all regulated dams.

The SDP reviews proposed dams and classifies them based upon the potential hazard they pose. If a probable loss of life situation exists below a dam, the SDP classifies that dam as Category I (high hazard). The SDP reviews the flood plain below Category II (low hazard) dams at least once every five years. These periodic reviews are performed to determine if any structures have been built in the flood plain. The classification of a dam may change to Category I if a structure has been built in the breach zone.

The design of a Category I dam must meet certain criteria. The SDP reviews plans for construction or modification to ensure compliance with design standards, and monitors construction to confirm that Category I dams are built or modified according to the approved plans. The SDP also inspects existing dams to verify their condition and continued compliance with state laws, regulations, and policies. If a dam is not in compliance, the owner will be required to repair or modify the dam to bring it back into compliance. This often requires hiring an Engineer of Record to address the problems of non-compliance.

### **1.4 Owner's Role**

The owner of a dam also has certain responsibilities and liabilities. The owner must inspect and maintain the dam on a regular basis. Routine inspection and maintenance allows early detection of many problems that may occur with a dam. The owner should learn as much as possible about the operation of their dam.

### **1.5 Contractor's Role**

The contractor's primary role is to construct the dam and the appurtenant works in accordance with the plans, specifications, and instructions from the Engineer of Record. It is the contractor's responsibility to notify the engineer of any changes in the site conditions exposed during construction that vary from those shown on the drawings, in the specifications, or in any documents on site investigations. The contractor must also ensure the construction is conducted in a safe manner, that all local regulations are adhered to during construction and that the construction site is secure. The contractor is not responsible for the design or modifications to the design.

### **1.6 Enforcement Actions**

The EPD will require owner(s) of a dam not in compliance with the Safe Dams Act to bring their dam into compliance. Routine maintenance and compliance with the conditions of the permit are required.

Occasionally, an owner will not maintain their dam or will resist complying with the Safe Dams Act, Rules for Dam Safety and the permit conditions. The EPD has several mechanisms for bringing the dam into compliance. Consent Orders are the most commonly used method. This is essentially an agreed upon contract between the owner and the EPD that establishes deadlines, sets performance goals, sets a monetary settlement, etc.

An Administrative Order is pursued against those owners who refuse to comply with the Safe Dams Act and/or permit conditions. Fines of up to \$1000 per violation plus civil penalties up to \$500 for each day the violation continues can be assessed. Other enforcement actions are also possible.

## **1.7 Project Concept**

### **1.7.1 Preliminary Hydrology and Hydraulics Analysis**

After establishing a general concept of the proposed dam project, the dam owner will need to have the EOR perform calculations with regard to the project hydrology and hydraulics. These preliminary calculations will provide information necessary for the Safe Dams permitting process.

### **1.7.2 Preliminary Geotechnical Assistance**

Limited geotechnical engineering involvement early in the planning process for a dam project is considered beneficial. A brief reconnaissance can disclose a number of surface features that may provide indication of the subsurface conditions that exist at the site. These observations involve such items as the extent of alluvial depositions, topography, rock outcroppings, and vegetative cover. A desktop study to include at least the geology of the site may provide significant additional information. Depending on the complexity of the project, other desktop evaluation techniques may be considered. This information will assist the owner and the design engineer in establishing the best preliminary conceptual design for the project, and will provide valuable information concerning those areas where more detailed geotechnical evaluations should be concentrated.

### **1.7.3 Design Submittal Process**

#### **1.7.3.1 Predesign Meeting (Recommended)**

The design process begins with the predesign meeting where the design approach is discussed and important decisions are made regarding the design parameters to be used. During the meeting, any known unusual conditions or constraints should be discussed with the Safe Dams Program staff. The design team will provide minutes of the meeting to all in attendance.

#### **1.7.3.2 Submittal Meeting (Required)**

The design package is submitted to the Safe Dams Program at the submittal meeting where it is assigned to a reviewer who will perform the review. The package will be checked to determine if the submittal is complete. If the package is considered complete, the plan review should



be completed within 90 days. If the package is determined to be incomplete, the design engineer will be required to provide the missing items before the review process will begin and the plan review meeting scheduled. The 90-day time period shall not begin until the package is complete. In order for a package to be considered complete, it must include the following elements, if appropriate:

1. Visual Inspection Report
2. Geotechnical Report
3. Design Report including Hydrology & Hydraulic Calculations
4. Construction Drawings
5. Technical Specifications
6. Operation and Maintenance Plan
7. Emergency Action Plan

(Note: the required elements may vary based on agreements made at the predesign meeting.)

#### 1.7.3.3 Resubmittal

For those projects where the initial review results in more than minimal comments, a resubmittal of the design package will be required after the comments have been addressed by the EOR. The engineer will also include with the resubmittal the original comments from the initial review. The resubmittal must be made by the design engineer no more than 90 days after the plan review meeting or it will be considered a new submittal.

#### 1.7.3.4 Secondary Review

Once the design engineer has resubmitted the design package along with the initial comments, the SDP will review the resubmitted package within 30 days. The purpose of this review will be to verify that the initial comments have been appropriately addressed.

#### 1.7.3.5 Resubmittal Meeting

If the secondary review finds that the engineer has not addressed the comments or if the reviewer has comments on newly submitted material, a resubmittal meeting will be held within 21 days of the resubmittal. This meeting will be similar to the initial review meeting when either minor or significant comments are presented and discussed with the design team.

The process will continue by moving either to an approval meeting or requiring a resubmittal for further review.

#### 1.7.3.6 Approval Meeting

The approval meeting will be scheduled when the design engineer has addressed the “minor” comments resulting from the SDP review of the initial submittal. The SDP will verify that the comments have been addressed and approve/stamp the various items in the package and authorize the construction process to begin.

#### 1.7.4 Land Ownership

1.7.4.1 Introduction - The issue of land ownership varies greatly from project to project. However, in each case, the parties must verify ownership of the property where the proposed dam, spillway, downstream plunge pool, exit structures and/or miscellaneous monitoring devices are sited, and all associated property owners must be included in the permitting process. Owner(s) will be responsible for acquiring all associated permits, contracting of engineers, monitoring consultants, construction contractors and testing agencies, as well as the future operation and maintenance of the project.

1.7.4.2 Projects Contained on Multiple Tracts - In some cases, such as a subdivision development, the proposed dam and reservoir facilities could potentially fall on multiple tracts, creating more than one Owner. In this event, it is necessary for each Owner to obtain the required permits. Multiple owners most often combine efforts in planning, designing and constructing the proposed dam. Owners are jointly and severally liable for the long term operation, maintenance and liability of the project.

1.7.4.3 Projects Requiring Land Acquisition - In the case of a project such as a municipal water supply reservoir or other large reservoir, the proposed dam and reservoir limits may encroach upon multiple property owners. In this case, the developer or entity proposing the project may need to acquire the land containing the dam, spillway, reservoir at normal pool elevation, downstream plunge pool, exit structures, and/or all miscellaneous monitoring devices and structures associated with the construction and maintenance of the project.

1.7.4.4 Easements - It is possible, the Owner will need to purchase easements for areas upstream of the dam which are impacted by the normal pool elevation of the reservoir, and for the land upstream of the dam affected by the rise in water due to the 100 year flood event or other larger design storms up to and including top of dam elevation. Additional easements may need to be acquired for access to structures or specific shoreline features. It may also be necessary for the owner to grant easements through the dam and reservoir property to utility companies and/or other specific access requirements. Easement requirements are often governed by local, state or federal ordinances.

1.7.4.5 Wetlands - Should the proposed project impact or destroy areas which have been identified as wetlands, the Owner may be required by the United States Army Corps of Engineers (Corps) to acquire property

elsewhere to mitigate the loss of wetlands due to the construction of the proposed dam and reservoir. Owner should be aware that the destruction and mitigation of wetlands is an issue that can significantly impact the cost and time required to achieve permitting of a Category I dam. A detailed review of the wetland issue is not given in these guidelines, but should be investigated by the Owner prior to proceeding with extensive project design.

1.7.4.6 Summary - Although it is impossible to outline all potential land ownership issues in these guidelines, the Owner of the proposed dam project should prepare to address the issues discussed here, as well as any others resulting from the impact of the proposed project.

#### 1.7.5 Emergency Action Plans

1.7.5.1 An Emergency Action Plan (EAP) is a formal plan that identifies potential emergency conditions at a dam and outlines the procedures for the owner of the dam to follow to minimize property damage and loss of life and possibly save the dam.

1.7.5.2 An emergency is defined as a condition that develops unexpectedly, endangers the structural integrity of the dam and/or downstream property and human life, and requires immediate action.

1.7.5.3 An EAP is needed to preplan the coordination of necessary actions to be taken by the dam owner and local and state officials. This preplanning will help provide for timely notification, warning, and evacuation in the event of an emergency.

#### 1.7.6 Utility Coordination

1.7.6.1 Introduction - The Owner and/or their EOR must determine whether the proposed dam and reservoir project will impact the location or operation of any existing utilities. In the event that utilities are impacted, the Owner should contact the impacted utility company and determine the course of action required for the abandonment and/or relocation of the impacted utility. Costs related to utility relocation will vary from project to project and may be the responsibility of the Owner.

1.7.6.2 Impact on Existing Drainage Structures - In addition to utilities which may require relocation, the Owner and EOR should assess the impact of the project on the operation of existing storm drainage structures, and/or adjacent dam outflow structures that may be impacted by the increase in tailwater elevation due to the proposed project. Modifications to these structures may be necessary to assure proper function after the completion of the new dam and reservoir.

1.7.6.3 New Utilities - The Owner should assess the requirement for new utilities in the areas immediately surrounding the proposed dam and reservoir. These new utilities should be located with consideration of the desired function as well as of the limitations regarding placement of new

utilities within the dam embankment or the reservoir and flood plain limits.

1.7.6.4 Roadways - The Owner and EOR should assess the impact of the reservoir normal pool and flood elevations on existing and proposed roadways and bridges within the area. Should it be determined that a roadway is significantly impacted, the local, state, federal or private entity responsible for the roadway should be contacted regarding the possibility for abandonment, relocation and/or raising of the impacted roadway or bridge.

1.7.6.5 Summary - Although each project will encounter different utility issues, the Owner of the proposed project should assess the impact of the proposed project and address these issues in the early stages of design. This will help avoid major delays or problems after significant portions of the project design or construction have been finished.

## **2. DAM BREACH MODELING PROTOCOL**

### **2.1 Overview**

A dam is defined in O.C.G.A § 12-5-372 as being 25 feet or more in height from the natural bed of the stream downstream of the low point of the top of the dam, or having a maximum impounding capacity of 100 acre-feet or more. Dams are further broken down in O.C.G.A. § 12-5-375 as Category I (high hazard) and Category II (low hazard). Category I dams are defined as dams where improper operation or dam failure would result in probable loss of human life, while Category II dams would not be expected to cause probable loss of human life. Only one downstream hazard (one probable loss of life) need be identified in order to classify a dam as Category I. Potential hazards are considered to be any structure which, in the event of a dam failure, will have water adjacent to them.

Dam breach modeling is an engineering tool for characterizing and identifying threats to life and property posed by the catastrophic failure of a dam. Because of the degree of uncertainty and the magnitude of loss (life), it is incumbent that modeling decisions be conservative.

The two primary tasks in the analysis of a dam breach are the prediction of the reservoir outflow hydrograph and the routing of that hydrograph through the downstream valley. Predicting the outflow hydrograph can be further subdivided into predicting the breach characteristics and routing the reservoir storage and inflow through the breach. Many models do not directly simulate the breach; rather, the user determines the breach characteristics independently and provides that information as input to the routing model or the user prepares a hydrograph representing the outflow from the reservoir. There are several methods to determine breach parameters: comparative analysis of similar cases, predictor equations (empirical predictor and parametric), and physically-based breach development models (hydraulics and sediment transport). Once the flows are routed through the downstream valley, prediction of damage can be ascertained from the results.

Prior to 2015, the Georgia Safe Dams Program (SDP) required the use of the National Weather Service (NWS) DAMBRK model. DAMBRK is a DOS based system and is no longer supported by the NWS or by BOSS, Inc. which developed a shell to make the program more user friendly. Therefore, SDP no longer accepts use of NWS DAMBRK or BOSS DAMBRK.

### **2.2 Model Selection**

The SDP requires the use of the most recent fully released version of the US Army Corps of Engineers' HEC-RAS to perform dam breach analysis with an unsteady flow simulation. HEC-RAS is currently one of the most widely used models for dam breach analysis. The unsteady flow component of HEC-RAS can perform subcritical, supercritical or mixed-flow regime computations. The governing equations for unsteady flow are the conservation of mass (continuity) and momentum equations derived from the full equations of motion (St. Venant equations). For a dam breach analysis, the reservoir outflow is dynamically routed downstream. HEC-RAS is also able to interface with digital terrain data. A wide variety of federal agencies recommend HEC-RAS for detailed modeling. It is capable of considering downstream obstructions, including backwater, and allows dynamic reservoir routing. HEC-RAS is available for free and can be downloaded from the USACE website at <http://www.hec.usace.army.mil/software/hec-ras/downloads.aspx>.

Other models may be used with prior approval from the SDP if unique conditions can justify their use over HEC-RAS. In cases where potential hazards are in an unconfined floodplain, flood waves must be routed through an unconfined floodplain, or there are other conditions that are better served by use of a two-dimensional (2D) model such as overland urban flow or flat terrain, then a 2D modeling approach should be performed. 2D modeling must be used for ring dikes.

FEMA's GeoDam-BREACH or DHS's DSS-WISE are two simplified modeling programs that may also be used as a low cost screening tool. If a downstream hazard is found using these screening tools, then the dam may be classified as a Category I dam without additional modeling. However, if a downstream hazard is not found using these screening tools, a more rigorous model using one of the previously documented approaches must be used to determine the classification of the dam. If a 2D model is required to properly route the flood from a dam breach, then these simplified models are not appropriate and shall not be used.

### **2.3 Pre-Modeling Meeting**

Before performing a dam breach analysis to be submitted to the SDP, any outside entity shall schedule a pre-modeling meeting in order to verify SDP concurrence with the general modeling approach, as well as basic parameters such as storage volume, breach width, breach time, Manning's "n" values, modeling extents, etc. If there are reasons to locate the breach somewhere other than at the maximum section of the dam, that should also be discussed at the pre-modeling meeting. Additionally, it may be necessary to model the breach occurring at multiple locations along the length of the dam as well as at any saddle dikes.

### **2.4 Model Inputs**

The magnitude of flooding caused by a dam failure is affected by many factors. The most important are:

- The volume of water held behind the dam
- The height of water behind the dam
- The size of the breach created
- The time required for the breach to form
- Downstream reach characteristics

When evaluating dams for classification, the SDP assumes a non-hydrologic failure due to overtopping with the reservoir filled to the top of dam when the breach occurs. It is assumed that there are minimal inflows to the reservoir, that none of the spillways are functioning, and that the breach progresses to the downstream invert of the dam. Some of these parameters are physically measurable and involve minimal prediction. However, the breach width and breach formation time must be estimated and input in the breach model.

A set of equations to determine breach width and breach formation times for embankment dams was proposed by Dr. David Froehlich in his paper "Embankment Dam Breach Parameters and Their Uncertainties" which was published in the December 2008 edition of ASCE's *Journal of Hydraulic Engineering* (Froehlich (2008)). The SDP requires the use of the Froehlich (2008) equations for computing the average breach widths and times of embankment dams, but with a minimum average breach width of three (3) times the height of the dam, and a maximum breach time of a half (½) hour. These equations have been found to correlate well with breach widths for actual failures for every dam size, and they are widely used and respected in the engineering community. Side slopes for the breach shall be modeled as a 1:1 vertical:horizontal slope. For all

non-earth dams, dam breach parameters shall be determined based on the US Army Corps of Engineers Training Document 39, Using HEC-RAS for Dam Break Studies (USACE TD-39). Selected breach parameters shall be discussed at the pre-modeling meeting.

All bridges and culverts should follow USACE TD-39 and the HEC-RAS Manual. Additionally, any openings in all downstream bridges, culverts, or other structures must be modeled as fifty percent blocked at the time of breach. It is assumed that downstream bridges, culverts, and other structures will breach when overtopped to a depth of two feet. Base flows (or pilot flows) used shall also conform to these documents. Any departure from recommendations in these documents must be adequately detailed and justified.

All additional modeling inputs and parameters, such as cross-sections, Manning's "n" values, and other input variables shall conform to USACE TD-39, the USACE HEC-RAS User's Manual (HEC-RAS Manual), and general good engineering judgment. All model input variables must be sufficiently justified and documented.

Survey data shall be acquired in a method which best represents the topography and other features of the dam inundation zone. Field run survey of the dam, including the profile of the crest, dimensions of any open channel spillways, and downstream invert shall be provided. Additionally, field run survey of the finished floor elevation (FFE) and lowest adjacent grade (LAG) of all potential hazards shall be provided. All survey shall be performed in or converted to the appropriate zone of Georgia State Plane Coordinates.

## **2.5 Model Report**

Complete input and output, as well as any spreadsheets used, shall be provided both in hard copy and on CD or DVD. All files needed to run the model shall also be included on the CD or DVD. Thumb drives will not be accepted. Spreadsheets shall be submitted with cells unlocked. CDs or DVDs must be clearly labeled with the name of the dam, county, name of the software, and version. The hard copy should contain 10-point or larger font, with one page of input/output per printed page. The front cover of the report shall clearly identify the dam and owners' names, the county where the dam is located, and the date. The body of the report must be printed on 8½ by 11-inch white paper. Maps and drawings on 11 by 17-inch paper are acceptable if appropriately folded into the report. Larger drawings must be provided in a jacket at the end of the report and numbered with sequential plate numbers. Pages must be numbered sequentially. Tabs should readily locate major sections of the report, and are required for each appendix. An executive summary will be required at the beginning of the report for each analysis. It should include a description of the dam and pertinent points of interest including potential hazards, listing flood depths and destruction factors at each potential hazard. The report shall contain a complete description of the analysis including:

- Table of contents
- Executive summary
- Photographs of the dam and points of interest
- Survey information including source and accuracy
- Summary of modeling inputs
- Aerial photos of points of interest that may be available
- Flood crest profile plot
- Stage/flow hydrograph plots at all points of interest
- Potential hazard addresses and construction type (concrete block, timber frame, anchored or unanchored mobile home, etc.)
- Data on all downstream bridges, road crossings, and dams including profile, bridge/culvert opening dimensions, spillway data, etc.

For one-dimensional models, the following output shall be given for every cross-section which is located at a potential hazard or other critical location (channel expansion or contraction, bridge and road crossings, etc.):

- Standard cross-section output tables and plots
- Standard profile output table # 1 and plot
- Critical water surface elevation & depth
- Total flow rate
- Cumulative flow volume for the channel, left and right overbanks
- Maximum WSEL
- Channel invert
- Average velocity
- Velocity of the channel, left & right overbanks
- Energy grade slope
- Channel bed slope
- Maximum water surface elevation slope
- Summary of warnings and notes, if applicable
- Explanation of any warnings produced by the program

Topographic inundation maps shall be provided both as hard copy and Shapefile format. These maps shall be prepared on the most current aerial photography available, and shall include at a minimum the following information:

- Cross-section locations with bank point plots and river station (for one-dimensional models)
- Channel centerline (for one-dimensional models)
- Dam breach location
- Limits of inundation
- Potential hazards labeled with Address
- Distance downstream
- Depth of flooding above stream invert



- Depth of flooding above finished floor elevation
- Depth of flooding above lowest adjacent grade
- Maximum flow velocity
- Destruction factor
- Roadways and dams labeled with
- Name of the road or dam
- Distance downstream
- Depth of overtopping

## **2.6 Probable Loss of Life**

Dams in Georgia are regulated based on probable loss of life as determined by the Director of the Environmental Protection Division, Georgia Department of Natural Resources. Probable loss of life criteria is based on ACER Technical Memorandum No. 11 published by the U.S. Department of the Interior, Bureau of Reclamation (1988). Loss of life is considered probable by the SDP when any of the following conditions exist:

- A structure is flooded by 18 inches or more of water above FFE.
- A structure is flooded by 30 inches or more of water against the building at LAG.
- A structure is flooded such that the destruction factor (maximum velocity in feet per second x maximum depth in feet) is equal to or greater than 15.
- An unanchored mobile home is flooded such that the destruction factor is equal to or greater than 9.
- A structure which is flooded such that the destruction factor is 7 or greater shall be evaluated using engineering judgment to determine if other factors warrant a probable loss of life designation.

The SDP recommends classification of dams according to whether probable loss of life is present downstream. The number of lives endangered is not considered, only that there is probable loss of life. In doing this, the hope is to preserve all life at risk in the inundation zones below dams in Georgia.

## **2.7 Deviations from these Guidelines**

All deviations from these guidelines must be requested in writing including the deviation requested and supporting documentation for the deviation. Approval of deviations will be solely at the discretion of the SDP, and will only be approved in writing.

### 3. VISUAL INSPECTION REPORTS

#### 3.1 Introduction

The Georgia Safe Dams Act of 1978 as amended (the Act) requires EPD to ensure compliance on all regulated dams. Once EPD determines a dam is to be regulated (Category I), the dam must meet certain criteria, complying with design standards. For these newly-regulated *existing* dams, the owner must provide a condition assessment, comparing existing conditions to the Safe Dams Act and Rules for Dam Safety (the Rules). The report shall list the deficiencies that require repair or modification in order to bring the dam into compliance so that it may be permitted. Development of the report requires hiring an Engineer of Record (EOR). This compliance or condition assessment report is commonly known as the Visual Inspection Report (VIR).

#### 3.2 Legal Basis

Section 12-5-376(g) of the Act asserts that the owner of an existing dam must engage an engineer registered in the State of Georgia to submit a VIR. Further, the Rules for Dam Safety, 391-3-8-.08 (2) (b) states “When a visual inspection, performed by an engineer, reveals that abnormal stress exists or that the dam was not constructed in accordance with the requirements of the Act or these Rules, a detailed engineering survey meeting the requirements of this section shall be performed prior to final action on the permit application. Such visual inspection may be provided by the applicant, in accordance with Section 12-5-376(g) of the Act, or by the Division, or by another agency under contract with the Director on behalf of the Division.” As cited in the Act and Rules, the minimum information to be included in the VIR is:

- Regional vicinity map showing the location of the dam
- Historical plans, elevations, sections, as-built drawings, etc., if available
- Determination of height of dam
- Detailed description of spillways and low-level drain
- Description of instrumentation and internal drainage system
- Condition of the dam and appurtenant works, e.g. signs of structural deterioration, seepage, surface cracks, settlement, erosion

#### 3.3 Components of a VIR

The origin of the VIR is the U.S. Army Corps of Engineers’ National Inspection Program, authorized in 1978 partly in response to the 1977 Kelly Barnes Lake Dam failure in Georgia, which claimed 39 lives. The National Inspection Program included “Phase I reports” at non-federal dams across the United States. From 1978 to 1981, approximately 9,000 non-federal dams were inspected. The Georgia Safe Dams Program went on to adopt the Phase I format and termed it the “Visual Inspection Report.”

As cited in Section 3.2 above, the VIR is prepared under the guidelines contained in the Act and the Rules. The assessment of the condition of the dam is based upon available data and visual inspection. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational/hydrologic and hydraulic evaluations are beyond the scope of this investigation; however, this investigation is intended to identify the need for such studies. It should be realized that the reported condition of the dam is based on observations of field conditions at the time of the inspection along with data available to the inspection team. Likewise, the condition of the dam

depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. Similar to the Phase I format, the VIR should contain the following:

- Basic Dam Information - state and national ID numbers, engineer's inspection date, location of dam, ownership information, height of dam, inspection summary
- Visual Inspection - details and conditions of impoundment, embankment, crest, slopes, principal and emergency spillways, low-level drain, internal drainage system, downstream channel
- History and Classification - date built, who designed it, who built it, regulatory history, history of dam modifications, downstream damage potential
- Visual Assessment - stability, spillway capacity, emergency spillway activation
- Compliance - urgency, standards/law violations
- Appendices - photographs, figures, maps, correspondence, as-built drawings

### **3.4 Submitting to Georgia Safe Dams Program**

Dams reclassified as Category I dams must have a VIR. A complete permit application shall include the VIR, either as a standalone document or incorporated into the design report. The complete requirements for a permit application can be found in Section 1 of this document. It may be beneficial to have a preliminary review of the VIR prior to final development of the design documents. EPD is willing to review the VIR prior to complete permit application submittal, if requested.

## 4. GEOTECHNICAL EVALUATIONS

### 4.1 Introduction

The geotechnical design study guidelines that follow are predicated on a “typical” project, generally involving a small or medium size Category I dam in the Piedmont Geology. It should be understood that each and every dam project is unique relative to geotechnical considerations, and the geotechnical guidelines should be modified accordingly. Structures in differing geologies, such as solutioned limestone or Coastal Plain sediments may require significantly more extensive geotechnical studies. In addition, larger dams and dams with very long crest lengths may necessitate additional geotechnical investigations. These guidelines are not intended to provide a cookbook approach. Instead, they are intended to provide a general checklist to remind the geotechnical consultant that the SDP considers a thorough geotechnical evaluation appropriate, particularly for new Category I structures, or existing Category I dams requiring modification.

Geotechnical evaluations for rehabilitation projects should consider the seriousness of the deficiency. For major rehabilitation projects such as breached dams, excessively steep slopes, extensive seepage related problems, etc., the geotechnical evaluations should essentially be the same as that utilized for a new dam. The evaluation should be modified, as necessary, to target the major deficiency(s) identified. Limited geotechnical evaluations are typically acceptable for minor rehabilitation projects such as minor seepage, unsuitable vegetation and minor slope reconfiguration.

### 4.2 Literature Review

To aid in planning the geotechnical evaluation, and to provide additional information for evaluating the findings of the study, available information contained in the literature should be reviewed.

#### 4.2.1 Geologic Maps

As a minimum, state geologic mapping will provide an indication of the geologic setting of the site. Local detailed mapping may be available in certain areas.

#### 4.2.2 Soil Surveys

Most Georgia counties have existing soil surveys that contain information on the near surface materials. These may be particularly useful in identifying flood plain materials and potential borrow sources.

#### 4.2.3 USGS Quadrangle Maps

These maps show topography, land use, most dams, and lakes.

#### 4.2.4 Other Sources

For specific projects, the study of aerial photographs, low flow studies of streams, and groundwater resource studies may be useful. These are particularly of interest in karst areas.

### 4.3 Subsurface Exploration

The scope of the subsurface exploration for new Category I dams, and existing dams with major deficiencies would be similar. Some modifications to the following descriptions, which are primarily targeted for a new

dam would be necessary relative to such items as the practical location of borings and the type of sampling and testing to be performed.

#### 4.3.1 Soil Test Borings

Soil test borings should be provided within the footprint of the dam and associated structures. Boring locations on existing dams should target the specific deficiencies identified and consider practical locations for performing borings. No borings may be necessary for relatively minor deficiencies if sufficient documentation concerning the design and construction of the dam is available. Otherwise, a minimum of three soil test borings drilled along the crest of the dam is considered appropriate.

4.3.1.1 Dam Centerline - Soil test borings along the centerline of the dam should be at a maximum spacing of approximately 100 feet, with a minimum of three borings for dams with a short crest length.

4.3.1.2 Embankment Toe - Borings at the upstream and downstream toe should be considered for most dams.

4.3.1.3 Conduit, Drain and Saddle Dam - Additional borings should be placed as needed to identify subsurface conditions within these specific areas.

4.3.1.4 Channel Spillways - Channel type spillways in the abutment area should be evaluated with borings, if a significant depth of excavation is anticipated. These borings should at least penetrate the depths of excavation and identify the properties of materials at the base of the channel.

4.3.1.5 Depths and Samples - Boring depths within the embankment footprint area, should generally mirror the height of the embankment above each individual boring, with a minimum depth of 15 feet or until refusal. Disturbed samples obtained in conjunction with Standard Penetration Resistance testing, or other suitable methods, should be made on maximum five-foot centers.

#### 4.3.2 Test Pits

Shallow test pits excavated with a backhoe can provide more useful information in certain portions of the site. The excavations allow a more thorough assessment of the upper stratigraphy, and can provide indications of potential difficulties that may be encountered during construction.

4.3.2.1 Flood plain - Soil test borings alone often do not clearly represent the conditions encountered within flood plain areas. Alluvial deposition is typically complex. Test pits can provide an indication of the variations, depths of organic material, and difficulties that may be encountered relative to groundwater inflow.

4.3.2.2 Shallow Rock - Test pits may be used to supplement the evaluation of general areas where shallow rock is encountered. This helps discern if the refusal materials are fairly continuous rock, and whether the rock surface is uniform. This may be particularly useful in karst geology.

4.3.2.3 Channel Spillways - Test pits may be an inexpensive first step of evaluating areas where the depths of excavation anticipated for channel spillways are minimal.

### 4.3.3 Rock Coring

Some rock coring should be performed within the footprint area of the dam and spillway if refusal is encountered at depths less than about half the originally planned boring depth, with appropriate consideration of the geology of the site.

4.3.3.1 Depths - The amount of rock core to be obtained in each hole depends on a number of factors including the size of the dam, geologic setting, and rock quality. A minimum of 10 feet of rock should be cored at each location.

4.3.3.2 Packer Tests - Packer permeability tests should be made where rock coring is performed, to determine the water transmissivity characteristics of the upper rock.

### 4.3.4 Monitoring Wells

Monitoring wells may serve more than one purpose. Refer to the section on in-situ testing for permeability tests.

4.3.4.1 New Dams - Wells may be necessary to establish the general stabilized groundwater conditions within the footprint area of the dam.

4.3.4.2 Existing Dams - Some monitoring wells on existing dams may be utilized if the lake is still impounded. This is particularly useful in assessing seepage related deficiencies. Strategically placed wells can assist in establishing the phreatic surface through an existing dam.

### 4.3.5 Test Samples

4.3.5.1 Undisturbed Samples - A sufficient number of relatively undisturbed samples should be obtained for the representative foundation materials. Sufficient samples are needed to accurately characterize all of the differing types of materials present that are able to be evaluated. This will be helpful in determining what materials that may be left in place to support the dam embankment.

4.3.5.2 Bulk Samples - Disturbed bulk samples from test pits or auger cuttings should be collected, particularly for explorations made in channel type spillway areas and borings performed through existing dams.

### 4.3.6 Other Exploration Techniques

Several other exploration techniques may be considered in special situations. These are atypical, and would relate to specific projects and areas of concern. Examples include dilatometer, pressuremeter, or cone penetrometer soundings, particularly in soft foundation materials that may be considered for support of the dam. Geophysical exploration techniques may also be appropriate in some instances.

## 4.4 **Borrow Study**

The ultimate purpose of a borrow evaluation is to identify sufficient quantities of acceptable borrow materials that can be used in the construction of the dam embankment. This can only be accomplished if

adequate explorations and laboratory analyses are completed to determine the soil profiles in the borrow areas.

#### 4.4.1 Locations

It is regarded as generally good practice to limit the location of borrow areas so that excavation below pool level does not take place within 200 feet of the dam's footprint. The exploration should start at the dam site and extend outward in all directions to avoid overlooking nearby areas of borrow material.

4.4.1.1 Channel Spillways - For projects involving the excavation of channel spillways in the abutment areas, it is normally intended that these materials will be utilized in the construction of the dam. The exploration techniques described in Section 4.3.1.4 and 4.3.2.3 are applicable.

#### 4.4.2 Exploration Techniques

The exploration must be sufficient to characterize the formation(s), both from a geological and engineering perspective. The study should demonstrate homogeneity relative to the formation(s) under consideration. Exploratory holes should be placed at maximum 500 foot centers on a rough grid system at all practical locations.

4.4.2.1 Test Pits -Test pits are the preferred exploration technique for the evaluation of borrow sources where the potential depths of excavation are limited, or where the occurrence of suitable material is limited to near surface materials. Soil stratigraphy can be determined in more detail, and variability and the inclusion of unsuitable materials may be more readily observed with test pits. Discreet sampling of specific layers of the stratigraphy, or combined samples of the vertical profile can easily be obtained by this technique.

4.4.2.2 Borings - Soil test borings or auger borings are typically required where greater excavation depths are planned/possible.

#### 4.4.3 Sampling

Small grab samples of the materials penetrated are useful for general classification purposes. Sealed samples of this type can be used to determine in-situ moisture contents. Bulk samples are required on all representative materials to provide materials for laboratory testing. Sufficient quantities of bulk material should be obtained based on the types of tests to be performed.

### 4.5 **In-Situ/Field Testing**

In-situ testing, or field testing, may be considered in the evaluation of foundation conditions for proposed Category I dams and in the evaluation of conditions within and beneath existing Category I dams. Typical conditions that may warrant in-situ testing include soft compressible foundation materials that cannot be sampled routinely for laboratory testing, evaluation of seepage through foundations and existing embankments, evaluation of the continuity and integrity of foundation rock, and the determination of excavation quantities and methods.

The utilization of any of these test methods will depend on the size and length of the dam, the type and extent of foundation materials encountered, and the economic feasibility of a particular method over another.

These methods may be used to supplement more common exploration techniques such as soil test borings. Some geologic formations may necessitate the use of one or more of these methods.

#### 4.5.1 Site Reconnaissance

A thorough field reconnaissance of the entire dam site and adjacent areas by geotechnical engineers and/or geologists are considered mandatory for any dam evaluation. Typically, a reconnaissance is performed prior to implementing the field exploration to determine the best methods to employ. Additional site reconnaissance may be in order during or after the field exploration to help with the interpretation of the data being obtained. Vegetative cover, rock outcroppings, and small topographic features that may not be discerned from the site topographic survey may also provide useful input. The primary emphasis of the site reconnaissance should be within the embankment footprint and areas immediately upstream and downstream. These would include the flood plain area, abutment areas, and any potential channel type spillway alignments within the abutments or areas removed from the dam site. In certain instances, the reconnaissance may include much of the reservoir footprint as well. Potential borrow sources should also be observed.

#### 4.5.2 Geologic Mapping

Site specific geologic mapping may be warranted in some instances. This would be particularly applicable to larger dams, and those located in certain geologies. The applicability of such a method is directly related to the amount of rock outcropping that may be identified during the general site reconnaissance. In the absence of outcroppings, geologic mapping may be of limited use. Where shallow rock exists, that is not otherwise exposed, test trenches may be appropriate to expose these materials for direct observation.

#### 4.5.3 Field Permeability Tests

Field permeability tests are generally considered to be more representative of the hydraulic conductivity of foundation materials and existing embankment materials than are laboratory permeability tests. The field testing techniques may be the only practical means of establishing foundation permeability for certain material types.

4.5.3.1 Foundation Soil - The in-situ permeability of potential foundation materials may be determined by performing field permeability tests. Selected zones of the foundation profile including alluvial materials which may be allowed to remain in place, residual foundation soils, and partially weathered rock are conducive to this technique. The monitoring wells that may have been installed to better establish the ambient groundwater conditions typically can be used for the field permeability test. Bailing or slug tests are typical. Pumping tests or inflow tests may be appropriate where higher permeabilities exist. Monitoring wells should be carefully constructed to assure that the zone of material desired for testing has been isolated within the screened section of the well by appropriate seals such as bentonite and grout. The field testing technique is generally considered to provide the horizontal permeability values directly, without the need for adjusting vertical laboratory permeability test results. In addition, a broader cross-section of the subsurface profile can be tested by this technique. Care should be exercised in higher permeability situations to assure that the values being measured do not represent the actual well materials involved in the well construction. These field techniques are typically only applicable to zones of material below existing groundwater levels. Therefore, laboratory testing techniques are generally required for materials above the groundwater level so that saturation of the material can be established prior to testing.



4.5.3.2 Existing Embankment Fill Materials - Similar techniques as utilized for the foundation soils can be considered for determining permeability values of existing dam embankment fill materials. This procedure is generally only applicable to the materials that exist below the currently established phreatic surface through the dam. Therefore, the existing reservoir would need to be impounded at the time of testing. This technique is not applicable where the lake has been temporarily drained.

4.5.3.3 Foundation Rock - Packer permeability tests are typically performed to determine the hydraulic conductivity of foundation rock. Either single or double packers are commonly employed to help isolate specific zones within the foundation rock profile. In most instances, the hydraulic conductivity of the material is controlled by fractures and discontinuities within the rock. However, the test results are commonly expressed as an equivalent permeability over the length of the test section. Relatively short test sections may be employed to help isolate higher permeability zones. As with the monitoring well type permeability tests, care should be exercised to assure that the hydraulic conductivity values being determined do not represent the hydraulic limitations of the packer test equipment.

#### 4.5.4 Other Field Tests

4.5.4.1 Strength Testing - Various field testing techniques may be considered where soft or lower consistency foundation materials exist that cannot be accurately modeled by Standard Penetration Testing or undisturbed sampling. The vane shear test is commonly employed in very soft cohesive deposits. Pressure-meter or dilatometer testing may be considered for a broad range of material types and consistencies. Cone penetrometer soundings may also be considered. To some extent, these field testing techniques have evolved as preferable in certain locations and certain geologic settings. These techniques normally would only be considered where direct support of a new embankment on very weak materials is being considered, or to supplement laboratory testing in materials that are difficult to sample.

4.5.4.2 Geophysical Methods - A variety of geophysical testing techniques are available and may be considered in certain applications. These approaches would typically be applicable to a very limited number of dam projects due to the specialized nature. The most common technique is the shallow seismic refraction survey which can be useful in profiling difficult excavation materials. The seismic refraction survey would likely have most applicability in a dam study to generally screen potential borrow areas, since this technique can be negatively impacted by existing groundwater conditions. This typically provides a relatively low cost and expedient technique that generally does not require an invasive approach similar to test pits or borings.

4.5.4.3 Other Tests - Other field testing techniques may be considered for certain specialized applications. One possible test that would fit into this category would be tracer dye testing. This is used principally to determine the flow direction and rate of flow in karst geology.

## 4.6 **Laboratory Testing**

The laboratory testing program should generally include a determination of shear strength parameters, permeability, and compressibility properties of soils. Appropriate in-situ tests may be considered for these

parameters relative to the foundation materials. However, laboratory testing on remolded samples of potential embankment materials is required. A relatively extensive testing program is needed to characterize all of the various material types included in the foundation and the embankment. A minimum of two tests of each type for each material identified should be performed. It is considered inappropriate to perform a single test on any significant material type since this test may not represent the typical value of the material being tested.

#### 4.6.1 Characterization Testing

Testing should be performed to provide indicator tests for use in evaluating materials during construction. These tests also provide identification of the major different types of materials involved so that more extensive testing can be targeted to specific material groups.

4.6.1.1 Classification Tests - General classification tests, typically suitable for classifying soils by the Unified Soil Classification System (USCS) would include gradation tests (sieve and hydrometer, as required) and Atterberg limits tests.

4.6.1.2 Compaction Tests - Proctor compaction tests, and associated natural moisture content tests are needed for remolded materials to establish the basis for the density requirements for additional testing. Standard Proctor compaction tests are typically utilized.

#### 4.6.2 Strength Testing

Strength parameters are required for the stability evaluation of both new and existing dams. Tests would typically be performed on relatively undisturbed samples of foundation materials, and existing embankment materials. Remolded samples of potential borrow materials are typically utilized for new embankments.

4.6.2.1 Triaxial Shear - Laboratory strength parameters are typically evaluated through saturated consolidated undrained triaxial shear strength tests with pore pressure measurements. These provide both total and effective strength parameters.

4.6.2.2 Direct Shear - Direct shear tests may be considered in certain instances. However, these tests are becoming less common for use in earth dam stability evaluations.

#### 4.6.3 Consolidation Testing

An adequate number of consolidation tests on undisturbed samples from the foundation of the dam is required to establish the settlement characteristics. Consolidation tests should also be performed on samples from proposed borrow areas that are remolded to provide reliable settlement and deformation data on each soil type proposed for the embankment.

#### 4.6.4 Permeability Testing

An appropriate number of permeability tests must be performed on undisturbed samples from the foundation of new and existing dams and from the embankment materials within existing dams where seepage related concerns are to be addressed. In addition, remolded samples of proposed borrow materials for new embankment construction will also require permeability testing. These tests are typically performed on saturated samples and would establish hydraulic conductivity characteristics of the various soil types involved. Both falling and constant head tests can be considered.

#### 4.6.5 Dispersion Testing

Currently SDP requires some type of test to evaluate the soil's dispersion potential.

4.6.5.1 Crumb Test - The relatively simple crumb indicator test may be considered in instances where dispersive soils are unlikely.

4.6.5.2 Pinhole Dispersion Test - The more widely accepted pinhole dispersion test may be required, particularly in geologic formations that include materials that have the potential for dispersion.

### 4.7 **Geotechnical Engineering Analyses**

After initial review of published geologic, soil, and topographic data, site reconnaissance and preliminary subsurface exploration appropriate to the project size and scope, the type of dam and proposed cross-section should be selected. At this time, the detailed subsurface exploration and analysis program should be formulated. The type and quantity of required data, field and laboratory test methods, and types and numbers of analyses and trial sections depend on the hazard category and proposed project function. The intent of the geotechnical design should be to produce a safe and satisfactorily functioning structure at the lowest feasible cost.

The geotechnical design should include:

- A. Provisions for monitoring and maintenance to assure satisfactory performance throughout its design life.
- B. Stability of the structure both during construction and subsequent operation.
- C. Maintenance of stability and function during and after seismic events.
- D. Ability to experience minor consolidation settlements without adversely affecting the appurtenant structures.
- E. Monitoring, collection, and control of seepage through earth embankments, foundations, and the abutments.

#### 4.7.1 Stability Analysis

The purpose of a slope stability analysis is to determine a factor of safety defined as the ratio of resisting forces (gravity forces and soil shear strength) to driving forces (gravity forces and other shear stresses) along a line of equilibrium which defines the potential failure surface. The factors of safety must conform to the minimum requirements of the most recent edition of the Georgia Safe Dams Act and Rules for Dam Safety as amended.

The primary purpose of the stability analysis is to determine if the design configuration will remain stable under various loading conditions. These include the end-of-construction condition as well as during embankment fill construction which depends on the construction schedule and external loading. The end of construction condition is typically only of concern relative to rapid fill placement on very soft foundations. The steady state stability of the downstream slope must be analyzed with the reservoir at normal pool elevation after development of the steady state phreatic

surface. In addition to the end-of-construction and steady state seepage conditions, the stability of the upstream slope under rapid drawdown conditions must be analyzed. In limited instances, rapid drawdown due to submergence of the downstream toe may be a consideration. After the stability under these loading conditions is developed for static loading, the seismic stability analysis should be performed for the downstream slope.

For the end-of-construction conditions, the shear strengths of the foundation and dam fill must be evaluated. Total stress conditions may exist where the fill is placed rapidly upon foundation materials which may develop excess pore pressures. Where the foundation materials are very fine grained and the build-up of excess pore pressure could be detrimental, such pressure should be monitored during construction. For the dam embankment itself, the undrained conditions should be modeled.

For steady state conditions, the model should assume that the phreatic surface has been developed. The phreatic surface will begin at the "normal" pool elevation of the upstream face and extend to the internal drainage system, as determined through use of constructed flow nets or finite element seepage analysis. Effective drained strength parameters should be used during this phase of the analysis.

Rapid drawdown could occur if there is a release of the impoundment waters at a rapid enough rate to prevent dissipation of the pore pressures at the upstream face of the dam. Excess pore pressures may result and may cause an upstream slope failure which could ultimately lead to the breaching of the dam.

After completion of the static analyses, the loading considerations should be analyzed considering the appropriate seismic ground acceleration forces. Typically a pseudo-static analysis of only the downstream slope at steady state seepage conditions is performed. Stability analysis for earth embankments should consider both slip circle methods such as Bishop's, Spencer's, Morganstern-Price, Janbu's, etc. or, when appropriate, sliding wedge analyses. There are numerous available computer programs which are accepted by governing authorities for performance of such analyses. The designer must also use an independent verification method to determine that the computer stability analyses are correct.

#### 4.7.2 Seepage Analysis

Water will seep through all earth embankments over a period of time. Therefore, it is imperative that this seepage be recognized, monitored, and controlled. Seepage analyses should be performed to assess the effectiveness of available seepage control options, provide quantitative data for the design of seepage control structures, and predict seepage behavior of the dam embankment and its foundation. The analyses can also provide information for locating piezometers for use in monitoring seepage through the completed dam embankment and foundation.

Upon development of the phreatic surface, the permeability of the embankment and foundation materials determines flow rates and quantities as well as any seepage reduction and seepage collection techniques needed. Steady state flow, the hydraulic gradient and possible exit gradients and their long-term effects on embankment performance are of particular interest. Seepage reduction techniques such as cut-off keyways, slurry walls, and clayey core zones should be considered. The seepage analysis can also be used in selecting the most effective type of internal drainage system for the dam and foundation.

Permeability data should be obtained from appropriate laboratory and field tests. The seepage analysis should be performed upon completion of the field and laboratory testing and checked for the proposed dam cross-section. Either a graphical flow net analysis or a more sophisticated numerical finite element model can be used.

Analytical models will aid the designer in determining critical areas within the overall system. These include areas of excessive pore pressure and high gradients. The analyses should consider the proposed drainage system to permit accurate modeling of the phreatic surface, and exit gradients or uplift potential at the dam's toe, etc. Such analyses will also aid in determining if extraordinary precautions such as relief wells will be required in the final design.

It is imperative that the design engineer be aware of the implications of the analyses and should perform an independent check of any computer calculations to verify that the results are reasonable and within tolerable limits for the structure.

#### 4.7.3 Settlement Analysis

Both the new dam embankment and the foundation soils will consolidate beneath the weight of superimposed embankment materials. The amount and rate of settlement will depend on the consolidation characteristics of the underlying soils and the rate of pore pressure dissipation. Consolidation and resulting settlement of the embankments can result in sagging of the dam crest as well as differential settlement along conduits which penetrate the dam. Excessive settlement can cause misalignment of conduits, separation of joints, and possible conduit failure which results in leaking and possible soil piping (internal erosion of embankment soils). Therefore, it is imperative that settlement be analyzed to determine foundation treatment, camber, etc. for the embankment and appurtenant structures. Laboratory consolidation tests should be performed to determine the compression and drainage characteristics of the embankment materials. The engineer should perform a one-dimensional settlement analysis which considers the variable loadings across the dam footprint to determine areas of critical movement. Differential settlement should be considered relative to potential cracking of the embankment and the need for chimney drains, settlement accommodation along conduits, and the associated joint extensibility for any jointed conduits. The effects of the calculated vertical movements on both the embankment and the appurtenant structures must be carefully considered in the design.

## 4.8 Instrumentation

Various instrumentation devices are typically required in conjunction with new dams, and may be necessary on existing dam rehabilitation projects. Instrumentation can be installed both to monitor the performance of specific factors during construction and after completion of construction, particularly during initial reservoir filling. Foundation performance may be monitored with piezometers and settlement devices. Embankment performance may be monitored through devices to measure piezometric levels, settlement, and seepage quantities. Other less common instrumentation may be considered for unusual conditions. Any instrumentation selected should target specific items to be evaluated, establish critical thresholds that suggest the need for a specific action, and establish the details of the monitoring program. Monitoring requirements are established later in these guidelines under Section 5.

#### 4.8.1 Piezometric Levels

The monitoring of Piezometric levels may be an important consideration for specific zones within the foundation of a dam during construction and fill placement, and to evaluate the development of the phreatic surface within the embankment during and subsequent to initial reservoir filling.

- 4.8.1.1 Locations - Piezometric levels may require monitoring within specific zones of embankment foundations, particularly where extensive low consistency fine grained materials exist or where there are concerns over the development of high pore pressures during embankment construction (end-of-construction stability). In such instances, the monitoring device will typically measure piezometric levels at specific locations. It is typically desirable to measure piezometric levels within the completed embankment as the reservoir fills and steady-state seepage conditions develop. Devices for this purpose typically require a broad vertical zone be monitored as the piezometric levels rise within the embankment. Piezometer locations in the foundation would typically be concentrated in the flood plain portion of the embankment footprint. Piezometric levels within the embankment will typically require devices placed at both edges of the crest, at or slightly beyond the downstream toe of the dam, and potentially within the downstream slope, particularly if berms are utilized on taller structures. These devices should be aligned to allow the phreatic surface development to be plotted. Multiple stations of such instrumentation may be needed on longer embankments.
- 4.8.1.2 Observation Wells - Observation wells and open top piezometers may be considered for many applications. These are typically well suited to monitoring the performance of foundations outside the embankment footprint during construction and within the embankment during initial reservoir filling. Short screened sections are typically utilized for foundation monitoring. Longer screened sections are typically utilized to monitor the unconfined phreatic surface within the embankment during initial filling. The observation wells are typically installed within the embankment after the fill is topped out.
- 4.8.1.3 Remote Reading Piezometers - These types of piezometers are well suited to monitoring foundation conditions during and subsequent to construction. Both pneumatic and electric vibrating wire type piezometers have been utilized for this purpose. They may be installed in the foundation of a dam prior to embankment construction, with tubing and wires placed in a manner that does not obstruct the subsequent construction. Remote readout locations outside the embankment footprint are typically utilized. These may not be as reliable.

## 4.8.2 Settlement

The settlement performance of a dam and foundation is typically a consideration during and immediately following embankment construction. A typical scenario is a relatively thick compressible zone in the foundation of the proposed dam and settlement estimates performed during design indicate that significant settlements may occur.

- 4.8.2.1 Location - The settlement devices should target more compressible foundation zones, particularly in the vicinity of structures such as conduits. This would normally dictate a location within the flood plain area of the dam footprint. The settlement devices are often concentrated along the centerline; however, they may be placed in other areas.
- 4.8.2.2 Settlement Plates - Conventional settlement plates with riser pipes are the simplest form of settlement monitoring device for the foundation. These are generally placed after foundation preparation is completed and immediately prior to commencement of embankment construction. Accurate elevations are obtained periodically during construction. These elevations should be referenced to the project datum. Additional



readings are required immediately prior to and subsequent to adding additional sections of riser rod. These devices will create an obstruction to the earthmoving equipment during construction so care should be taken to protect them.

4.8.2.3 Remote Reading Settlement Transducers - Both pneumatic and electric vibrating wire settlement transducers may be considered. These are typically placed at strategic locations with the cables and tubing routed outside the embankment footprint to a stationary readout location. Such devices lessen the obstructions that exist during earthwork. They may not be as reliable.

4.8.2.4 Surface Monuments - Surface monitoring points for settlement measurement should be installed immediately after topping out the embankment. These would be placed along the crest of the dam, and should be adequately protected.

#### 4.8.3 Seepage

The monitoring of seepage quantities during initial reservoir filling, and throughout the subsequent life of the structure, provides useful information on the performance of the dam. This monitoring is typically facilitated by measuring the outflows from internal drainage system components.

4.8.3.1 Piped Outlets - Piped internal drainage system components are common. The outlet location should be protected through the use of headwalls, rip-rap, etc. The exposed portions of the piping system should be durable, and include animal guards. Pipes should be placed to allow routine measurement of flow. This typically requires that the invert of the pipe be placed at least a foot above the local subgrade level.

4.8.3.2 Relief Wells - Relief wells into the foundation are utilized on certain projects, particularly for gravity dams. These should be placed to allow for easy monitoring of the outflows and such that they are protected from damage.

4.8.3.3 Weirs - Seepage monitoring weirs may be considered in applications where seepage outflows exit from non-point sources, such as rock toe drains. The collected seepage should be routed into a small pool upstream of the wier, and sufficient fall should be provided to allow the V-notch weir to perform as intended. Staff gauges are typically required to determine the level of the water in the pool upstream of the weir in conjunction with seepage quantity calculations.

#### 4.8.4 Other Instrumentation

Additional types of instrumentation may be considered in certain special applications. The engineer should determine if specific project requirements dictate the need for specialized instrumentation.

4.8.4.1 Inclinerometers - These devices may be installed in situations where measurement of horizontal movements is required. A fairly common application would be on an existing dam where concerns exist over slope instability.

4.8.4.2 Crack Monitoring – Crack monitoring devices may be needed on appurtenant structures, or to evaluate movements across discontinuities of concrete gravity dam sections.

## **4.9 Geotechnical Report**

Once the field exploration, laboratory testing program, and geotechnical analyses have been completed, a final report outlining these items as well as the geotechnical aspects of construction should be prepared. A wide range of format approaches to the report are possible. However, the following items should generally be included.

### 4.9.1 Introduction

This would include a general statement of the purpose of the geotechnical study.

### 4.9.2 Project Information

A relatively detailed description of the project being evaluated should be documented as part of the report. This is particularly useful should the design change significantly from the time the geotechnical study has been performed to the completion of the design documents.

### 4.9.3 Exploration Procedures

This section would include a description of the field and laboratory testing procedures utilized in the study.

### 4.9.4 Site Description

A brief description of the surface features of the project area. This would generally include the project location, surface topography, vegetative cover, and identifiable surface features. This would in essence be the content of the site reconnaissance observations.

### 4.9.5 Subsurface Conditions

A brief summary of the subsurface conditions identified by the field exploration program should be included. This would generally identify the major types of materials penetrated and any correlations between borings that can be derived from the data obtained. This section of the report would also identify information gleaned from the desktop study and/or field mapping of geologic conditions. The intent of this section would be to relate the identified subsurface conditions to the known geologic conditions in the site area, and set the stage for addressing the handling of any special or unusual conditions in the conclusions and recommendations section(s) of the report.

### 4.9.6 Findings

This section would generally summarize the results of the geotechnical study that are not identified in other sections of the report. For example, information concerning the results of the stability, seepage, and settlement evaluations would be presented. These may be intertwined with other sections of the report and may not necessarily be placed in a separate section concerning the findings. By summarizing the evaluations performed, the basis for the design and construction conclusions and recommendations are established.



#### 4.9.7 Conclusions and Recommendations

This section of the report is the most critical and should identify all of the geotechnically related design and construction items that will impact, and be incorporated into, the design contract documents. Design and construction related conclusions and recommendations may be separated or combined. Any areas of uncertainty, such as items that can only be resolved by further evaluation during the actual construction process, should be clearly identified in this section. The following is presented as a general guideline for the items that would be addressed in this significant portion of the geotechnical report.

- 4.9.7.1 General Assessment - A brief summary of the more significant conclusions and recommendations, particularly identifying unusual or critical items that should be addressed in the subsequent design and construction.
- 4.9.7.2 Site and Subgrade Preparation - Recommendations concerning clearing, stripping, and grubbing of the embankment footprint area, spillway locations, and potential borrow areas should be included.
- 4.9.7.3 Foundation Preparation - Recommendations concerning undercutting and replacement of unsuitable materials should be included in this section. Special foundation preparation techniques to deal with partial undercutting of alluvial soils, preparation of exposed rock foundations, etc. would be included.
- 4.9.7.4 Groundwater and Dewatering - Dewatering requirements to construct the project would be identified. Specific areas that will likely require dewatering, and the extent to which groundwater lowering is needed, should be addressed. General information on the anticipated types of dewatering systems that would be appropriate should be presented.
- 4.9.7.5 Surface Water Diversion - A general discussion of the need to route surface flows from the drainage basin around and through the construction work area should be presented.
- 4.9.7.6 Seepage Considerations - The seepage evaluation should include estimates of potential seepage quantities, as well as any seepage reduction and seepage collection techniques needed. Seepage reduction techniques such as cut-off/keyways, slurry walls, and clayey core zones would be identified. Internal drainage system recommendations should be made for any foundation and embankment drains needed. Details concerning gradations of drainage aggregates and filter requirements, the need for special items such as relief wells, locations and minimum dimensions for drainage components, etc. should be addressed.
- 4.9.7.7 Embankment Geometry - The maximum recommended slope inclination based on the results of the stability evaluation should be made. The need for slope berms, minimum crest width recommendations, and the need to slope the crest back toward the reservoir should be discussed. Any requirements for zoning within the embankment would be included, specifically addressing material properties that would be considered appropriate for the individual zones within the dam.
- 4.9.7.8 Earthwork Recommendations - This section of the report would include the material types and quantities identified in potential borrow areas. It will also specify recommendations for minimum compaction requirements and moisture control of the materials placed during construction. The borrow site management should be addressed.

In addition, details concerning the placement procedures for the earthwork operations to assure adequate bonding between lifts, control of overly wet or dry material, cross slopes, management of the fill pad, etc. should be provided. Minimum testing recommendations for the earthwork must be included.

- 4.9.7.9 Settlement - Estimates of settlement, particularly at critical structure locations, should be provided if relatively compressible foundation conditions exist. In conjunction with the settlement assessment, anticipated settlement along conduits and the associated joint extensibility for any jointed conduits would be required. Variations in settlement should be considered to help resolve any special foundation preparation techniques or design requirements for internal drainage systems, such as chimney drains, as a result of excessive differential settlement potential. Typically, the settlement estimated at the base of the dam, as well as the settlement within the fill materials placed, would be provided. The need to compensate for any potential settlement, including cambering of the crest, special construction sequencing and surcharging requirements, etc. should be addressed.
- 4.9.7.10 Principal Spillway/Conduits - Any requirements along conduits that will penetrate the dam should be addressed. This would include concrete cradle requirements, filter collars, the need for camber in the pipe to accommodate settlement, and special backfill requirements adjacent to conduits. Allowable bearing pressures for outlet structures should be provided along with any special foundation preparation techniques appropriate for these areas.
- 4.9.7.11 Emergency/Channel Spillways - Items related to the excavation of any channel type spillways in the abutment areas should be addressed. The erodiability index of materials exposed at proposed finish grade should be determined for use in the spillway attack calculations. General suitability of reusing these materials in the embankment construction, groundwater considerations, difficult excavation potential, etc. should be considered. Protected spillway channels (such as RCC, concrete chute, etc...) in abutment areas or over the embankment should provide details concerning seepage reduction and underdrainage system requirements.
- 4.9.7.12 Erosion Control - The need for shoreline wave protection, grassing, berms, and protection of critical areas from surface runoff should be considered. Positive erosion protection techniques such as rip-rap should include addressing the bedding requirements for these materials.
- 4.9.7.13 Other Considerations - Any special requirements for items such as slurry walls, foundation grouting, special consideration of the geology in which the site is located, etc. should be addressed in the geotechnical report. In essence, any geotechnical issues which may impact the subsequent design and construction of the project must be considered.

#### 4.9.8 Instrumentation

Minimum instrumentation requirements should be included as addressed in a previous section of this guideline. These recommendations should include types of instrumentation, locations, and general approach to monitoring and reporting of these data.

#### 4.9.9 Construction Monitoring

The report should address requirements related to geotechnical evaluation and construction materials testing during construction. This would include the level of experience of the individuals required for the various portions of the construction monitoring, general testing requirements, and identification of the specific areas that require monitoring. Essentially full-time monitoring of all phases of the construction is required.

#### 4.9.10 Appendices

4.9.10.1 Supporting Data - All of the field and laboratory test results should be included as appendix items. Exploration location plans, subsurface profiles, boring records, laboratory test results, and any special details must be included.

4.9.10.2 Analyses - The actual calculations required for stability, seepage and settlement, as well as any other specific geotechnical calculations performed as part of the basis for the geotechnical study, must be included. This may be as an appendix item to the geotechnical report or may be submitted as a separate document along with the geotechnical study.

## 5. HYDROLOGY AND HYDRAULICS

### 5.1 Introduction

The scope of this section is to provide generalized guidelines for Hydrologic and Hydraulic data to be included in design reports submitted to the SDP of the DNR.

### 5.2 Hydrology

#### 5.2.1 Submittal Format

The United States Army Corps of Engineers HEC-1 format with supporting data is recommended for submittal. Other methods and software are acceptable, but must be discussed with the SDP prior to beginning the design work. It would be helpful to correlate the proposed method with HEC-1.

#### 5.2.2 Design Rainfall Events

The 6-hour rainfall event as defined in Hydrometeorological Report (HMR) No. 52 is the minimum storm event for the design of primary and emergency spillway flows. Longer rainfall events should be used if the size of the watershed dictates. The length of storm should follow the guidelines for the generation of the storm event.

#### 5.2.3 Time of Concentration and/or Lag Time

The method used to determine the watershed basin time of concentration should be indicated. Parameter limitations of each method should be followed. The following are a list of methods acceptable to the SDP:

- Natural Resources Conservation Service (NRCS formerly SCS) Curve Number method for drainage basins less than 2000 acres
- Combination Overland Flow and Full Channel Flow
- NRCS Technical Release (TR) No. 55
- Watershed lag techniques based on analysis of gauged watershed similar to the study watershed may also be used. Acceptable references for those procedures include Engineering Manual EM 1110-2-1417, Flood Runoff Analysis (Corps of Engineers) and Flood Hydrology Manual (Bureau of Reclamation).

#### 5.2.4 Use of Sub-Watersheds

Watersheds are divided into sub-watersheds when the shape or size of the watershed dictates. Consider using sub-watersheds when the watershed is greater than 2000 acres and the sub-watersheds have significantly differing characteristics such as slope, land use, soil type etc. Provide delineation of watershed and sub-watersheds with submittal.

#### 5.2.5 Curve Number Calculations

Curve number calculations are dependent on soil type and land use. Use a conservative curve number to account for future development in the watershed.

5.2.5.1 The curve number should be adjusted for the antecedent moisture conditions (AMC).

Example:

1. Principal Spillway - 50 or 100-year 6-hour, AMC-II
2. Design Storm PMP or fraction, 6-hour event, AMC-III
3. Design Storm PMP or fraction,  $\geq$  24-hour event, AMC-II

#### 5.2.6 Development of Design Storm Event

Use HMR No. 51 and No. 52 to develop a precipitation pattern. The curve number should be adjusted for the AMC.

### 5.3 **Hydraulics**

#### 5.3.1 Spillway Rating Curve

The selection of the type and number of outlet structures for a dam project can be impacted by numerous parameters. A typical dam will have two outlet structures, the principal or primary spillway and the emergency or secondary spillway.

5.3.1.1 Principal Spillway - The principal spillway, regardless of its configuration, will handle the daily flows from the dam and will control the normal pool elevation of the lake. Types of principal spillways include:

- (1) Standard Covered Risers
- (2) Siphon Systems
- (3) Standpipes
- (4) Chute Spillways
- (5) Labyrinth Weirs
- (6) Drop Structures
- (7) Culvert Spillways
- (8) Ogee Weirs
- (9) Side Channel
- (10) Fuse Gate
- (11) Morning Glory
- (12) Gated Structures

5.3.1.2 Secondary Spillway - The secondary spillway will provide additional discharge capacity as the lake level rises to prevent overtopping of the structure during the design storm. Types of secondary spillways include:

- (a) Concrete Chute Spillways
- (b) Vegetated Spillways
- (c) Articulated Block Spillways
- (d) Gabion Basket Spillways
- (e) Labyrinth Weirs
- (f) Overtopping Protection

### 5.3.2 Documentation

A rating curve should be developed for each of the potential discharge structures and then combined into an overall rating curve for the dam. The designer should evaluate how the different outlet structures will impact the discharges from the other structures and provide adequate energy dissipation for each of them.

The design documentation should include the equations used to calculate each of the rating curves and the design methodology it is based on. The rating curves in tabular format for all of the various outlet structures and a summary table of the discharges for the dam should be incorporated in the documentation.

### 5.3.3 Tailwater Rating Curve

The conditions directly downstream of the dam site can greatly affect the discharge capacity and stability of the dam and should be considered in the overall design. In situations where there is a restriction to flow immediately downstream of the dam (i.e. roadway culvert/bridge, lake, narrow valley section), the restriction should be evaluated as to its impact on the capacity of all of the dam's discharge and terminal structures. Typical stilling basin and plunge pool design requires that the tailwater elevation for the channel downstream of the structures be known and is a major factor in their design.

The outlet rating curve for any type of low level discharge conduits will be affected by the tailwater downstream of the dam and it should be factored into their design.

The methodology for determining the tailwater elevations downstream of a structure can vary widely with the complexity of the situation. The amount of data and accuracy of the information should be sufficient to determine the tailwater elevations.

Several of the computer programs used to determine downstream tailwater conditions are indicated below:

- |     |         |   |
|-----|---------|---|
| (1) | HY8     | Culvert Analysis                        |
| (2) | HEC-RAS | River Analysis System                   |
| (3) | HEC2    | Water Surface Profiles                  |
| (4) | HY7     | Bridge Waterways Analysis Model (WSPRO) |
| (5) | HY-4-69 | Hydraulics of Bridge Waterways          |
| (6) | WSP2    | Water Surface Profiles                  |

### 5.3.4 Energy Dissipation Design

Each spillway design involves the passing of water. This water is accelerated during design flows and will cause considerable damage if not controlled. The energy in the water must be dissipated using an approved methodology. Design calculations must be provided for each type of energy dissipater.

#### 5.3.4.1 Conduit Spillway Energy Dissipators

- Cantilever Plunge Pool
- Riprap Basin

- Contra Costa Energy Dissipater
- Bureau of Reclamation (USBR) Type VI - Impact Basin
- Saint Anthony Falls (SAF) - Stilling Basin

5.3.4.2 Concrete Chute Spillway Energy Dissipaters

- SAF Stilling Basin
- Deflector Buckets
- USBR Hydraulic Jump Basins

**5.4 Earth Spillway Attack Calculations**

Earth spillways are subject to erosion and possible failure during the design storm. Earth spillways must not activate until after the 50-year storm. Adequate resistance must be provided for the dam to perform safely.

- NRCS TR No. 48 – DAMS 2 – Computer Program (SITES Program)
- Earth spillways must not activate until after the 50-year, 6 hr AMC II storm

5.4.1 SITES

Oe/b or attack (as defined by the SCS or NRCS) is defined as the volume of water passing through the auxillary spillway divided by the width of the spillway (cfs/A.F.).

If $Oe/b < 1.5$	No SITES required
If $1.5 < Oe/b < 10$	SITES with conservative assumed parameters
If $Oe/b > 10$	Full SITES

The above only applies to dams less than 35 feet and with storage less than 1,000 acre-feet of storage. All dams above 35 feet or 1,000 acre-feet of storage shall have a full SITES analysis performed. Any special circumstances that could lead to a need to vary from this criteria must be discussed with the Georgia Safe Dams Program in advance. The assumed parameters used must be approved by the GaSDP in advance.

**5.5 Freeboard Calculations During the Design Storm**

Appropriate freeboard for wave action and runoff during the design storm shall be provided. The wave height should be calculated using fetch length and a minimum 50 MPH wind velocity. This height is added to the maximum reservoir surface elevation during the design storm event to determine the minimum top of dam elevation.

A methodology for wave height calculations can be found in NRCS TR No. 56 or ETL 1110-2-221.

In lieu of calculating freeboard by engineering analysis, a minimum of three feet above the design storm shall be provided on earth dams.

**5.6 Filling Schedule for Reservoirs**

The design package submitted for approval shall contain a proposed schedule for filling the reservoir. In general, reservoirs shall be filled in stages allowing time for the embankment and foundation conditions to adjust to the increased load caused by the reservoir. The overall duration of the filling schedule should be

based on the embankment and foundation performance as determined by properly installed instrumentation and by visual inspection. As general guidance, the reservoir filling schedule should be based on the following:

- First 1/3 of pool level - uncontrolled rate of filling
- Second 1/3 of pool level - no more than 2 feet per week
- Final 1/3 of pool level - no more than 1 foot per week

## **5.7 Time To Drain Reservoir**

The gated pipe structure or other system shall be designed to drain two-thirds of the volume at normal pool of the reservoir within ten days unless an alternative time frame is approved by the SDP. Calculations showing the rate and volume of drainage need to be provided. Downstream water usage and possible downstream flooding conditions before draining the reservoir should be considered.

## **5.8 Hazard Evaluation and Dam Breach Analyses**

Properly designed, constructed, and operated dams can be expected to improve the safety of downstream developments, especially during flood events. However, the failure of a dam can create a potential hazard greater than that which would exist without the dam. The consequences of dam failure must be fully evaluated in order to properly identify and define the extent of the potential “hazard zone”. The results of these analyses should be used to determine the classification of the structure and to develop an emergency action plan.

### **5.8.1 Studies to Define the Impact of Dam Failure**

The degree of study required to define the impacts of dam failure is site specific and will vary depending on the type of dam, size of reservoir, and downstream development. In some instances it will be apparent from field observations that loss of life or extensive property damage will result should the dam fail. In other cases, detailed studies utilizing sophisticated computer models will be required in order to fully define the downstream hazard zone. These analyses are commonly referred to as “dam break” or “dam breach” studies. Section 2 contains information on acceptable dam break modeling procedures.



## 6. PLANS AND SPECIFICATIONS

### 6.1 Introduction

Every proposed dam or dam repair requires a set of construction plans and specifications tailored to the project. These guidelines indicate items which generally should be included in any set of construction plans and specifications submitted to the Georgia SDP. This is not intended to be an all inclusive list, nor will all of these items be required for every project. Items may be combined for clarity or simplicity.

### 6.2 Construction Plan Guidelines

#### 6.2.1 Title Sheet

- 6.1.1.1 Location map
- 6.1.1.2 List of drawings
- 6.1.1.3 Twenty-four (24) hour contact and phone number
- 6.1.1.4 Owner's name, address, and phone number
- 6.1.1.5 Engineer's name, address, and phone number

#### 6.2.2 Reservoir Plan

- 6.2.2.1 No excavation within a minimum 200 feet minimum upstream from the toe of the dam (or as determined by the engineer)
- 6.2.2.2 Clearing limits
- 6.2.2.3 Existing topography - source (i.e. aerial, ground run, data source)
- 6.2.2.4 Existing features
- 6.2.2.5 Borrow/spoil areas
- 6.2.2.6 Property/easement limits and owners/easement holders
- 6.2.2.7 North arrow and scale
- 6.2.2.8 Wetlands
- 6.2.2.9 Archeological/cultural resources
- 6.2.2.10 Demolition

#### 6.2.3 Site Plan

- 6.2.3.1 Site grading
- 6.2.3.2 Existing topography
  - source (i.e. aerial, ground-run, data source)
  - contour interval 5ft.
- 6.2.3.3 Existing features
- 6.2.3.4 Borrow/spoil areas
- 6.2.3.5 Clearing limits
  - minimum 50 feet downstream of dam toe
- 6.2.3.6 Property/easement limits and owners/easement holders
- 6.2.3.7 Proposed structures, spillways and features
- 6.2.3.8 Demolition
- 6.2.3.9 North arrow and scale
- 6.2.3.10 Geotechnical exploration locations
- 6.2.3.11 Survey control points

- 6.2.3.12 Wetlands
- 6.2.3.13 Archeological/cultural resources
- 6.2.4 Erosion and Sedimentation Control Plan
  - 6.2.4.1 Meet Georgia's Sedimentation and Erosion Control Act of 1975 as amended and any additional local ordinances, certifications.
  - 6.2.4.2 Sedimentation control features
  - 6.2.4.3 Installation details
  - 6.2.4.4 Construction schedules
  - 6.2.4.5 Grassing schedules
  - 6.2.4.5 Erosion control notes
  - 6.2.4.6 Existing topography
  - 6.2.4.7 Site grading
  - 6.2.4.8 Existing features
- 6.2.5 Profiles and Sections
  - 6.2.5.1 Dam cross sections
    - foundation preparation
    - embankment zoning
    - upstream and downstream slopes
    - seepage collection and drainage features
  - 6.2.5.2 Dam centerline profiles
    - overbuild
    - seepage collection and drainage features
  - 6.2.5.3 Emergency spillway profile
  - 6.2.5.4 Principal spillway profile
    - conduit camber
  - 6.2.5.5 Seepage reduction
    - clay blanket
    - keyway
    - slurry wall
    - grout curtain
    - other relevant items
- 6.2.6 Seepage Collection
  - 6.2.6.1 Drain Types
    - chimney
    - blanket
    - finger
    - toe

- foundation
- filter collar
- rock toes
- other
- 6.2.6.2 Drain Plans
- 6.2.6.2 Drain Profiles and Sections
- 6.2.6.3 Drain Details

- outlet headwalls
- cleanouts
- collection pipe
- animal guards

#### 6.2.7 Instrumentation Plan

- 6.2.7.1 Settlement device locations
- 6.2.7.2 Phreatic surface monitoring device locations
- 6.2.7.3 Instrumentation details
- 6.2.7.4 Installation details

#### 6.2.8 Structural Plans

- 6.2.8.1 Structural sections and details
- 6.2.8.2 Waterstop details
- 6.2.8.3 Joint details

- locations

- 6.2.8.4 Trash rack details
- 6.2.8.5 Spillway slab

- underdrains
- anti-cavitation details
- minimum 18 inch slab thickness, unless justified otherwise

- 6.2.8.6 Outlet pipe and concrete cradle details

- corrugated metal pipe is not acceptable
- filter collar

- 6.2.8.7 Intake structure details

- 6.2.8.8 Miscellaneous Details

- 6.2.8.9 Shoreline wave protection
- 6.2.8.10 Internal drainage outlet

- minimum 3 inch protrusion with a 12 inch drop (so flow can be measured)

- 6.2.8.11 Plunge pool details
- 6.2.8.12 Rip-rap details

- limits
- thickness
- type
- bedding

6.2.8.13 Seepage reduction details

- clay blanket
- keyway
- slurry wall
- grout curtain
- others

### **6.3 Construction Specification Guidelines**

#### 6.3.1 Site Preparation

- 6.3.1.1 Reservoir clearing
- 6.3.1.2 Clearing and grubbing
- 6.3.1.3 Waste disposal
- 6.3.1.4 Stripping
- 6.3.1.5 Demolition

#### 6.3.2 Erosion, Sedimentation and Pollution Control

- 6.3.2.1 Meet Georgia's Sedimentation and Erosion Control Act of 1975, as amended, and any additional local ordinances.
- 6.3.2.2 Pollution control

#### 6.3.3 Dewatering and Diversion

- 6.3.3.1 Diversion of water
- 6.3.3.2 Removal of water

#### 6.3.4 Earthwork

- 6.3.4.1 Undercutting
- 6.3.4.2 Excavation
- 6.3.4.3 Rock removal
- 6.3.4.4 Borrow area development
- 6.3.4.5 Fill materials placement
- 6.3.4.6 Backfilling
- 6.3.4.7 Rock fill

#### 6.3.5 Foundation Treatment

- 6.3.5.1 Drilling and pressure grouting
- 6.3.5.2 Slurry trench
- 6.3.5.3 Keyways

- 6.3.5.4 Treatment of rock surface
- 6.3.5.5 Rock anchors
- 6.3.6 Conduits
  - 6.3.6.1 Reinforced concrete pressure pipe
  - 6.3.6.2 Steel pipe
  - 6.3.6.3 Ductile iron pipe
  - 6.3.6.4 PVC siphon pipe
- 6.3.7 Seepage Collection Systems
  - 6.3.7.1 Toe drains
  - 6.3.7.2 Blanket drains
  - 6.3.7.3 Chimney drains
  - 6.3.7.4 Finger drains
  - 6.3.7.5 Foundation drains
  - 6.3.7.6 Filter collars
  - 6.3.7.7 Polyvinyl chloride (PVC) pipe
  - 6.3.7.8 HDPE Pipe
  - 6.3.7.9 Aggregates
  - 6.3.7.10 Geotextiles
- 6.3.8 Erosion Protection
  - 6.3.8.1 Rip-rap
  - 6.3.8.2 Other
- 6.3.9 Grassing and Vegetation
  - 6.3.9.1 Soil preparation
  - 6.3.9.2 Seeding
  - 6.3.9.3 Mulching
- 6.3.10 Fencing
  - 6.3.10.1 Fence
  - 6.3.10.2 Gates
- 6.3.11 Instrumentation
- 6.3.12 Concrete
  - 6.3.12.1 Formwork
  - 6.3.12.2 Reinforcement
  - 6.3.12.3 Accessories
  - 6.3.12.4 Cast-in-place concrete
  - 6.3.12.4 Precast concrete
  - 6.3.12.4 Roller compacted concrete
  - 6.3.12.4 Waterstops

### 6.3.13 Metals

- 6.3.13.1 Trash rack
- 6.3.13.2 Structural steel
- 6.3.13.3 Miscellaneous metals
- 6.3.13.4 Anchor bolts
- 6.3.13.5 Handrails

### 6.3.14 Equipment

- 6.3.14.1 Sluice gate
- 6.3.14.2 Valves

## 6.4 **Breach Plans**

An owner may choose to breach (remove) the dam rather than modify the dam.

### 6.4.1 Permits

The dam owner should obtain all necessary permits before proceeding with the breaching of the dam. Permits from applicable Federal, State and Local governments may be necessary. A stream buffer variance from EPD may be required. The SDP should be provided with copies of the required permits. Owners of Category I dams are required to submit an application to breach their dam. The application shall be accompanied by plans and specifications detailing the proposed breaching of the dam.

### 6.4.2 Draining the Lake

The breaching of the dam must be done with the lake drained. Consideration should be given to the method of draining the lake. Impact on things such as the fish and downstream channel should be considered. The proposed method of draining the lake should be coordinated with SDP.

### 6.4.2 Breach Dimensions

The dimensions of the breach may vary from project to project. In general, the breach width at the base of the dam should be at least equal to the height of the dam. A greater width may be warranted based upon the soil type, drainage basin and other factors. The side slopes of the breach should be no steeper than 2H to 1V. The soil type may dictate a flatter slope.

### 6.4.3 Breach Section

The breach section must be stabilized to limit erosion. It should also be protected so that sediment is not transported downstream of the breach.

### 6.4.4 Storm Detention

Storm water detention may be required by local government agencies.

#### 6.4.5 Impact to 100-year Floodplain

The breaching of the dam may have an impact on the 100-year floodplain in the vicinity of the dam. Government agencies may require the evaluation of the impacts to the 100-year floodplain.

#### 6.4.6 Disturbed Areas

Areas disturbed by the breaching of the dam should be stabilized. The lakebed may also need to be stabilized.

#### 6.4.7 Certification

The EOR will be required to monitor the work performed in breaching the dam. Periodic inspections similar to other dam construction work will need to be conducted. A final inspection involving SDP will be required. The EOR will need to provide certification along with Record Drawings verifying the work was performed as approved.

## 7. CONSTRUCTION MONITORING

### 7.1 Introduction

The best dam design can turn out to be a failure without proper monitoring of the construction. It is therefore very important that construction be adequately monitored. It is also important to monitor the performance of the dam following the completion of construction.

#### 7.1.1 Construction Versus Post Construction

The monitoring program for the construction of a new dam, or the remediation of an existing dam, includes both monitoring the actual construction period, and post construction monitoring during initial reservoir filling (refilling). This section of the guidelines deals primarily with the actual construction period.

#### 7.1.2 Definition of Engineer

The design engineering firm or team should remain involved with the construction monitoring of a dam. The EOR for the design is expected to provide written certification upon completion of the work. The engineer may include the design engineer or his authorized representatives. In most instances, a geotechnical engineer involved with the project for the design firm, or as a subconsultant to the design firm, will provide many of the construction monitoring activities. In particular, issues that deal with the geotechnical aspects of construction including, but not limited to, foundation preparation, filter drain construction, and earthwork should be evaluated by the geotechnical engineer. Senior technicians working under the direction of the engineer may be involved with the actual testing of such items as the earthwork. In addition, other engineering disciplines may be involved for project management, structural evaluations, etc.

#### 7.1.3 Level of Involvement

The construction operations should be monitored on an essentially full-time basis. All portions of the construction activities that will remain as part of the permanent completed construction should be adequately monitored by the design engineering team. Many of the construction activities require meeting not only minimum performance requirements, but also observing the details of the actual construction. For example, the earthwork requires more than mere density testing which would provide an indication of the degree of compaction and moisture content in place. The adequacy of all of the materials placed in the dam to preclude the possibility of allowing permeable zones within the impervious portions of the dam, preparation of each lift surface to provide adequate bonding, etc. are as important, if not more important, than merely meeting performance criteria. This can only be determined by essentially full-time observation of the construction activities.

#### 7.1.4 Need for Engineer Involvement

The design of a dam continues through the construction phase and into post construction phase. Interpretations of subsurface data, constructability issues, and modifications necessitated by the selected contractor's experience and equipment mandate that representatives of the design team remain involved throughout the construction process. These individuals are most familiar with the design and the assumptions made, and are in the best position to recommend appropriate modifications, if needed.



### 7.1.5 Adherence to Plans and Specifications

The primary function of the construction monitoring team will be to assure that the contractor complies with the intent of the approved plans and specifications.

### 7.1.6 Design Changes/Field Conditions

Situations occasionally occur where the design will need to be altered due to unforeseen field conditions. By having a representative of the design engineer on-site it helps to facilitate a quick resolution to these situations. Changes that are significant will need to be reviewed and approved by the SDP prior to the change being implemented. Minor modifications must be reported and documented in the monitoring reports and on the as-built drawings.

### 7.1.7 Certification

At the completion of construction, the Rules for Dam Safety requires that the EOR certify in writing the construction work was completed in accordance with the approved plans. Only through adequate involvement of the design team during construction can such certification be provided. The engineer must have first-hand knowledge of the construction activities to provide such a certification.

## 7.2 **Preconstruction Notices**

### 7.2.1 Notice of Intent to Start Construction

At least 10 days prior to the start of construction, the owner is required to notify the SDP in writing of the date that construction will commence.

### 7.2.2 Notice of Preconstruction Meeting

It is in the interest of all parties that a preconstruction meeting be held between the contractor, designer, geotechnical engineer and the owner. This is an opportunity to review specific items of interest, critical aspects of the construction, and the sequence of the work. A notice of the preconstruction meeting should be provided to SDP at least seven (7) days prior to the meeting. Depending on the complexity of the project, the SDP representatives may wish to attend this meeting. The notice of the preconstruction meeting is the responsibility of the owner.

### 7.2.3 Land Disturbance Permits

A copy of the Land Disturbance Permit as required by local and state ordinances shall be forwarded to the SDP prior to commencement of construction.

### 7.2.4 Stream Buffer Variance

A stream buffer variance may be required by local government officials. If required, a copy should be sent to SDP. For up to date information on stream buffer variances and erosion and sedimentation control, go to the following site – [www.gaepd.org](http://www.gaepd.org).

### **7.3 Routine Construction Monitoring Reports**

The following is a brief listing of several of the typical aspects of construction monitoring that should be completed. This should not be considered an all-inclusive list and should be amended or expanded to account for the individual dam design being constructed. In essence, all aspects of the construction phase should be monitored and reported.

#### **7.3.1 Clearing and Grubbing**

The engineer should evaluate the site after the contractor has completed the clearing and grubbing operations to determine that adequate procedures have been followed to allow for subsequent construction. This monitoring would typically be reported in a daily inspection report.

#### **7.3.2 Subgrade**

The engineer should monitor the subgrade and foundation preparation for the dam. This would involve items such as stripping, undercutting of unsuitable material (particularly flood plain undercutting), and keyway/cutoff construction. The conditions observed, including items such as depths of excavation, quantities, etc. should be documented in the daily field reports. All subgrade areas should be approved for fill placement by the geotechnical engineer prior to subsequent construction. This monitoring would typically be reported in a daily inspection report.

#### **7.3.3 Drains**

The engineer should monitor all aspects of the internal drainage system construction. The internal drainage system may include a number of components including foundation drains, blanket drains, chimney drains, etc. Since these systems are filtered, the monitoring should assure that all filters completely enclose more pervious materials in the drain, and that the drains extend into the desired material for the proper control of the phreatic surface. Field adjustments to the drain construction are common and should be documented in daily inspection reports.

#### **7.3.4 Outlet Works**

The construction of outlet conduits and their associated intake and outlet structures should be monitored by the engineer. Intake control structures typically require assessment of allowable bearing pressures and adequate subgrade preparation techniques. Outlet structures commonly incorporate some underdrainage. Conduit alignments typically include concrete anti-seepage cradles, as well as filtered seepage collars. The engineer should monitor the configuration of any excavations required for conduits, and closely assess all backfilling procedures adjacent to this critical area of the dam. Adequate density tests and concrete tests on any structures should be provided and reported. All subgrades for cradles and structures should be approved for subsequent construction by the geotechnical engineer. This monitoring would typically be reported in a daily inspection report.

#### **7.3.5 Earthwork**

All aspects of the earthwork operations should be monitored by the geotechnical engineer and/or his representatives on an essentially full-time basis. Routine density testing and moisture control should be reported. In addition, the construction techniques utilized by the contractor should be evaluated to assure conformance with the project specifications. The engineer's representatives should assure that all materials placed in the various portions of the embankment are suitable for the intended use,

and that proper lift treatment is performed by the contractor to assure adequate bonding of the individual lifts. The engineer's representatives will determine if moisture adjustments are needed at the fill pad prior to subsequent fill placement. This may include either wetting or drying material to achieve a suitable moisture content. The engineer's representatives should assure that the contractor is using appropriate equipment in the grading activities. Reporting would typically include daily inspection reports summarizing the grading activities and the individual density test reports.

#### 7.3.6 Instrumentation

The details of the instrumentation program have been outlined elsewhere in these guidelines. During construction, instrumentation may be placed during the construction process, or at the completion of the general embankment construction. In many instances, instrumentation will include devices that are intended to be read during the actual construction process. For example, settlement plates or devices placed at the base of the dam are typically read periodically throughout the construction process. The engineer should observe the installation of all instrumentation, and be provided with the periodic readings during construction. This data should be compared to design projections to determine if any modifications or further assessments are needed.

#### 7.3.7 Construction Photographs

It is considered good practice to take photographs or video recordings of critical aspects of the construction. These may be in the form of regularly scheduled periodic photographs of the work progress, or specific photographs of certain aspects of the construction. The intent would be to provide a permanent record should any difficulties arise during initial reservoir filling or during subsequent operation of the dam. Photographs should be adequately labeled and dated, and are typically maintained in the design engineer's file. Copies are to be provided to the SDP to document conditions.

### 7.4 **Special Construction Monitoring Reports**

This section provides general guidelines for the collection and presentation of information required for some special construction monitoring reports. In applying these guidelines, the site engineer should use good judgment and elaborate upon them as required by the particular geologic/foundation setting and engineering requirements. These guidelines are not intended to include all requirements or items for inclusion in these special reports. However, they do provide guidance to formulate a data acquisition program for planning and documenting such specialized work.

#### 7.4.1 Pressure Testing of Conduits

All principal outlet and drawdown conduits through an embankment dam shall be pressure tested in accordance with the following procedures and recommendations.

- 7.4.1.1 The Safe Dams Program shall be notified at least 48 hours prior to the testing of the conduit.
- 7.4.1.2 Prior to backfilling the conduit, it shall be tested and meet either of the following conditions:
  - a. Conduits shall be water tested to a minimum of 10 feet of head at the upstream invert and are required to hold this head for a minimum of 2 hours.

- b. Conduits can be supplied from the manufacturer with testable joints. After the conduit sections are placed, each joint shall be required to maintain a static air pressure of not less than 50 psi for a minimum of 5 minutes.

- 7.4.1.3 All pipe joints shall be inspected during the testing procedure. Any visible leaks shall be repaired regardless of the test results.
- 7.4.1.4 Failure of the conduit to meet the requirements of the test shall be investigated by the contractor and reported to the design engineer along with recommendations for correcting the failure. The conduit shall be retested and must meet the requirements of the test prior to backfilling. The testing results and any corrective measures must be reported in the construction monitoring reports.
- 7.4.1.5 The Safe Dams Program shall approve the testing procedures for non-standard conduits, i.e. siphons, box culverts, etc.
- 7.4.1.6 The Safe Dams Program may require outlets constructed on yielding foundations to pass a second pressure test after the embankment has been completed.
- 7.4.1.7 The Design Engineer shall record all conduit pressure tests. The information shall be submitted for review and contain the following data:

- Testing procedure and requirements
- Equipment - Equipment used to perform the test
- Records - A copy of the continuous record of the test and any re-test

#### 7.4.2 Laboratory Material Certification

All drain and filter materials obtained from an off-site source should be regularly checked for compliance with the project specifications. Documentation shall be provided that the materials supplied for inclusion in the dam embankment meet the required gradation limits. Such documentation should include a certified copy of the supplier's gradation tests. Synthetic filter material should be clearly marked for identification and include the manufacturer's certification for the material identification number actually shipped to the job site.

#### 7.4.3 Grouting

Evidence shall be submitted that an acceptable grout curtain was constructed within the foundations of the proposed dam structure. To satisfy these requirements the report shall contain the following information:

- 7.4.3.1 Drilling Equipment - Equipment that was used to drill the exploratory and grout holes
- 7.4.3.2 Grout Equipment - Equipment that was used to mix the ingredients of the grout and pump the slurry down the holes
- 7.4.3.3 Laboratory Equipment - Laboratory equipment that was used for on-site quality control tests
- 7.4.3.4 Grout Mix Criteria - Specified performance values/properties of grout mix(es)
- 7.4.3.5 Trial Mixes - The results of any tests and trials that were made on a variety of grout mixes prior to the main grouting operation
- 7.4.3.6 Design Mixes - The grout design mix(es)
- 7.4.3.7 Water Testing - The results of all water pressure tests in exploratory or grout holes
- 7.4.3.8 Field Test Results - The results of all field tests conducted on each of the grout mixes during the grouting program with identification of non-compliant results and remedial action. Field tests should include, but not be limited to, sedimentation, slurry density, Marsh Funnel viscosity and unconfined compressive strength.

7.4.3.9 Profile - A longitudinal profile of the grout curtain showing drilling depths and grout takes for each stage of the grout holes.

#### 7.4.4 Slurry Wall

Evidence shall be submitted that a relatively impervious slurry trench cutoff was successfully installed within the foundation of the proposed dam structure. To satisfy these requirements, the report shall contain the following information:

- 7.4.4.1 Excavation Equipment - Equipment that was used for construction of the working platform and for trenching
- 7.4.4.2 Slurry Equipment - Equipment that was used for mixing the slurry
- 7.4.4.3 Backfill Equipment - Equipment that was used for mixing and placing the backfill
- 7.4.4.4 Test Equipment - Equipment that was used for the control tests
- 7.4.4.5 Backfill Mix Design - Slurry backfill mix design
- 7.4.4.6 Acceptance Criteria - Specified performance values/properties of slurry and backfill mix
- 7.4.4.7 Field Test Results - Results of control tests, with identification of non-compliant results and remedial actions. Control tests on the slurry shall include, but not be limited to, pH, unit weight, filtrate loss and viscosity. Control tests on the backfill shall include, but not be limited to, permeability, Atterburg Limits, slump, percentage passing the No. 200 sieve, water content, bentonite content and unit weight.
- 7.4.4.8 Profile - A longitudinal profile of the slurry wall showing excavation depths, materials excavated and backfill placed.

#### 7.4.5 Blast Monitoring

It is assumed that all blasting operations shall be conducted in strict accordance with existing ordinances and regulations. To ensure that no appreciable vibration was transmitted to existing structures or facilities a monitoring report should be prepared for each blasting event. This report should include, as a minimum, the following information:

- 7.4.5.1 Preblast Inspections - Documentation of any preblast observations.
- 7.4.5.2 Monitoring Equipment - List of equipment used to monitor the blast.
- 7.4.5.3 Time and Location - Date, time and location of blast.
- 7.4.5.4 Monitoring Locations - List of structures/facilities monitored.
- 7.4.5.5 Acceptance Criteria - Allowable vibration parameters.
- 7.4.5.6 Monitoring Records - Seismograph records and interpretation.
- 7.4.5.7 Post Blast Inspections - Documentation of any post blast observations.

### **7.5 Post Construction Monitoring**

The purpose of the post construction monitoring program is to provide information as to the behavior of the recently constructed or rehabilitated dam. This information will be used in conjunction with as-built drawings and construction photographs to evaluate the performance of the newly constructed dam and any previously existing portion thereof. The recorded data will be compared to normal assumptions for the dam in order to monitor lake filling and provide means for future monitoring, operations, and maintenance as specified in Georgia's Safe Dam Act of 1978 as amended.

### 7.5.1 Record Drawings

A set of record drawings shall be submitted to the SDP following completion of construction and within the time limits as specified in the permit. The record drawings package shall include as a minimum the following:

- 7.5.1.1 Approved Modifications - All previously approved design and construction modifications incorporated into the final document.
- 7.5.1.2 Monitoring Program - A monitoring and instrumentation program.
- 7.5.1.3 Acceptance Criteria - A list of critical design assumptions and expected behaviors that need to be validated initially and long term.
- 7.5.1.4 Instrumentation Locations - The location of all post construction monitoring instrumentation.
- 7.5.1.5 Certification - A written certification from the EOR that the dam was constructed as shown on the above documents and as approved.

### 7.5.2 Lake Level

After certification by the design engineer and approval of the SDP, filling of the lake may commence. Adherence to the reservoir filling schedule shall be controlled by operation of the outlets works in order to maintain the differential rise in lake level and maintain flow. In the event that sudden changes occur which may be indicative of a potential dam failure, the lake level shall be lowered and the SDP notified immediately. Otherwise, after the lake reaches the normal operating level, the approved water control, inspections, and maintenance plans shall be initiated.

### 7.5.3 Physical Condition of Dam

Areas of potential weakness and their effects on dam stability should be identified. Visual observations should be made in conjunction with instrumentation monitoring to adequately assess the safety of the dam. Initial surveillance of the dam's performance should be conducted by the design engineer to confirm design assumptions and to evaluate performance. Many unusual or abnormal conditions can be identified by a walking tour of the dam crest, slopes, toes, and abutments. Long-term inspection, operation, and maintenance shall be the responsibility of the dam owner and/or operator as specified in Georgia Safe Dam Act of 1978 as amended.

### 7.5.4 Instrumentation Reading

All data should be compared with design assumptions for and expected behavior of the dam. If no unusual behavior or evidence of problems is detected, the readings should be maintained for future reference and review by SDP staff during yearly inspections. Threshold readings that indicate the development of potentially hazardous conditions should be established. Action should be taken if the data deviates from expected behavior or approaches the threshold readings, depending on the nature of the potential hazard. Possible actions include:

- Performing detailed visual inspection.
- Repeating measurements to confirm behavior.
- Notifying the owner's engineer and the SDP.
- Increasing frequency of measurements.
- Designing and constructing remedial measures.
- Installing additional instrumentation.

- Operating the reservoir at a lower level.
- Implementing emergency measures.

#### 7.5.5 Photographs

Photographs or videos are useful in documenting the initial site investigation, subsurface excavation, construction, and as-built conditions. They are helpful for providing a historical perspective in evaluating whether or not there has been any change from previous conditions. Photographs and videos should be maintained for future reference in the event remedial or emergency action is required. Photographs, or digital images, of the entire construction process should be provided to the SDP.

## **8. OPERATION AND MAINTENANCE**

### **8.1 Introduction**

Operation and maintenance (O&M) of a dam is the responsibility of the dam owner. O&M requires effort and expenditures throughout the life of the dam to maintain safe conditions and assure proper functioning.

### **8.2 Dam Owner Responsibilities**

The dam owner's responsibility for operation and maintenance begins when a dam construction project is completed. This responsibility shall continue throughout the life of the dam.

#### **8.2.1 Keys**

The dam owner is responsible for providing the SDP access to the dam and any appurtenant structures. The owner should remove any locks where a key does not exist, including locks for piezometers and other monitoring devices.

The dam owner shall provide the SDP with keys for access to the dam and keep the SDP abreast of any changes in locks. In an emergency situation, the SDP shall obtain access to the dam using either the dam owner-supplied keys or by other methods as deemed necessary.

### **8.3 Records**

The dam owner will maintain records of all inspections, operation and maintenance activities, and any structural modifications to the dam. The SDP may inspect these records at any reasonable time during the life of the dam.

### **8.4 Operations**

Operation includes the administration, management, and performance of non-maintenance actions needed to keep a dam safe and functioning as planned. Dam owners should operate their dam in:

- 8.4.1 Compliance with applicable Federal, state, and local laws, regulations, and ordinances.
- 8.4.2 Compliance with applicable conditions in any real property instruments required for installation, operation, and maintenance of the dam.
- 8.4.3 A manner that will result in the least adverse impact on the environment and that will permit the dam to serve the purpose for which it was installed.
- 8.4.4 Keeping with the commitments established in the O&M plan.

### **8.5 Maintenance**

Maintenance includes work to prevent deterioration of the dam, repair damage, or replace components of the dam if they should fail. This includes both the routine and recurring needs such as repainting exposed surfaces, fertilization and management of vegetation, and clean out of channels. Damage to completed dams caused by normal deterioration, drought, or vandalism is also considered maintenance regardless of whether it occurs immediately or several years after the dam is completed.



## **8.6 Operation and Maintenance Plan**

The O&M plan is to be prepared by an engineer in coordination with the dam owner, during the planning and/or design phase. Details of the O&M plan will be commensurate with the complexity of the dam and potential hazard. The O&M plan is to include requirements that are deemed necessary during the planning, design, and construction process. These requirements include such items as types and frequency of inspections, written records, reports, and references to related plans such as an emergency action plan. Also, the plan should describe normal or routine actions such as regrading, painting, removal of debris, fertilizing and/or reestablishing of vegetation, and mowing or grazing restrictions.

Each plan must be tailored to the specific dam to which it applies. In addition, a list of known and anticipated items of O&M that will be needed and the duration of the O&M requirements is to be included.

### **8.6.1 General**

This section shall identify the O&M responsibilities of the owner. In addition, a list of known and anticipated items of O&M that will be needed and the duration of the O&M requirements is to be included.

### **8.6.2 Operating Plan**

This section should contain the details of the dam operation for each purpose for which the dam is installed such as water for irrigation, water supply, or recreation. Environmental documents prepared during planning should be reviewed in case they contain specific monitoring or mitigation requirements as part of the O&M requirements.

### **8.6.3 Performing O&M**

This section should contain an explanation of how the O&M activities will be carried out along with a list of O&M techniques and inspections deemed appropriate by the dam owner.

### **8.6.4 Inspection**

A schedule for making inspections and for completing items of O&M should be stated, and a list of critical items that will be examined during the recurring and special onsite inspections should be included.

### **8.6.5 Reports**

Specify the types and timing of records that the dam owner will provide to SDP (EPD) and records that dam owner will maintain.

## 9. EMERGENCY ACTION PLANS

### 9.1 Overview

One should not believe that periodic safety inspections performed by the State or a consultant are sufficient to prevent failure of the dam. The dam owner should still plan for the worst. Having an effective Emergency Action Plan (EAP) is critical to reducing the risks of loss of life and property damage from a dam failure. A dam failure would be a personal as well as a legal calamity to a dam owner. Many dam owners are local residents and know the people, businesses, schools, and other institutions that would be impacted by a dam breach flood.

### 9.2 What is an EAP?

An EAP serves as a formal document that identifies potential emergency conditions at a dam and specifies preplanned actions to be followed to minimize property damage and loss of life should those conditions develop. The plan is designed to be used by non-technical staff to define conditions that trigger emergency response. It provides clear directions for use during stressful situations, specifying the dam owner's responsibilities to ensure timely and effective action. The EAP contains procedures and information to assist the dam owner in issuing early warning and notification messages to the responsible downstream emergency management authorities and individuals at risk. The plan should also contain inundation maps to show the emergency management authorities the critical areas for action in case of an emergency. Organizations and/or individuals who own or are responsible for the operation and maintenance of dams are encouraged to use these guidelines to develop, update, and/or revise their EAPs. EAPs generally contain six basic elements:

- Notification Flowchart
- Emergency Detection, Evaluation, and Classification
- Responsibilities
- Preparedness
- Inundation Maps
- Appendices

These elements should be included in a complete EAP. The dam owner is responsible for the development of the EAP. To be effective, the development or revision of an EAP must be done in coordination with those having emergency management responsibilities at the state and local levels. Emergency management agencies will use the information in a dam owner's EAP to facilitate the implementation of their responsibilities. State and local emergency management authorities will generally have some type of plan in place, either a Local Emergency Operations Plan (EOP) or a Warning and Evacuation Plan.

### 9.3 Components of an EAP

The following minimum information should be provided in the EAP to ensure that a consistent and complete EAP is developed. There may be justification for not providing information in some of the sections. For example, the dam may be small enough and located such that there is clearly only one potential hazard. In that instance, an inundation map is not necessary. Considerations of not providing data for the following sections must be discussed with the Safe Dams Program in advance of the development of the EAP.

### 9.3.1 Title Page

The EAP title page should identify it as an “Emergency Action Plan” and specify the dam name and reservoir or lake name. The state ID and other identifying names must be included, along with the dam owner’s name or organization and a street address or location of the dam site.

### 9.3.2 Table of Contents

### 9.3.3 Plan Signatures

The EAP should be signed by all parties involved in plan implementation, including the Safe Dams Program, to ensure that everyone is aware of the plan and understands the agreed-upon responsibilities.

### 9.3.4 Plan Overview

These initial pages of the EAP should summarize the critical responsibilities for responding to an incident and implementing the plan.

### 9.3.5 Notification Flowcharts

A Notification Flowchart identifies who is to be notified of a dam safety incident, by whom, and in what order. The information on the flowchart is critical for the timely notification of those responsible for taking emergency actions. One chart or a set of charts may be needed, depending on the complexity of the hazards associated with the dam and the potentially-affected downstream areas. Notification Flowcharts need to present the following information:

- emergency level of the Notification Flowchart if more than one flowchart is required
- individuals who will notify dam owner representatives and/or emergency management authorities
- prioritization of notifications
- individuals who will be notified

The Notification Flowchart should include appropriate contact information such as names, positions, and telephone numbers. Supplemental contact information can be included in a list or table of emergency contacts. This may include fax numbers, e-mail addresses, direct connect numbers, and alternate contacts.

The Notification Flowchart should designate the following. Note that it is usually recommended that one person be responsible for contacting no more than three or four other parties.

Dam owners will contact:

- engineer/management staff/public affairs officer
- local emergency authorities or 911 centers
- state dam safety program representatives
- other regulatory authorities
- upstream and downstream dam owners

Local emergency management authorities will contact:

- other local responders such as police or fire
- state emergency management authorities
- affected residents and businesses
- appropriate NWS (National Weather Service) WFO (Weather Forecast Office)

Notification Flowcharts should be easy to follow for each emergency level and should allow for information to be exchanged upward and downward between the contacts. One flowchart that represents all emergency levels is preferred for simplicity. However, it may be necessary to develop a flowchart for each emergency level for clarity. Color coding may also be helpful. If necessary, narrative information supplementing the flowchart may be provided on the page following the flowchart.

If other forms of mass communication or notification are used, these may need to be incorporated into the Notification Flowchart and associated procedures.

#### 9.3.6 Statement of Purpose

The EAP should include a brief statement describing the purpose of the EAP. Two examples are provided below:

**Example 1:** “This Emergency Action Plan defines responsibilities and provides procedures designed to identify unusual and unlikely conditions that may endanger Alpha Dam in time to take mitigating action and to notify the appropriate emergency management authorities of possible, impending, or actual failure of the dam. The plan may also be used to provide notification when flood releases can create major flooding.”

**Example 2:** “The purpose of this EAP is to safeguard the lives and reduce damage to the property of the citizens of Alpha County living along Beta Creek, in the event of failure of the Beta Creek Dam or flooding caused by large runoff.”

#### 9.3.7 Project Description

A description of the dam, the basic dam characteristics (dam height, maximum storage, length of dam), its location, and the State and NID identification numbers should be provided in this section. The basic dam characteristics can be obtained from Georgia Safe Dams Program if the owner does not have this information. A dam vicinity map and a simple drawing showing the dam’s features are recommended, along with a list of any significant upstream or downstream dams and downstream communities potentially affected by a dam failure or by flooding as a result of large operational releases. Note that the dam owner should redact design information and site-specific concerns in EAP copies that are distributed to outside organizations if the organizations do not need the information to implement the plan.

#### 9.3.8 The EAP Response Process

There are generally four steps that should be followed when an incident is detected at a dam. The steps are:

- Step 1: Incident detection, evaluation, and emergency level determination
- Step 2: Notification and communication
- Step 3: Emergency actions
- Step 4: Termination and follow-up

Early detection and evaluation of the condition(s) or triggering event(s) that initiate or require an emergency response action are crucial. It is important to develop procedures for reliable and timely determination of an emergency level to ensure that the appropriate response actions are taken based on the urgency of the situation. Procedures for early notification are required to allow all entities involved with plan implementation to respond appropriately. Preventive or mitigating actions can be taken to attempt to address conditions at the dam. Eventually, a determination will need to be made concerning termination of the incident. After the incident is over, follow-up activities may be required. All of these steps make up the general EAP response process and should be discussed in the plan.

**Step 1: Incident Detection, Evaluation, and Emergency Level Determination.** For Step 1, an unusual condition or incident is detected and confirmed. Unusual conditions or incidents are unique to each dam and, to the extent possible, should be identified in the EAP. The following information should be included or referenced in the plan to assist the dam owner in this step:

- Measures for detecting existing or potential failures
- Operating information, such as normal and abnormal reservoir level data
- Description of monitoring equipment, such as water level sensors and early warning systems
- Monitoring and instrumentation plans
- Inspection procedures
- Process for analyzing and confirming incoming data

After an unusual condition or incident is detected and confirmed, the dam owner will categorize the condition of incident into one of the established emergency levels based on the severity of the initiating condition or triggering event(s). Both the dam owner and emergency management authorities should understand the emergency levels and each other's expected responses. Consistency of the emergency level categories is recommended to eliminate confusion for emergency responders whose jurisdiction contains multiple dams and dam owners.

The four dam safety emergency level categories recommended are:

- High flow
- Non-failure
- Potential failure
- Imminent failure

The EAP should describe how each emergency level applies. Information to assist the dam owner in determining the appropriate emergency level should be developed and included in the EAP. The four recommended emergency levels are discussed below.

**High Flow.** The High Flow emergency level indicates that flooding is occurring on the river system or within the dam's drainage basin, but there is no apparent threat to the integrity of the dam. The High Flow emergency level is used by the dam owner to convey to outside agencies that downstream areas may be affected by the dam's spillway release. Although the amount of

flooding may be beyond the control of the dam owner, information on the timing and amount of release from the dam may be helpful to authorities in making decisions regarding warnings and evacuations.

Notifications should be predetermined based on correlations between releases and the timing of impacts to downstream areas. High Flow emergency level notifications are typically made to local jurisdictions that would be affected, the NWS, downstream dam owners, and other agencies, as necessary. For smaller dams that have no downstream impact from releases, this category may not be necessary. If the High Flow emergency level is used, dam owners should consider developing a table that correlates gate openings and/or reservoir levels to outflows, expected downstream impacts, and agencies that will be contacted.

**Non-Failure.** The Non-Failure emergency level is appropriate for an event at a dam that will not, by itself, lead to a failure, but requires investigation and notification of internal and/or external personnel. Examples are (1) new seepage or leakage on the downstream side of the dam, (2) presence of unauthorized personnel at the dam, and (3) malfunction of a gate.

Some incidents, such as new seepage, may only require an internal response from the dam owner. Others, such a gate malfunction, may lead to unexpected high releases that could pose a hazard to the downstream public and would require the notification of outside agencies.

**Potential Failure.** The Potential Failure emergency level indicates that conditions are developing at the dam that could lead to a dam failure. Examples are (1) rising reservoir levels that are approaching the top of the non-overflow section of the dam, (2) transverse cracking of an embankment, or (3) a verified bomb threat. Potential Failure should convey that time is available for analyses, decisions, and actions before the dam could fail. A failure may occur, but predetermined response actions may moderate or alleviate failure.

**Imminent Failure.** The Imminent Failure emergency level indicates that time has run out, and the dam has failed, is failing, or is about to fail. Imminent Failure typically involves a continuing and progressive loss of material from the dam. It is not usually possible to determine how long a complete breach of a dam will take. Therefore, once a decision is made that there is no time to prevent failure, the Imminent Failure warning must be issued.

**Step 2: Notification and Communication.** All parties must understand that the formal declaration of public emergency by emergency management authorities can be a very difficult decision. During this step, the dam owner should provide any information that will assist in that decision. An early decision and declaration are critical to maximizing available response time. To assist in this notification step, the EAP may include checklists and/or prescribed messages to help the caller adequately describe the emergency situation to emergency management authorities.

**Step 3: Emergency Actions.** After the initial notifications have been made, the dam owner will act to save the dam and minimize impacts to life, property, and the environment. During this step, there is a continuous process of taking actions, assessing the status of the situation, and keeping others informed through communication channels established during the initial notifications. The EAP may go through multiple emergency levels during Steps 2 and 3 as the situation improves or deteriorates. The dam owner should develop tables that include specific actions for minimizing impacts of dam safety incidents.

**Step 4: Termination and Follow-up.** The EAP should explain the expected termination and follow-up procedures for dam safety incidents and emergencies. A Dam Emergency Termination Log may be developed and used to document conditions and decisions. Government officials are responsible for declaring an end to the public emergency response.

#### 9.3.9 Preparedness

At a minimum, the EAP should address the following categories related to preparedness:

- Surveillance and monitoring
- Evaluation of detection and response timing
- Access to the site
- Response during periods of darkness
- Response during weekends and holidays
- Response during periods of adverse weather
- Alternative sources of power
- Emergency supplies and information
- Training and exercising
- Alternative systems of communication
- Public awareness and communication

#### 9.3.10 EAP Review & Update: document control

#### 9.3.11 Appendices

The appendices should contain supplementary information and material that was used to develop the EAP. Most importantly, an inundation map must be included. The inundation map must clearly delineate the potentially flooded areas. The following flood inundation information should be shown at important downstream locations: peak flood stage, floodwave arrival time, time to peak discharge, maximum water surface elevation, and peak discharge. The appendices should have well-labeled maps that include local roads, drainages, population centers, landmarks, etc. The appendices can also have detailed operation and maintenance requirements, dam break information and analyses, blank forms and logs, and a resource sheet showing contractor contact information and locally-available resources such as gravel.

### 9.4 Testing the EAP

In order to familiarize the local emergency management agencies with the dam, its potential downstream consequences, and the EAP, it is prudent to test the EAP. At a minimum, an orientation meeting can be held with key people so that everyone becomes familiar with the EAP, key roles and responsibilities, and procedures. For more advanced testing, a drill, tabletop exercise, functional exercise, or full-scale exercise can be held (listed in order of involvedness). For more information on setting up a test of your EAP, contact your local emergency management agency.

### 9.5 Updating the EAP

EAPs are living documents. Without periodic maintenance, the EAP will become outdated and ineffective. The EAP should be updated promptly to address changes in ownership and contact information, significant changes to the dam, or emergency procedures. The EAP should be reviewed at least annually for adequacy and updated as needed. For example, the dam owner should call all contacts

on the Notification Flowchart to verify phone numbers and names and to see if the contact still has ready access to the EAP. Also, available resources identified as needed during an emergency, such as gravel and equipment should be checked. Even if no revisions are necessary, the review should be documented. The EAP needs to go through document control. This includes a revisions page with revision dates and the removal of outdated pages.

## **9.6 Submitting to Georgia Safe Dams Program**

Category I dams in the State of Georgia must have an Emergency Action Plan. A complete permit application shall include the EAP. Additional requirements for a complete permit application may be found in Section 1 of this document.

## **9.7 References**

North Carolina has developed an EAP template. Their template is a fillable form that can be adapted for use in Georgia for any size dam. In designing the template, North Carolina relied on EAP forms and formats from several states and from federal agencies, along with lessons learned from actual emergencies at dams. Although the North Carolina template is 68 pages in length, several pages contain explanations of terminology and others are more appropriate for larger dams. The template can be accessed from the website [www.damsafetyaction.org](http://www.damsafetyaction.org).

The Federal Emergency Management Agency, FEMA, has developed the Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners which is available for download from FEMA at [www.fema.gov](http://www.fema.gov).

The Georgia Safe Dams Program also accepts the use of the USDA Natural Resources Conservation Service (NRCS) EAP template. A fact sheet of information on that template, directions on how to obtain it, and a copy of it can be found at [www.damsafetyaction.org](http://www.damsafetyaction.org).

Additional information on the content and development of an EAP can be obtained from the websites listed above and at [www.damsafety.org](http://www.damsafety.org) (the Association of State Dam Safety Officials).