Emergency Action Plan Template for Florida Dams Instruction Manual

Florida Dam Safety Program

January 2023

Acknowledgements

The *Emergency Action Plan Template for Florida Dams* (EAP Template) and companion *Emergency Action Plan Template for Florida Dams Instruction Manual* (Instruction Manual) were developed by drawing liberally on the work of several agencies: the Florida Department of Environmental Protection (DEP); the five Regional Water Management Districts of Florida; the USDA Natural Resources Conservation Service; the Texas Commission on Environmental Quality; the Federal Emergency Management Agency (FEMA); the Federal Energy Regulatory Commission; the National Dam Safety Review Board Emergency Action Plan Workgroup; the National Weather Service; the Association of State Dam Safety Officials; and the United States Army Corps of Engineers.

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Disclaimer

The mention of a specific product, company, or web address is for information purposes only and does not constitute an endorsement of that product, company, or service.

Assistance to the Preparer

The Instruction Manual is a valuable tool to aid the preparer in completing this EAP Template. Additional information and draft EAP reviews may be requested by contacting the State Dam Safety Officer by mail, email or telephone through the contact information provided below.

Tracy C. Woods, P.G.
State Dam Safety Officer
Stormwater and Technical Services Program
Division of Water Resource Management
Florida Department of Environmental Protection
2600 Blair Stone Road, MS 3595
Tallahassee, FL 32399-2400
850-245-7530 (office) / 850-274-3636 (emergency cell)
Tracy.Woods@FloridaDEP.gov
http://www.floridadep.gov/water/engineering-hydrology-geology/content/florida-dam-safety-program

Table of Contents

Introduction

General

Dam safety in Florida is the responsibility of each dam owner, which includes the Florida Department of Environmental Protection (DEP), the five regional water management districts (Northwest Florida Water Management District, Suwannee River Water Management District, St Johns River Water Management District, Southwest Florida Water Management District, and the South Florida Water Management District), the United States Army Corps of Engineers, local governments, public-private partnerships, and private entities. The DEP State Dam Safety Officer (SDSO) manages Florida's National Dam Safety Program State Assistance grant that is issued and administered by the Federal Emergency Management Agency (FEMA). The primary purpose of the grant is to provide financial assistance to strengthen the Florida Dam Safety Program to improve dam safety regulations, raise public awareness, provide training to dam owners and industry specialists, and increase emergency preparedness.

An Emergency Action Plan (EAP) is a written document that identifies critical roles and the persons in them and the specific actions they should take if an unusual or emergency event develops at a specific dam. The purpose of an EAP is to lessen the risk of dam failure and mis-operation to protect human life, and economic, environmental, and lifeline interests, and other concerns, such as water quality degradation. The dam owner is responsible to ensure that the information in the EAP is accurate and current to effectively warn and evacuate people in inundation zones should an emergency situation develop. An EAP is not a substitute for proper dam maintenance and remedial construction. Rather, it facilitates recognition of dam safety problems as they develop and it establishes procedures to follow as quickly as possible to minimize risk.

To facilitate the preparation of EAPs for dams in Florida, the FDSP developed the *Emergency Action Plan Template for Florida Dams* (EAP Template) and this companion *Emergency Action Plan Template for Florida Dams Instruction Manual* (Instruction Manual). The EAP Template includes the six basic elements recommended by the Federal Emergency Management Agency (FEMA 64: *Federal Guidelines for Dam Safety*): notification charts, emergency detection and classification, responsibilities, preparedness, inundation maps, and appendixes (training, exercises, and plan updates). The purpose of the EAP Template is to simplify the preparation of an emergency plan, reduce cost, provide consistency between individual EAPs, and identify effective lines of communication between Florida's dam owners, FDSP staff, and the Florida emergency management community. An owner(s) with several dams in the same area may develop one EAP to cover all of the dams. Each dam will need to be described separately, and there may need to be separate inundation or vicinity maps (or both) and, possibly, notification charts for each dam.

One of the critical components of an EAP is the evacuation map(s) showing the aerial extent and arrival times of expected flooding and flood depths above ground surface at structures from an assumed uncontrolled release at a dam. The evacuation map provides information for emergency personnel to respond more quickly than they would otherwise. Dam break studies provide the source information to prepare evacuation maps. However, the cost of these studies is often cited as the primary impediment to EAP development. Under some circumstances, simplified engineering methods may be used to provide useful inundation maps at a reduced cost. These inundation maps are referred to as simplified inundation maps (SIMS). Two methods to develop SIMS are: (1) Photo-Based Mapping, whereby potential at-risk structures are identified on photo-based maps without engineering analysis, and (2) Simplified Engineering Analysis using simplified engineering assumptions and methods. Each method and its appropriate application are described in the *Overview of Emergency Action Plan Preparation* section below. SIMS may be used to form the permanent basis of emergency and evacuation planning or an interim basis for such plans, until more detailed mapping can be obtained.

A Simplified Engineering Analysis was used to develop the SIMS for the "Example Dam" (an earthen dam), which is shown, along with the calculations, in Appendix A-3: *Inundation Map and Calculations*, herein. This simplified approach may be used if the downstream floodplain is relatively flat and constant. If a floodplain is highly variable, the flood wave depth can vary significantly with changes in channel geometry; for example, the flood depth can be higher than the dam height in narrow channels. In such cases, SIMS may not provide conservative inundation estimates for emergency planning purposes. The Example Dam has a floodplain with somewhat varying channel properties, but it was chosen to provide an example of the basic calculation procedures, as well as show how the analysis can be adapted for floodplains that have some variability. For dams situated above populated areas and/or complex downstream flood plains, or dams in a series, a more rigorous modeling approach with two-dimensional unsteady state flow capability, such as HEC-RAS, version 6 or later, is recommended. An inundation study using HEC-RAS, version 6, was subsequently performed for the Example Dam.

Instruction Manual Information

This Instruction Manual provides general EAP information and specific instruction for dam owners to prepare an EAP that is tailored to their dam using the EAP Template dated January 2023. This manual also provides reference material to instruct others on the use of the completed EAP. The EAP Template is a dynamic document that is meant to be modified to accommodate the owner's organizational structure and dam system. Additional information and draft EAP reviews may be requested by contacting the State Dam Safety Officer (SDSO) by mail, email or telephone through the contact information provided below.

Tracy C. Woods, P.G.
State Dam Safety Officer
Stormwater and Technical Services Program
Division of Water Resource Management
Florida Department of Environmental Protection
2600 Blair Stone Road, MS 3595
Tallahassee, FL 32399-2400
850-245-7530 (office) / 850-274-3636 (emergency cell)
Tracy.Woods@FloridaDEP.gov
https://floridadep.gov/water/engineering-hydrology-geology/content/florida-dam-safety-program

Overview of Emergency Action Plan Preparation

Coordinated planning with all parties will lay the foundation for a responsible and thorough EAP. The following 9 preparatory steps are recommended for completion of an EAP:

Step 1. Obtain the geographic and technical information for the dam and the areas downstream of the dam and perform a field reconnaissance to verify the information. These data will be used for the creation of a project location map, project watershed map, inundation map, and evacuation map. The procedures for collecting the geographic information needed to create an inundation map are included in Appendix A-3.

Step 2. Prepare inundation and evacuation maps, either based on hydrologic-hydrodynamic modeling or Photo-Based Mapping or Simplified Engineering Analysis methods. These maps are to clearly depict the estimated flooded areas from a dam break. SIMS prepared using Photo-Based Mapping and Simplified Engineering Analysis are described below.

- Photo-Based Mapping — The following procedures are used to create SIMS for dams with limited downstream development.
    - View a hardcopy or electronic copy of an USGS Quad Map and identify the contour elevation of the dam crest height. Assuming a flood inundation elevation equal to the dam crest height will provide a conservative inundation area estimate.
    - Trace the contours equal to the dam height on both downstream sides of the dam until reaching a large open body of water (such as a large regional river, lake or ocean). At this point, the flood waters are assumed to create a negligible impact on the larger water body. Draw a line from the end of one downstream inundation contour to the end of the other downstream inundation contour, following the contour of the larger water body, to define the area of inundation. Shade the enclosed area to highlight the whole inundation area.
    - Copy the outline of the inundation area onto an aerial photograph and identify the structures within the estimated inundation area.

      The two steps above may be performed simultaneously using an electronic program, such as DEP Map Direct, in which the topographic contours may be shown on the aerial view and the user can draw in the view and print out a map of the selected view. The public has free access to this program and the FDSP may be contacted for assistance in its use.
- Simplified Engineering Analysis — The following is a brief summary of the detailed instructions provided in Appendix A-3: *Inundation Maps and Calculations:*
    - Determine a Dam Breach Peak Discharge (flow rate) at the dam using a reasonable conservative estimate calculated from empirical equations.

- Estimate the peak discharge at locations of interest downstream of the dam by applying the Generalized Flood Attenuation Curves (Washington State Department of Ecology, 2007) to the Dam Breach Peak Discharge.
- Evaluate the peak flood wave depth, peak flood wave stage, and peak flood wave arrival times at the locations of interest downstream of the dam.

Detailed instructions for SIMS labeling and a Simplified Engineering Analysis and the resulting SIMS for the Example Dam are provided in Appendix A-3: *Inundation Maps and Calculations*.

Step 3. Identify those situations or triggering events that could result in an event level and require action.

Step 4. Identify all jurisdictions, agencies, and individuals who will be involved in the EAP. Contact the local emergency management's and sheriff's offices for assistance. Coordinate the development of the EAP with these other parties.

- Determine the persons who will fill the roles and responsibilities identified in the EAP Template. Identify who will be the Incident Commander during the event. The Incident Commander may change as the situation develops and different entities become involved. The Incident Commander is responsible for managing and directing persons and organizations during the emergency. Generally, the local or county Sheriff or Emergency Management Director is the Incident Commander.
- Identify who will be responsible for being the point of contact with the media (generally the Sheriff or Emergency Management Director).
- Identify who will be the primary contact for the Water Management District (WMD) and confirm that the current SDSO is listed.

Step 5. Identify primary and auxiliary communications systems, both internal (between persons at the dam) and external (between dam personnel and outside entities).

Step 6. List and prioritize the order of notification for all persons and entities involved in the notification process, and draft the Notification Charts.

Step 7. Develop a draft of the EAP using the information obtained in Steps 1 through 7 above. The recommended format is provided in the EAP Template. Request the persons with roles (minimally, the Emergency Management Director or Sheriff and SDSO) to review the draft EAP and provide comments.

Step 8. Hold at least one coordination meeting with the dam owner, local agencies, and other parties listed on the notification charts to discuss the draft EAP in detail, providing instruction and context (this Instruction Manual is a useful resource for this discussion). Request comments, corrections, questions, and concerns to provide input to consider for editing the draft EAP.

Step 9. Make any necessary revisions to finalize the EAP and distribute it digitally to at least those who have responsibilities under the plan. It is recommended that the dam owner keep the final EAP in both digital and hardcopy formats.

Specific Instructions for Completing the EAP Template

The specific instructions that follow are provided to assist the preparer with completing an EAP using the EAP Template dated January 2023. The title page, table of contents, EAP overview, sections 1 through 5, and appendices described below follow the order of the EAP Template. The preparer is advised to follow along in the EAP Template to benefit from the instructions and information provided in the following pages.

The EAP Template contains fixed information that will remain the same for the most part but may be tailored to best serve the purpose of the dam owner. The blanks indicate where information that is specific to the dam system needs to be entered. There are two styles of blanks. The first style has helpful text showing the type of information to input, e.g., Insert Directions from the West. The second style has no text because it follows the name of the information, e.g., Dam Name: . Carefully complete each blank throughout the EAP Template to provide accurate and current information.

Title Page

The title page should identify the document as an EAP and specify the dam(s) for which it is developed. It should also include the National Inventory of Dams ID (NID) number (which, if unknown, may be obtained by contacting the SDSO), the county where the dam is located, the WMD for the dam location, the type and number of an existing permit for the dam, the Downstream Hazard Potential for the dam, and the month and date the EAP is completed. The title page should also include a regional or county map and a local map showing the dam location and GPS coordinates. Once the document is reviewed and deemed complete, the dam owner or dam owner's representative will print and sign their name and date the title page. The copy number should also be recorded on the title page, with number "1" as the master EAP (this is the original EAP for the dam owner to maintain). Insert the month and year of completion in the footer, along with the page number and total page numbers. Complete the information for the header with the dam name, NID ID number, and county.

The following descriptions and links are to assist the preparer in acquiring the information required for the title page.

- National Inventory of Dams Identification Number: The NID ID number may be obtained from the SDSO, whose contact information is provided in the *Instruction Manual Information* section above. Also include the NID ID number in the dam information sheet. (Appendix A-7: *National Inventory of Dams (NID) Data*).
- Water Management District (WMD): The WMD jurisdictional boundaries are based on watershed boundaries.
    - To access any of the five WMDs, go to https://floridadep.gov/districts and select a WMD on the state map.

  - To identify the WMD for a specific dam location, go to DEP Map Direct and select the "Open Map Direct" icon. Select "ADD MAP LAYERS in the left-hand column and click on the plus sign that appears. Type "Water Management Districts" into the search bar. The search should return the "Water Management Districts (areas)" layer. Select the "Add Layer to Map" icon. Close the add data window and enter the dam address or town into the search window in the upper right-hand corner. Zoom to the dam's location to see the WMD where it is located.
- Permit Type / Number: If the dam is a permitted structure (as opposed to a dam constructed/altered before permitting rules went into effect), enter the permit type and number.
- Downstream Hazard Potential: The Downstream Hazard Potential classifications are defined in Appendix E: Glossary of Terms, in the EAP Template. Contact the SDSO for additional clarification, if needed.
- Month and Year: Enter the month and year that the EAP was completed, which is usually the month that the dam owner or dam owner's representative signs the document.
- Regional or County Map: Use Google Maps or a similar website to create the regional map. Look up the closest intersection or address to the dam and select the zoom that includes the major roads within the county or region. Verify that the map information is correct. Choose the "Map" tab in the upper righthand corner of the Google website screen for this map. Once this has been inserted onto the title page of the EAP Template, label the dam location with the dam name.
- Local Area Map: Use Google Maps or a similar website to create the local map. Look up the closest intersection or address to the dam and select the zoom option that shows the rural roads around the dam. Verify that the map information is correct. Choose the "Satellite" tab in the upper righthand corner of the Google website screen for this map. Once this has been inserted in the title page of the EAP Template, label the dam location with the dam name and GPS coordinates (in the State Plane coordinate system).

Table of Contents

The preparer will need to update the table of contents (TOC) once the information in the EAP is complete. Make the TOC "clickable" so the sections / subsections are hyperlinked to those parts of the document for quick and easy access. There are several websites where information may be found on how to create a clickable TOC. It is also advisable to keep at least two hardcopies of the EAP in a three-ring binder at the dam site and with the dam owner or dam operator. Format the document so that the pages are double-sided and each section starts on a separate front-facing page that is not the back of another section. Side and top

tabs should be utilized in the printed document to find various sections quickly and easily in the EAP. Side tabs should be used to identify the sections within the document. Top tabs should be used for the most relevant sections, or topics, needed during an event, e.g., the EAP Flow Chart, Notification Charts, Expected Actions, Inundation Maps, and Evacuation Maps. The title page may printed twice, once for the front cover and once for the report. A binder spine insert, identifying the document as an EAP, and the dam name, location, and date, may easily be created in Word.

EAP Overview

EAP Flow Chart

The EAP Flow Chart of the EAP Template presents the steps to follow from the time the event is first detected and an event level is determined to the termination and follow-up actions of an event. This specific flow chart should be included as-is in your EAP to show the procedures to follow. This flow chart serves as a quick reference to the various sections that provide more information regarding the event level determination, notification, actions, and event termination.

Summary of EAP Process

This section does not require any input, and it should remain in the EAP as-is to explain the steps to follow when an event is detected and verified. This is when the EAP is "activated."

Dam Description and Potential Impact Area Summary

This subsection includes a brief description of the purpose of the EAP, the directions to the dam, the potential impact areas, and the dam and reservoir description.

Purpose

The purpose of the EAP is to provide a systematic means to accomplish the following.

- Identify emergency conditions threatening a dam.
- Expedite effective responses to prevent a dam failure.
- Prevent or reduce loss of life and property damage should a dam failure occur.

Complete the blanks with the information indicated in each blank.

Directions to Dam

Fill in the U.S. National Grid (USNG) alphanumeric coordinate for the dam location. The National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey website, https://geodesy.noaa.gov/TOOLS/usng.html, is a useful tool where latitude and longitude coordinates may be converted to USNG. Obtain and confirm directions coming from the north, east, south, and west and enter the data in the appropriate boxes. Ensure the routes are clearly shown in the maps on the Title page or in Appendix A to aid an emergency response.

Potential Impact Area

The inundation maps to provide in Appendix A-3 are typically those showing inundation areas (rather than the entire study area) should the dam fail or be mis-operated. Typically, three hydrological scenarios are run in modeling simulations: Sunny Day and 100-Year and Probable Maximum Precipitation (PMP) storm events. Other incremental storm events, such as the 1/2-PMP storm event, may be instructional for a Professional Engineer to determine the Downstream Hazard Potential of the dam. The selected inundation maps and the evacuation map(s) should be cited by their titles in this section by editing the provided text. Fill in the blanks with the dam name.

Dam Description

For any dam description information not readily available, contact the SDSO to see if it is available from another source. If the information is not available, indicate "Unknown" in the Template. The dam data parameters are each defined in Appendix E: *Glossary of Terms.*

The following explains how to obtain data to aid in completion of this section of the EAP.

- Public Land Survey: Input the section (S), township (T), and range (R) for the dam location in the blanks. This information may be obtained by locating the dam on the DEP Map Direct website and turning on the "Public Land Survey System" layer. The public has free access to this program, and the SDSO may be contacted for assistance in its use.
- Latitude/Longitude: Enter the latitudinal and longitudinal coordinates for the centerline of the dam. This information can be obtained by locating the dam on the DEP Map Direct website and double clicking the "Draw Points" tool on the centerline of the dam and then clicking "Add to Map." The latitude and longitude of the selected location will be displayed.
- Normal Storage: See one of the following three sources of data for the normal storage.
    - As-built design plans for the dam/reservoir.
    - Reservoir storage records.
    - USGS Quad map – measure area behind dam at each contour elevation up to the contour corresponding to the normal storage elevation.

General Roles and Responsibilities

This section of the EAP should identify the following.

- Who is responsible for the operation and maintenance of the dam.
- Who is responsible for observing the dam during extreme flooding events, during holidays, on weekends, and during normal conditions.
- Who is responsible for implementing each of the required various phases of the EAP.
- Who is in charge of emergency response.
- What are the communication and coordination channels.

- Where is the location of the incident command center or emergency operating center.
- What are the lines of succession and assumptions of responsibility necessary to ensure uninterrupted emergency-response actions under any conditions.

The Template provides a list of necessary roles and responsibilities for successful EAP implementation. Complete the blanks with the person assuming each role, and affiliation, if indicated. See the following for guidance on filling out select roles.

Dam Owner's Technical Representative: Name, Affiliation

It may be appropriate to rename this role as the "Dam Operator's Technical Representative" if the dam operator is different than the dam owner and the operator has responsibility for the dam operation and maintenance. It is recommended that the Technical Representative is a Professional Engineer who is experienced in the evaluation of dam systems and has a standing contract with the dam owner/operated, if not in their employ.

Incident Commander (e.g., Sheriff, Emergency Operations Center): Name, Affiliation
This name should be obtained by calling the emergency operations center that is local to the dam location and requesting the agency and name of the person who would respond in the event of an emergency at the dam. A follow up call should be made to that person, if different than the agency contacted. Verify the responsibilities listed are correct for their role and agency.

Emergency Management Services: Name, Affiliation
The responsibilities listed in this section and under Incident Commander may be combined if that is the agency that will perform those activities. Otherwise, identify the person and affiliation for the local emergency management service. Verify the accuracy of the associated responsibilities with the responsible person.

Water Management District: Name
See https://floridadep.gov/districts for contact information for the WMD to determine the appropriate contact for inclusion in this EAP.

DEP Bureau of Emergency Response: Name, Affiliation
See https://www.floridadisaster.org/dem/ for the contact information for the Florida Division of Emergency Management to determine the appropriate contact for inclusion in the EAP.

DEP State Dam Safety Officer: Tracy Woods, P.G.

Confirm the name shown is the current SDSO and the responsibilities have not changed. Notify the SDSO that an EAP is being prepared for the particular dam owner and dam(s).

Department of Homeland Security: Name, Affiliation
No change is necessary unless the preparer knows of responsibilities specific to the dam system.

Section 1.0 Event Detection and Level Determination

Section 1.1 Event Detection
This subsection consists of a brief description of the possible ways an event may be detected. Once reported, the dam owner or operator must verify the situation and determine the appropriate event level. The language provided in the EAP Template in this section does not need revision.

Section 1.2 Event Level Determination
The EAP Template includes definitions of the three event levels and general notification requirements for each level. The EAP Template includes Table 1.1: *Event Level Determination Guidance Table* which shows a list of indicators of the onset of problems that might cause failure of the dam. There are no blanks to complete in this section, but the table may be modified should any of the concerns below be a specific concern that is not already listed.

- Slumping, sloughing, or slides on the dam or the abutment
- Cloudy or dirty seepage or seepage with an increase in flow, boils, piping, or bogs
- Seepage around conduits
- Cracks, settlement, misalignment, or sinkholes
- Erosion or riprap displacement
- Animal burrows
- Growth of trees and brush
- Failure of operating equipment
- Abnormal instrument readings
- Leakage of water into the intake tower or drop inlet
- Undermining of spillways
- Overtopping of the dam
- Sabotage

Section 1.3 Examples of Emergency Situations
Table 1.1: *Event Level Determination Guidance Table,* is included in this section to provide examples of typical event level scenarios for earthen dams. Each emergency situation is correlated to an event level. This table should be included and augmented, as necessary for the particular dam system.

Section 1.4 Site-Specific Concerns

Specify pre-existing conditions for the dam system and indicate site-specific factors or scenarios which may potentially trigger an unusual or emergency situation and activate the EAP. The items listed could include historic events, such as a previous incident or dam failure, and past actions. Historical information should be kept with the master EAP to provide additional information. These concerns could also include risks or hazards to the dam. These scenarios should include the vulnerability to appropriate known emergency conditions, such as severe thunderstorms with lightning and excessive rains, hurricanes, tornadoes, earthquakes, etc. The following have been provided as examples to provide the preparer with ideas.

- Excessive rains cause dam overtopping (or excessive erosion). This may be applicable to High Hazard Potential dams that were built with a total spillway capacity for the 100-year storm event, rather than the current capacity standard for a PMP storm event.
- The dam contains trees growing out of the embankment which have not been culled for dead growth and decaying tree stumps and voids that have not been compacted with soil.
- Historical events, any actions taken, and incident results.
- Site photographs related to site-specific concerns.

Section 2.0 Notification and Communication

Section 2.1 Notification Charts

Three notification charts, one for each event level (the event levels are described in Section 1.2 *Event Level Determination)*, are provided in this section that need to be filled out with the name, phone number, and email address for each contact. Contact information has already been provided for the Florida State Watch Office, the SDSO, and the State Highway Patrol Dispatch in the Watch and Warning Level notification charts. Find the National Weather Service (NWS) nearest to the dam location by looking on the website https://www.weather.gov/StormReady. The contact information for the regional Emergency Response Offices (EROs) may be found at website https://floridadep.gov/dle/oer. Enter the name of the locations and phone numbers for the NWS and the ERO.

Although emergency management agencies send emails through distribution lists to multiple recipients, call and confirm that each individual listed in the specific notification chart is aware of the situation. The circled numbers included on each notification chart depict the order that the dam owner or representative or operator should call the respective contacts. The SDSO may be contacted for assistance in identifying the correct contacts and their alternatives to complete the notification charts and Section 2.3: *EAP Contacts*.

The charts should clearly summarize the following information for each of the three levels.

- Who is to be notified.

- Who is responsible for notifying each owner representative and public official.
- The order in which individuals or offices are to be notified.
- Individual names, position titles, office and emergency cell phone numbers, email addresses, and alternative contacts.

Section 2.2 Prescript Messages

Prescripted messages are available for the Watch and Warning Event Levels. The preparer will need to fill in the blanks with the information indicated by the text in each blank. The fixed language may remain as is in the EAP Template or modified as needed (e.g., providing more river or stream names that might be impacted in an event). The caller delivering the message will need to choose between bolded words in some instances, e.g., **are or are not,** the inundation maps applicable to the weather condition, or the downstream river or stream, etc.

Section 2.3 EAP Contacts

A contact list is provided that needs to be completed with information for the primary and alternate contacts for each role listed. Information for the SDSO, Department of Homeland Security, the State Highway Patrol Dispatcher, and the State Watch Officer is provided. Many emergency personnel do not want their home or personnel cell phone numbers listed, so it's always a good idea to contact each person and request the contact information to include in the EAP.

Section 2.4 Dam Owner's Organization and Roles and Responsibilities

Identify the organization's dam safety personnel, roles and responsibilities in this section. For example, this section may be completed with limited organizational information to identify the owner's dam safety personnel and indicate who has authority to act as the Incident Commander until the person designated with this role in the EAP is available. The format and content are open to suit the dam owner's needs.

Section 3.0 Expected Actions

The actions to take at the dam to remedy an observed situation or prevent or delay failure after an event is first discovered are presented for each event level. Complete the blanks for each event as indicated in the descriptive text. Actions should only be undertaken under the direction of the dam owner's engineer or Technical Representative. Because of uncertainties about their effectiveness, preventative actions are usually carried out at the same time as notification of an impending failure. The EAP should identify ways of preparing for an emergency, increasing response readiness in a uniform and coordinated manner, and helping to reduce the effects of a dam failure. The goal is maximum readiness to respond in minimum time.

Potential emergencies are categorized by conditions, and specific actions to take are identified in Table 3.1: *Typical Remedial Actions* to reduce the possibility of either underreacting or

overreacting. This table is meant to be included in its entirety and augmented with site specific categories and actions, as appropriate.

Section 3.1 Unusual Event Level

In an unusual event, the situation is slowly developing, as described in Section 1.2 *Event Level Determination*. An example of a situation and general response is as follows:

- Situation: A problem has been detected at the dam which requires monitoring or action to repair or correct.
- Response: At this time, the distress condition is manageable by dam personnel. An Unusual Event Level will continue until the problem is corrected, or it progresses rapidly to a possible dam failure situation (corresponding to a Watch Event Level, as described in Section 1.2 *Event Level Determination*).

Section 3.2 Watch Event Level

Under this condition, the event situation is rapidly developing and a potential failure situation is occurring. The Watch Event Level is described in Section 1.2 *Event Level Determination*. An example of a situation and general response is included below.

- Situation: A problem has been detected that is progressively getting worse.
- Response: Efforts to correct the situation will be taken but a possibility exists that the dam could fail if these efforts are unsuccessful. There is no immediate danger; however, if conditions continue to deteriorate, the dam could fail.

Section 3.3 Warning Event Level

Under this condition, the event situation is that of an appearance of imminent dam failure or that the dam failure is in progress. The Warning Event Level is described in Section 1.2 *Event Level Determination*. An example of an anticipated failure and general response is included below.

- Failure: The owner or operator has determined that conditions will progress to failure of the dam and an uncontrollable release of the reservoir. If the failure has already occurred, the flood wave is now moving downstream. Flooding will start immediately and will continue to move downstream until water levels at the reservoir are stabilized.
- Response: Evacuation of downstream areas should continue in accordance with local plans, with the aid of the evacuation map that shows the areas expected to be inundated for the particular situation, e.g., heavy rainfall. It is normally the responsibility of local governments, under the direction of the Incident Commander, upon receiving such notification, to warn the public, make recommendations about evacuation, carry out the evacuations, and offer shelter to area residents. Sometimes, however, it is appropriate for the dam owner to warn certain individuals instead of, or in addition to, relying on local government officials, particularly with small dams that may only affect a few people or dams in remote locations.

Section 3.4 Locally Available Equipment, Labor, and Materials

A list of equipment, labor and materials that could potentially be needed to take the expected actions above should be provided in this section. The preparer should complete the record in Appendix C: *Resources Available* with the name of the services or goods, and contact and business names. The record should consider information to provide the following details, as needed.

- Support capabilities, such as personnel or organizations that can render assistance and the procedures for contacting them.
- The existence and location of supplies and equipment available for use in remedial actions, preferably as close as possible to the dam.
- Procedures for emergency purchase or procurement of supplies and equipment needed for remedial actions.
- Remedial construction and other activities to prevent a failure of the dam and who will carry them out.

Section 4.0 Termination and Follow-Up

When a situation is over that required the activation of the EAP, the declaration of an event level and subsequent required actions, the EAP operations must be terminated and follow-up procedures completed. The EAP should define these procedures. The standard language provided in this section does not need revision, but there are a few blanks to fill in, as defined in each blank.

Section 4.1 Termination Responsibilities

The EAP should identify the person responsible for terminating EAP operations and for relaying this decision to the person identified at the top of the Notification Chart. The Incident Commander is the person who typically terminates the event. The Notification Chart should also be used to notify the remaining contacts regarding the termination of the EAP. This is when the EAP is "deactivated."

Section 4.2 Follow-up

The EAP should define the person or entity responsible for assuring that the event has been properly documented and that all required forms are completed. The original event records are to be kept in the master EAP. A copy of the event records should be distributed to the dam owner's engineer or Technical Representative.

Section 5.0 EAP Distribution, Review, Revision, Training and Exercises

The following sections provide instructions for distribution, annual review and update, training, and exercises for the EAP.

Section 5.1 EAP Distribution
The text in this section may remain unchanged, and there are no blanks to fill in.

Section 5.2 EAP Annual Review and Updating
The fixed text in this section may remain unchanged, and the blanks should be completed as indicated.

Section 5.3 Training
The fixed text in this section may remain unchanged or be modified in consideration of the dam size and complexity of roles and responsibilities. The blanks should be filled in with the information identified in each blank.

Enough people should be trained to ensure adequate coverage at all times. Keep a record of training completed on the form in Appendix D-4: *Record of Training*. Schedule training for employees associated with the dam to familiarize them with the EAP by addressing the following.

- How to use the EAP.
- How to identify problems and their severity.
- How to use the notification procedures and the communications equipment.
- What resources are available.
- The importance of employees' roles during events.
- The importance of updating downstream information.

Section 5.4 EAP Exercises
It is recommended that the text in this section remain unchanged, with the exception of an annual exercise frequency for High Hazard Potential dams (see Downstream Hazard Potential in Appendix E: Glossary of Terms, in the EAP Template). Complete the blanks with the requested information.

Appendices – Maps, Forms, Resources, Supporting Data and Glossary

Each appendix description below includes instructions for completing the forms, maps, and other supporting information to include in the Template. Include Appendix -A, -B, -C, -D, and -E in the EAP, as shown in the EAP Template and described below. Consider including additional appendices, such as an alert system activation plan, or monitoring and operation plan, that will reduce the risk of an emergency and provide emergency preparedness.

Appendix A: Maps, Tables, and Details

The following appendices contain the following maps, calculations, and supplementary information.

- Appendix A-1: Project Location Map Example.
- Appendix A-2: Project Watershed Map Example.
- Appendix A-3: Simplified Engineering Analysis Calculations and SIMS.
- Appendix A-4: Plan View of Dam (Limited Distribution).
- Appendix A-5: Profile of Principal Spillway (Limited Distribution).
- Appendix A-6: Reservoir Elevation-Area-Volume and Spillway Capacity Data (Limited Distribution).
- Appendix A-7: National Inventory of Dams (NID) Data.

Create the project and watershed maps, computer generated inundation maps or SIMS, and evacuation maps and include this information as part of the EAP in Appendix A. Distribution of Appendices A-4 through A-6 should be limited to the master EAP and others who need this information, such as the dam owner's engineer, Technical Representative, and SDSO. These forms should not be included in all other copies of the EAP.

General Mapping Guidelines

The creation of multiple maps is required to complete the EAP guidelines. There are a number of items that should be included in the various maps as outlined below. The maps presented here in Appendix A are examples of SIMS and the information they should include. A number of items on each of the following example maps have been circled and numbered to identify different components that should be included on the map and a general description of that data. The actual maps created should not include these circles and numbers.

Please refer to the *Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures* (FEMA P-946) for additional elements to include in inundation maps created based on hydrologic-hydrodynamic modeling. In that guideline, also see example maps: Figure 11-8, *Example EAP map applying suggested map symbology*, and Figure 11-10, *Example of depth grid for a dam inundation with structures overlaid and attributed with maximum flood depths extracted from the depth grid.* The flooding depths above ground surface should be labeled for structures shown in inundated areas, along with the peak stage arrive times and flood velocities for each hydrologic event modeled.

There are shared map components that will be needed on all of the maps and there are also other specific items that are unique to the map on which they appear. A brief summary of the various items is presented here.

Maps to include in **Appendix A** of the EAP include the following.

1) **Project Location Map:** This map shows the general location of the dam and reservoir, typically on a regional scale.

2) **Project Watershed Map:** This map shows the watershed or basin boundaries of the dam and reservoir. This map is typically zoomed in closer to the area of the study than with the Project Location Map.

3) **Inundation and Evacuation Map(s):** The estimated inundation area from the dam breach studies is shown in the inundation and evacuation maps (which may be one in the same for SIMS). Ideally, inundation maps provide large-scale (close-up) detail of the flooded areas. Use a small-scale map as the grid index and draw boxes around the areas for the individual large-scale maps. The evacuation map(s) provides a small-scale (local to regional) view of the overall extend of inundation and optimal evacuation routes.

Shared Map Components to Include

The numbers and descriptions outlined here are identified with the same numbers on each of the maps.

1) Quick Reference Map Title: This is an abbreviated map title with larger text to quickly identify the map.

2) North Arrow and Scale: A north arrow or direction marker should be used to identify the map and project orientation. The scale bar is another required item that shows the correlation between the map and the actual distance portrayed.

3) Map Legend / Key: This critical piece of information explains the meaning of the various lines, shapes, and symbols that are used in the map.

4) Potential Flood Inundation Area: This information is required in the Inundation Map. It can optionally be included in the Project Location Map and Project Watershed Map, if the purposes of the maps are not obscured. Details for estimating the inundation area through a Simplified Engineering Analysis are provided in Appendix A-3.

5) Dam Reservoir: This is the boundary of the reservoir or water body impounded by the dam. The outline may already be present on USGS Quadrangle maps but this may need to be verified as some delineations will change over time due to various circumstances. This boundary should be well defined and should be a relatively accurate representation of the water surface acreage that is to be calculated in Appendix A-3. Though it should be well defined on the map, take caution to not thicken or distort the boundary line too much as it will skew the representation.

6) Roads and Highways: It is important to show the location of major and local roads and have them labeled. It is recommended to label all the roads on the map that are used to provide directions to the dam. The information should be consistent with the

information provided in the *Dam Description and Potential Impact Area Summary* section above.

7) Title Block: Include the name of the dam, NID ID number, county, source of the map data shown with date (i.e.-USGS Feb 2010), and the figure number and formal name of the map.

8) Base Map: This is simply the basic underlying layer of the map and may vary. Common examples include: USGS Quad maps, aerial photographs and satellite imagery, some of which may be obtained for free from online services.

Unique Map Components to Include

These numbered circles may appear on each example map but identify unique items specific to the map types as outlined here.

Project Location Map (Appendix A-1 – see example below)

1) Vicinity Map: (Also included in the Project Watershed Map) This is a smaller view frame inserted into the main project location map. This second viewport is typically zoomed out much farther than the main map to show on a broader scale, the location of the project. The vicinity map within the location map example shown in this document shows most of the state of Florida and the area of the state in which it is located.

2) County Lines and Labels: At certain scaled views or for projects near county borders, it is recommended to include the county line delineations to help identify nearby areas that may also be affected by a dam breach and may need to be involved in the EAP process.

Project Watershed Map (Appendix A-2 – see example below)

1) Vicinity Map: (also included in the Project Location Map) This is a smaller view frame inserted into the main project watershed map. This second viewport is typically zoomed out much farther than the main map to show on a broader scale, the location of the project. The vicinity map within the watershed map example shown in this document shows the county of the dam location and portions of surrounding counties.

2) Watershed / Basin Boundaries: This is the watershed or basin boundary of or surrounding the dam and reservoir. This map is typically zoomed in closer to the area of the study than with the Project Location Map. Labels and boundary lines should be used to identify the different watersheds or basins that are present in the surrounding area. These boundaries may help identify areas that could be affected by a dam breach.

Inundation Map (Appendix A-3)

These maps may consist of different kinds of base maps to show different information. There are two example maps provided below that show the potential flood inundation area; the first uses an aerial photograph and the second uses a USGS Quad map. The data included in each of the two maps are the same.

1) Flood Inundation Location: The area that is estimated to be inundated in the event of a dam breach should be shaded in on the map. Callouts that contain information about the projected inundation conditions at specific locations should be included on the map. The callouts should include the distance downstream from the dam, the peak flood wave depth, the peak flood wave stage (elevation), and the peak flood wave arrival time that could be expected. The flood depths above ground at downstream structures and peak velocities at points of interest should also be shown, if model data are available. The estimation methods and calculation forms for the SIMS Simplified Engineering Analysis are contained in Appendix A-3.

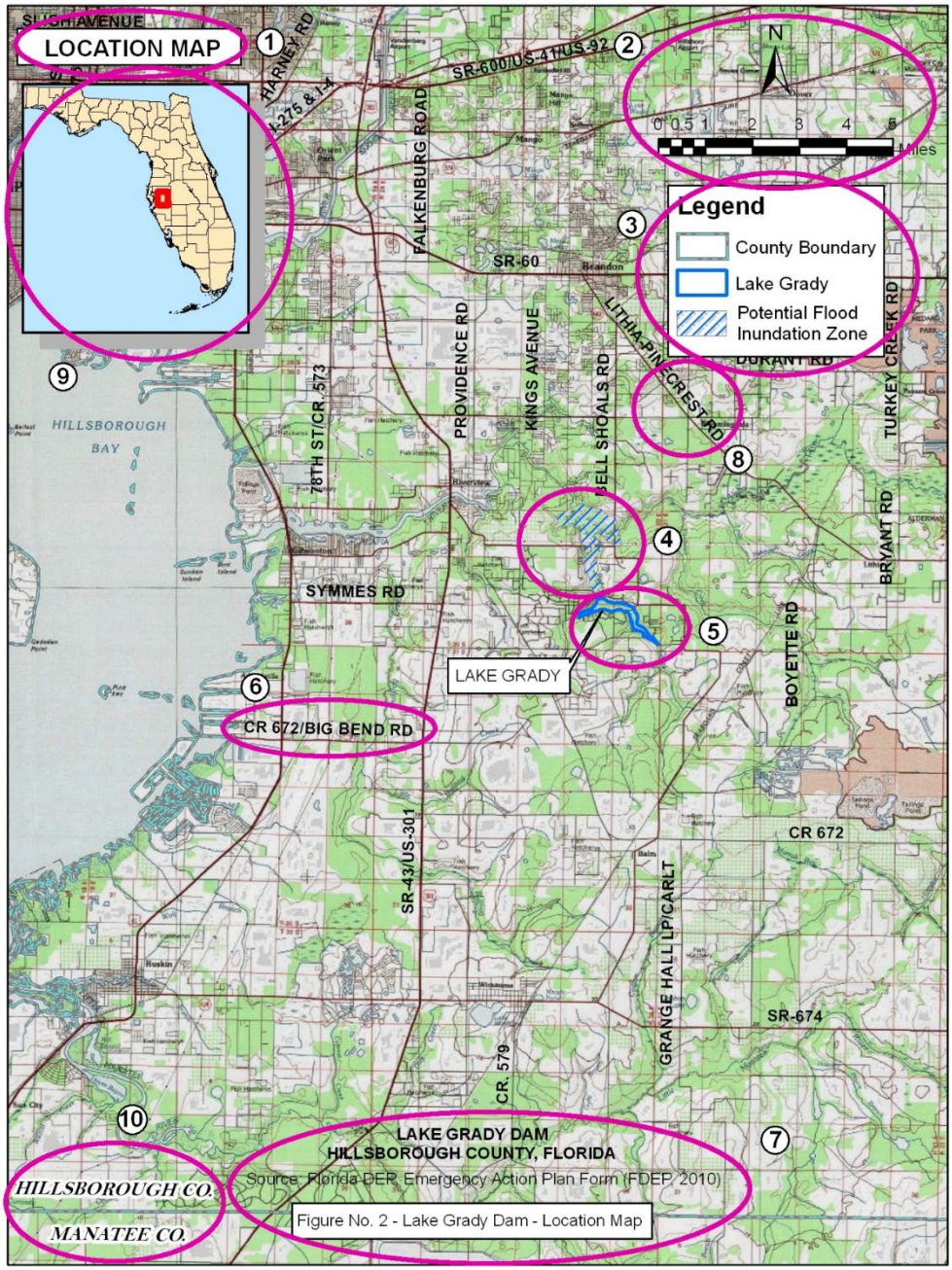
2) Reservoir/Lake Data: While the boundary of the water body should already be included (Shared Map Item Number 5), on the flood inundation map, additional information regarding the water body should also be shown. The water body (and name, if available) should be clearly labeled as well as include the elevation for which the flood breach surface acreage was calculated.

3) Points of Interest: Typically, it is beneficial to label locations such as roadways, bridges, homes, neighborhoods, nearby cities or towns, or any other structures and significant locations within the inundation area. Structures or other features within the vicinity of the dam that may serve as directional landmarks to emergency responders should also be labeled on the map.

Appendix A–1: Project Location Map

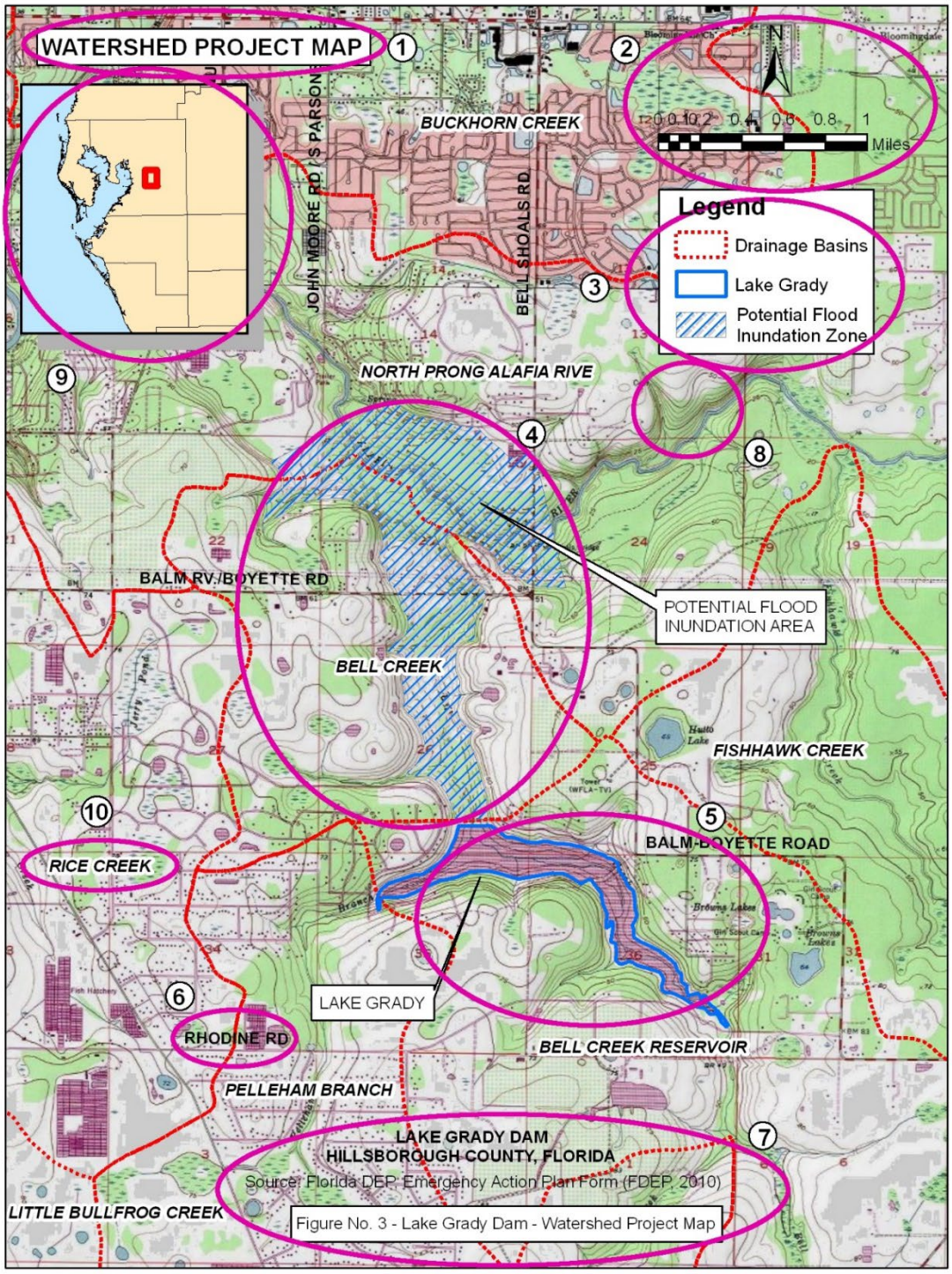
An example map has been included below and in Appendix A-2 for guidance on map elements. Obtain the USGS Quad Map in one of the following ways.

1. Download a copy of the USGS map needed from the website. (Note: Follow on-screen instructions for downloading a copy of the USGS map in your area).
2. Purchase a copy of the USGS map from one of the dealers indicated on the website.
3. Contact your closest USGS office for the ability to view their USGS map products by appointment.



Appendix A–2: Project Watershed Map

Obtain a copy of the USGS Quadrangle map in one of the methods identified in **Appendix A-1 Project Location Map.** Obtain the latest watershed areas and boundaries from your local WMD. To access any of the five WMDs, go to https://floridadep.gov/districts and select the WMD where the dam is located.



Appendix A–3: Simplified Engineering Analysis Calculations and SIMS

This appendix contains step by step instructions for collecting the geographic and dam parameter data, calculating an area of inundation using the Simplified Engineering Analysis method, and preparing Simplified Inundation Maps (SIMS). The Simplified Engineering Analysis presented below is based on empirical estimates of peak discharge at the time of dam failure. An example of completed calculations and the resulting SIMS for an "Example Dam" (an earthen dam) are included to provide guidance to the preparer.

The completed calculations and SIMS should be reported in an inundation study that is separate from the EAP. Likewise, if a hydrologic-hydraulic modeling evaluation is performed, the model input and output data and inundation and evacuation maps should be reported in a separate inundation study. Only the inundation maps (whether SIMS or from computer modeling) should be included in Appendix A-3 of the EAP. For large dam systems or a series of dams, there may be multiple inundation maps produced for the area. In such a case, it would be acceptable to only include the grid index map and the individual grid maps that show inundated structures and other features in Appendix A-3. This will reduce the size of the EAP and bring focus to the areas of concern in an emergency.

The instructions that follow are the recommended procedure for developing SIMS using the Simplified Engineering Analysis, but variations may be acceptable.

Geographic and Dam Parameter Data Collection

Topographic and Aerial Maps

Obtain a copy of the latest USGS Quad Map by using one of the methods identified in the instructions for Appendix A-l *Project Location Map.* The most current aerial photographs available of the potential inundation area should also be obtained to identify homes and structures that may be affected by a flood. Obtain a digital copy of the aerial image at the USGS Store website, https://store.usgs.gov/. Follow the on-screen instructions for the download of the aerial images.

Site Inspection

A visual inspection of the dam and its vicinity, including the downstream channel and potential impact areas, should be performed before creating a dam breach inundation map to field-verify the accuracy of the base maps and to evaluate the dam height and values for the channel morphology parameters to use in the inundation calculations. Values for the following features will be necessary at each location of interest to complete the Simplified Engineering Analysis presented below.

- Hydraulic cross-sectional area.
- Hydraulic radius.
- Average channel (bottom) slope.
- Manning's roughness coefficient.

Approximate Distance to Downstream River/Ocean

This parameter identifies the distance to the closest water body capable of absorbing or dissipating the flood wave resulting from a full dam breach. This distance is the distance the flood wave will travel before dissipating and terminating; at this point the flood wave will no longer be a threat to downstream features. The distance is estimated in feet and/or miles. Flow termination occurs when this peak flow reaches a water body with the capacity to handle this incoming flow. A water body's capacity to handle a flow generally means there will be a negligible rise in water surface elevation and/or adverse impacts such as erosion, scour, and risk to homes or structures.

Simplified Inundation Map Preparation

In preparing the Simplified Inundation map needed for the EAP, identify the dam data and the downstream channel properties in the blanks and table provided below. This information will be used in the Simplified Engineering Analysis below to calculate parameters needed to create the inundation map for the dam.

The following calculations are to be performed so the inundation map can be created. The following calculations are based on information provided in the Federal Energy Regulatory Commission's (FERC) Engineering Guidelines for the Evaluation of Hydropower Projects Chapter 2 – Selecting and Accommodating Inflow Design Floods for Dams – Appendix II-A. The calculations should be done using a calculator or computer software, and the results should be input in the blanks.

Enter the information and data for the dam below in the blanks.

Dam Name:
Latitude/Longitude:
City:
County:
Approx. Distance to Downstream River/Ocean:

$$\frac{\quad \text{feet}}{5{,}280\ \frac{\text{feet}}{\text{mile}}} = \quad \text{miles}$$

Reservoir Surface Elevation: feet

Dam Key Data Table:

Height of dam = feet
Normal storage = acre-feet
Maximum storage = acre-feet
Reservoir surface area = acres
Manning's roughness coefficient =

Enter the channel properties downstream of the dam location in the table below.

Downstream Channel Properties Table

Location i (Reach)	Distance x_i Downstream of Dam (miles)	Average Channel Bottom Slope (S) (feet/feet)	Average Channel Side Slope (z) (H:1V) (feet/feet)	Channel Bottom Elevation (b) (feet NGVD)
1				
2				
3				
4				

NGVD = National Geodetic Vertical Datum of 1929

Simplified Engineering Analysis Steps

Step 1 – Determine the peak discharge (flow rate) at the dam, referred to as the Dam Breach Peak Discharge (Q_p), using the empirical estimates available in the literature.

Empirical equations for predicting the Dam Breach Peak Discharge from a breached embankment dam have been developed by different investigators. The equations relate the peak discharge to the height and/or the volume of water behind the dam. Five empirical equations for calculating a Dam Breach Peak Discharge are considered in the SIMS engineering analysis provided below for the Example Dam: the United States Bureau of Reclamation (USBR (1988)), Evans (1986), Froehlich (1995), Pierce (2008) and the National Weather Service Simplified Dam Break Model (NWS SMPDK (1984)). A reasonably conservative value for the Dam Breach Peak Discharge should be selected from the resulting range of estimates. The five empirical equations considered are as follows.

Procedure	Empirical Equation	Units for Q_p, H and V_r
USBR (1988)	$Q_p = 75H^{1.85}$	ft^3/s and ft
Evans (1986)	$Q_p = 0.72V_r^{0.53}$	m^3/s and m^3
Froehlich (1995)	$Q_p = 40.1V_r^{0.295}H^{1.24}$	ft^3/s, acre-feet and ft
Pierce (2008)	$Q_p = 0.038V_r^{0.475}H^{1.09}$	m^3/s, m^3 and m
NWS SDBM (1984)	$Q_p = 3.1WH^{1.5}\left[\frac{C}{C+\tau H^{0.5}}\right]^3$	ft^3/s and ft

where: Q_p = Dam Breach Peak Discharge
V_r = Reservoir volume
H = Height of water in reservoir

W = Base width of breach (feet)
τ = Breach formation time (hours)
C = $23.4A_s/W$
A_s = Surface area of reservoir at H (acres)

Note 1: Degree of uncertainty in the estimated Dam Breach Peak Discharge (Q_p).

The USBR and Evans empirical equations use only one variable parameter, water height and reservoir volume, respectively, to predict the Peak Discharge from a breached embankment dam. Thus, the equations may overestimate or underestimate the Peak Discharge. The estimated Peak Discharges could have a high degree of uncertainty and should not be relied upon without comparison with estimates from multivariable empirical equations. The Pierce, the Froehlich and the NWS SMPDK empirical equations are based on multivariable relationships, using both water height and reservoir volume of water behind the dam to predict the Peak Discharge. The Pierce empirical equation is based on a multiple regression analysis of a composite database of eighty-seven (87) cases studies. According to Pierce, et al. (2010), the Pierce predictor equation is suited for practical applications where a best estimate of the Peak Discharge is desired. It yields less conservative values of Peak Discharge, compared to other regression relationships, such as the Froehlich and the NWS SMPDK predictors. For these reasons it is recommended to use several empirical equations and compare the results before selecting a Peak Discharge.

Note 2: Estimation of breach formation time (τ)

The breach formation time (τ) is usually estimated from rules of thumb:

$\tau = \frac{H}{10}$, where H is the depth (feet) of water at time of breaching and time is in minutes. This approach is based on relations in the NWS SMPDK model. The values of τ for the dams used in the model ranged from 0.1 to 2.0 hours.

$\tau = 0.02H + 0.25$, where τ is in minutes and H in meters, based on Von Thun and Gillette equations for erosion resistant dams.

$\tau = 0.00254\left[\frac{V_r^{0.53}}{H^{0.9}}\right] \times 60$; where V_r is in meter^3 and H is in meters. This approach is based on Froehlich equations.

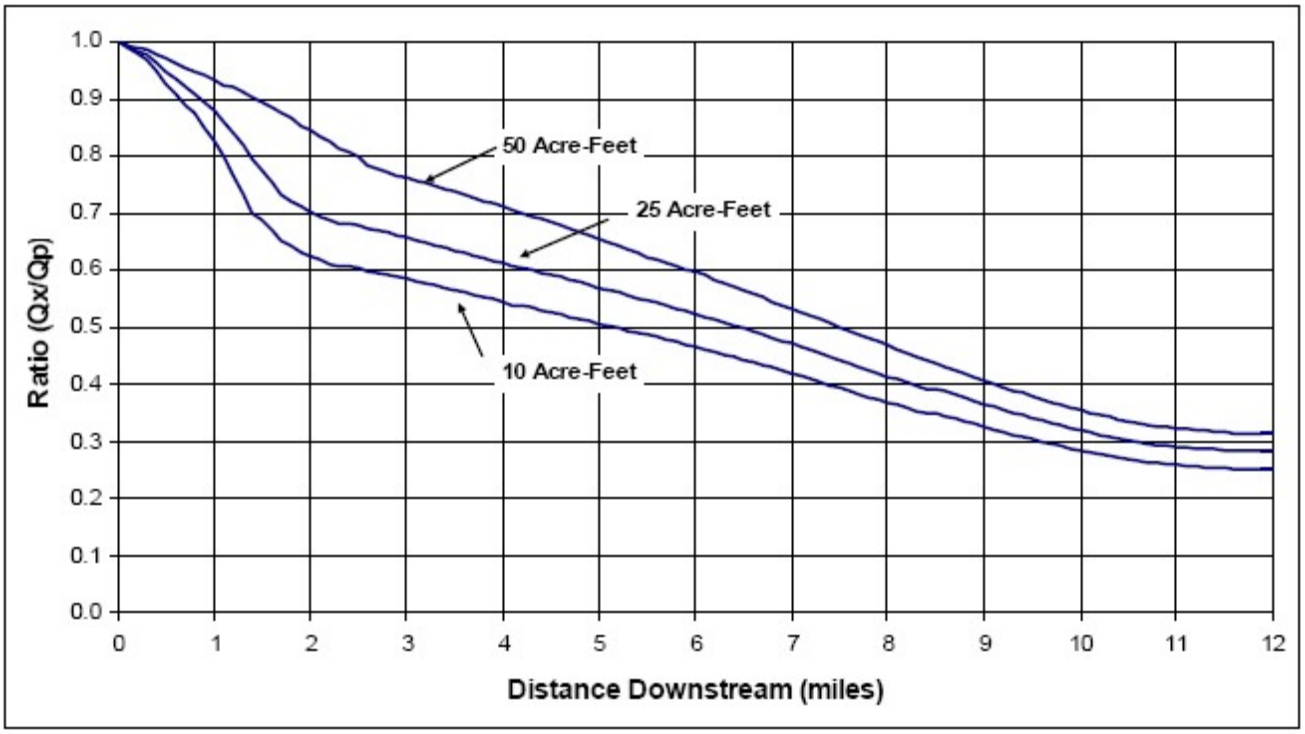
The breach formation time should be selected based on the range of values estimated from the methods, as well as personal knowledge of the conditions of the dam embankment. Verbal communication with other investigators indicates that it could take a minimum of 15 minutes for a breach to fully develop in most embankment dams.

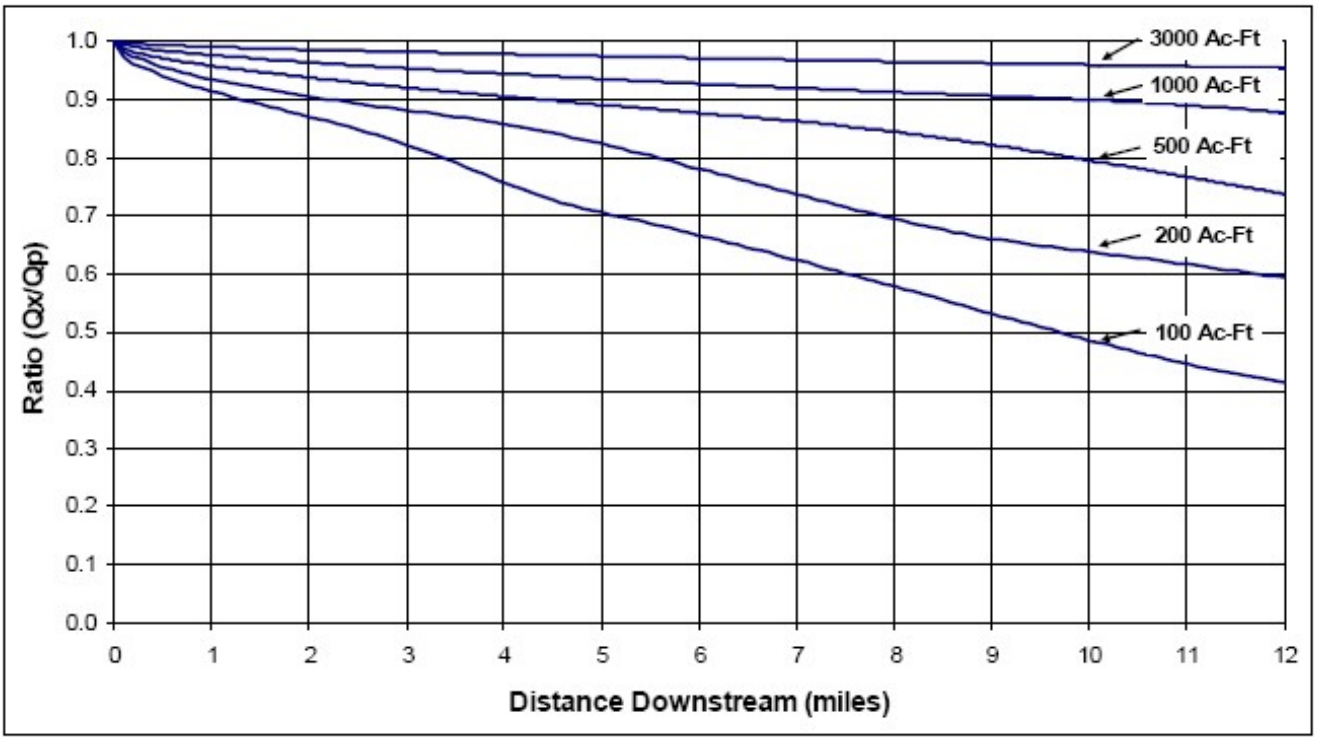
Step 2 - Determine the peak discharge (Q_i) at locations i of interest downstream of the dam. Attenuate the Dam Breach Peak Discharge (Q_p), obtained from Step 1, using the Generalized Flood Attenuation Curves shown below (Washington State Department of Ecology, 2007). Assuming the location *i* is at a distance x_i (miles) downstream of the dam, determine the peak discharge (Q_i) using the attenuation curve corresponding to the reservoir volume (acre-feet) to obtain the attenuation ratio ($Ratio(\frac{Q_i}{Q_p})$). Then, calculate Q_i using the following equation.

$$Q_i = Q_p \times Ratio(\frac{Q_i}{Q_p})$$

where: Q_i = Peak discharge (cfs) at a distance x_i downstream of dam
Ratio (Q_i/Q_p) = Reduction (ratio) of flood peak discharge at distance x_i downstream of the dam

Note: $Ratio(\frac{Q_i}{Q_p})$ is equal to the $Ratio(\frac{Q_x}{Q_p})$ in the *Generalized Flood Attenuation Curves* shown below.





GENERALIZED FLOOD ATTENUATION CURVES
Washington State Department of Ecology (2007)

Enter the results of the calculations from Step 2 in the Table below.

Q_i calculated at the four locations in table above using selected Q_p.

Location	Calculated Q_i	Ratio Qi/Qp

Step 3 - Determine peak flood wave depth (y_i) and peak flood wave arrival time (Ta_i) at the locations i downstream of the dam.

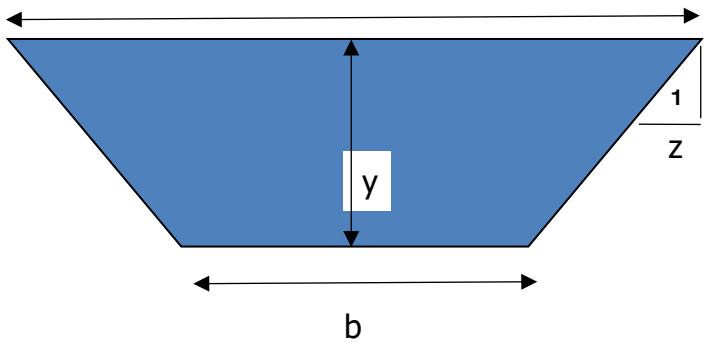
A key step in obtaining these parameters is solving Manning's equation for the peak flood wave depth (y_i) and cross-sectional area (A), using the peak discharge (Q_i) obtained from Step 2 and the flow channel cross-sectional geometry. Assume steady state flow at peak discharge.

Manning's Equation

$$Q_x = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n} \text{ OR } \quad \frac{nQ_i}{1.49S^{\frac{1}{2}}} = AR^{\frac{2}{3}}$$

where: Q_i = Peak discharge at a distance x_i downstream of the dam (cfs)
A = Flow area (hydraulic cross-sectional area) at the location i downstream of the dam (ft^2)
R = Hydraulic radius (ft)
S = Average channel (bottom) slope (ft/ft)
n = Manning's roughness coefficient

Channel Cross-Sectional Geometry
The cross-section of a typical channel is trapezoidal in shape, as shown below. The equations for determining the cross-sectional area, the hydraulic radius and the top width are as follows:



$$A = by + zy^2$$

$$R = \frac{A}{b + 2y(1 + z^2)^{0.5}}$$

$$d = b + 2zy$$

where: d = Top width, ft
b = Bottom width, ft
z = Average side slope (Horizontal: Vertical), ft/ft
y = Water depth, ft
A = Cross-sectional area, ft^2
R = Hydraulic radius, ft

The bottom and side slopes of the channel may be uniform or may vary significantly with distance downstream of the dam. For this reason, average channel properties may be estimated for the entire channel or for reaches between *i* locations. For example, an average channel bottom slope and an average side slope could be calculated for an entire channel if the channel is fairly uniform. However, different slopes could be calculated for the reaches between *i* locations where the channel slope varies.

Step 3(a) – Determine peak flood wave depth (y_i).

For each location *i*, solve the Manning's equation by a trial-and-error process. First, compute the value of the expression $\{\frac{nQ_i}{1.49S^{\frac{1}{2}}}\}$ using the peak discharge (Q_i), the Manning's roughness coefficient (n) of the channel and the channel bottom slope (S). Next, assume a value of the peak flood wave depth (y_i), calculate the corresponding cross-sectional area (A) and the hydraulic radius (R) of the channel. Then calculate the expression $\{ AR^{\frac{2}{3}}\}$. Compare the results of the expressions $\{\frac{nQ_i}{1.49S^{\frac{1}{2}}}\}$ and $\{ AR^{\frac{2}{3}}\}$. If the values are not equal, assume other values of y_i and repeat the process until there

is a close match between the values of the expressions $\{\frac{nQ_i}{1.49S^{\frac{1}{2}}}\}$ and $\{AR^{\frac{2}{3}}\}$. The value of y_i that results in a close match is the peak flood wave depth.

Note: The peak flood wave stage at each location *i* may be determined using the peak flood wave depth (y_i) as follows (this is the elevation where the peak flood wave will laterally intersect the land surface):

Peak Flood Wave Stage at Location *i*

= Peak Flood Wave Depth (y_i)
+ Channel Bottom Elevation at Location *i*

Step 3(b) - Determine the peak flood wave travel time (T_i) and the peak flood wave arrival time (Ta_i).

Suppose there are *m* locations of interest at distances *x* downstream of the dam. Each location *i* (i = 1, 2, 3,…, *m*) is at x_i distance downstream of the dam. The flood wave velocity (V_i) at location *i* can be calculated using the peak discharge (Q_i) and the channel cross-sectional area (A_i) corresponding to the peak flood wave depth (y_i) as follows:

$$V_i = \frac{Q_j}{A_i} \qquad (i = 1, 2, 3,\ldots, m)$$

The time (T_i) it takes the flood wave to travel the distance x_i is calculated as follows:

$$T_i = \sum_{i=1}^{m} \frac{(x_i - x_{i-1})}{V_i}$$

where: T_i = Flood wave travel time (*s*).

x_i = distance downstream from the dam (ft)

x_o = zero (0) feet, which is the location of the dam.

V_i = Flood velocity (ft/s) at location i downstream of the dam.

The peak flood wave arrival time (Ta_i) at location i can be determined by summing up the peak flood wave travel time and the breach formation time (τ):

$$Ta_i = T_i + \tau \quad (i = 1, 2, 3,\ldots, m)$$

Summary of Results

The detailed formulas provided above in Steps 1, 2 and 3 should be used to calculate the Peak Flood Wave Depth, Peak Flood Wave Stage, Peak Flood Wave Travel Time, and Peak Flood Wave Arrival Time for all locations identified above in the *Downstream Channel Properties Table*. These calculations will be used for the Simplified Inundation Map. Use the table below to enter the results of the simplified inundation mapping calculations for the four locations.

Location i	Distance x_i Downstream of Dam (miles)	Peak Flood Wave Depth y_i (feet)	Peak Flood Wave Stage (feet NGVD)	Peak Flood Wave Travel T_i Time (min)	Peak Flood Wave Arrival Time Ta_i (min)
1					
2					
3					
4					

Note: It is customary to add an additional two feet to the final peak flood wave depths and stages (calculated using the original peak flood wave depth) on the SIMS inundation map estimate. The addition of two feet should be footnoted. Also, the peak flood wave arrival times may be rounded down to the nearest minute.

SIMS Calculation Example

Below is an example dam with identified downstream channel properties and the calculations for the parameters needed to create the Simplified Inundation Map. A summary table of the results of the calculations is included at the end of the example. The example maps following the calculations display the results of the example below.

Example Dam Key Data Table

Height of dam = 25 feet
Normal storage = 1,360 acre-feet
Maximum storage = 1,870 acre-feet
Reservoir surface area = 164 acres
Manning's roughness coefficient = 0.09

Downstream Channel Properties Table

Location *i* (Reach)	Distance x_i Downstream of Dam miles	Average Channel Bottom Slope (*S*) ft/ft	Average Channel Side Slope (*z*) (H:1V) ft/ft	Channel Bottom Elevation (*b*) Feet NGVD
1	0.40	0.0024	28	20
2	0.60	0.0023	46	17.5
3	0.80	0.0027	29	15
4	1.15	0.0032	10	10

Simplified Engineering Analysis Calculations for the Example Dam

Step 1 – Estimate the Dam Breach Peak Discharge (Q_p) using the Key Data (see table above) and the empirical equations.

(1) USBR (1988) $Q_p = 75H^{1.85}$

$Q_p = 75(25)^{1.85}$ = 28,920 cfs

(2) Evans (1986) $Q_p = 0.72V_r{}^{0.53}$

$Q_p = 0.72(2{,}306{,}600)^{0.53}$ = 1,700 m^3/s = 59,930 cfs

(3) Froehlich (1995) $Q_p = 40.1(V_r^{0.295}H^{1.24})$

$Q_p = 40.1(1870)^{0.295}(7.6)^{1.24}$ = 20,030 cfs

(4) Pierce (2008) $Q_p = 0.038V_r{}^{0.475}H^{1.09}$

$Q_p = 0.038(2{,}306{,}600)^{0.475}(7.6)^{1.09}$ =3,650 m^3/s = 12,890 cfs

(5) NWS SMPDK Model (1984) $Q_p = 3.1WH^{1.5}\left[\frac{C}{C+\tau H^{0.5}}\right]^3$

Estimate W for earthen dam: $W = 3 \times H$ (W = 75 feet for the Example Dam)

Calculate C: $C = 23.4A_s/W = 23.4\ (164/75) = 51.168$

Estimate breach formation time (τ) using the following rules of thumb:

$\tau = H/10$ = 2.5 minutes; H is depth (feet) of water at time of breaching and time is in minutes. This approach is based on relations in the NWS SMPDK model

τ = 0.1 hours = 6 minutes (based on the lower range of the values used in the NWS SMPDK model: 0.1 to 2.0 hours)

$\tau = 0.02H + 0.25$ = 0.4 minutes (τ is in minutes and H in meters), based on Von Thun and Gillette equations for erosion resistant dams

$\tau = 0.00254\left[\frac{V_r^{0.53}}{H^{0.9}}\right] \times 60$ = 58 minutes; V_r is in meter^3 and H is in meters. This approach is based on Froehlich equations.

The breach formation times estimated above are 0.4, 2.5, 6, and 58 minutes, respectively.

Based on the site-specific conditions of the dam, a breach formation time of 15 minutes (0.25 hours) was selected. The Dam Breach Peak Discharge Q_p was then calculated using the NWS SMPDK empirical equation as follows:

$Q_p = (3.1)(75)(25^{1.5})\left[\frac{51.168}{51.168+(0.25)25^{0.5}}\right]^3$ = 27,030 cfs

Based on the range of values calculated (Pierce: 12,890; Froehlich: 20,030; NWS SMPDK: 27,030; USBR: 28,920; and Evans: 59,930 cfs), a conservative Dam Breach Peak Discharge, Q_p equal to 28,000 cfs was selected for use in the next step.

Step 2 – Determine peak discharge (Q_i) at four locations using the *Generalized Flood Attenuation Curves*.

Four downstream locations of interest, Locations 1 through 4, were established for the Example Dam. The channel properties in each reach are provided in the *Downstream Channel Properties Table* above. The Dam Breach Peak Discharge (Q_p = 28,000 cfs) was obtained from Step 1 above. Based on the reservoir maximum storage of 1,870 acre-feet (see *Example Dam Key Data Table*), approximate flood attenuation ratios (*Ratio* (Q_i/Q_p)) of 0.99 and 0.98 were obtained from the *Generalized Flood Attenuation Curves*, at downstream distances of up to 0.60 mile and 1.15 miles from the dam, respectively.

The peak discharges at Locations 1 and 2, Q_1 and Q_2, respectively, were calculated as $\{Q_1 = 0.99 \times 28{,}000\}$ and $\{Q_2 = 0.99 \times 28{,}000\}$, which are approximately 27,700 cfs. The peak discharges at Locations 3 and 4, Q_3 and Q_4, respectively, were calculated as $\{Q_3 = 0.98 \times 28{,}000\}$ and $\{Q_4 = 0.98 \times 28{,}000\}$ which are approximately 27,400 cfs.

Step 3(a) – Determine peak flood wave depth (y_i).

At x = 0.40 mile (2,112 feet), calculate $\{nQ_i/(S^{1/2})\}$ using the Example Dam Channel Properties (see table).

$$nQ_i/1.49\left(S^{1/2}\right) = \frac{(0.09)(27{,}700)}{(1.49)(0.0024)^{0.5}} = 34{,}153$$

$A = by + zy^2 \qquad R = A/[b + 2y(1 + z^2)^{0.5}]$

Assume y = 16.0 ft.

$$A = (20)(16) + (28)(16)^2 = 7{,}488$$

$$R = \frac{7{,}488}{\{20 + (2)(16)[1 + (28)^2]^{0.5}\}} = 8.1695$$

$$A\left(R^{2/3}\right) = (7{,}488)(8.1695)^{2/3} = 30{,}375 \neq 34{,}153$$

Try y =17.0 ft.

$$\mathrm{A} = (20)(17) + (28)(17)^2 = 8{,}432$$

$$\mathrm{R} = \frac{7{,}432}{\{20 + (2)(17)[1 + (28)^2]^{0.5}\}} = 8.6694$$

$$\mathrm{A}\left(\mathrm{R}^{2/3}\right) = (8{,}432)(8.6694)^{2/3} = 35{,}587 \neq 34{,}153$$

Try y = 16.7 ft.

$A = 8{,}142$; $\qquad R = 8.6694$

$$A\left(R^{2/3}\right) = 33{,}969 \cong 34{,}153$$

Peak Flood Wave Depth at Location 1 (y_1) = 16.7 ft.

$$\text{Peak Flood Wave Stage at Location 1} = \text{Peak Flood Wave Depth at Location1} + \text{Channel Bottom Elevation at Location 1}$$

$$\text{Peak Flood Wave Stage at Location 1} = 16.7 + 20 \text{ ft NGVD} = 36.7 \text{ ft NGVD}$$

Peak Flood Wave Stage at Location 1 = 36.7 ft NGVD

Step 3(b) – Determine the peak flood wave arrival time (*Ta*$_i$):

$$V_i = Q_i/A_i = \frac{27{,}700\ cfs}{8{,}143\ ft^2} = 3.4\ ft/s$$

$$T_i = x_i/V_i = \frac{2{,}112\ ft}{3.4\ ft/s} = 621\ sec = 10.4\ min$$

$$\text{Peak Flood Wave Arrival Time } (Ta_i) = \text{Flood Wave Travel Time } (T_i) + \text{Breach Formation Time}(\tau)$$

$$Ta_x = 10.4 + 15 \text{ min} = 25.4 \text{ min}$$

Peak Flood Wave Arrival Time at Location 1 (*Ta*$_1$) = 25.4 min

Summary of Results

The detailed calculations provided above for Location 1 of the downstream channel illustrate the simplified inundation mapping calculations (Steps 1, 2 and 3). The Step 3 calculations were also performed for the other three downstream locations (reaches) of the channel using the data presented in the *Downstream Channel Properties Table* and the peak discharges determined from Step 2. The table below is a summary of the results of the simplified inundation mapping calculations for the four locations.

Location i	Distance x_i Downstream of Dam (miles)	Peak Flood Wave Depth y_i (feet)	Peak Flood Wave Stage (feet NGVD)	Peak Flood Wave Travel Time T_i (min)	Peak Flood Wave Arrival Time Ta_i (min)
1	0.40	16.7	36.7	10.4	25.4
2	0.60	14.1	31.6	16.4	31.4
3	0.80	16.1	31.1	21.4	36.4
4	1.15	27.7	37.7	30.7	45.7

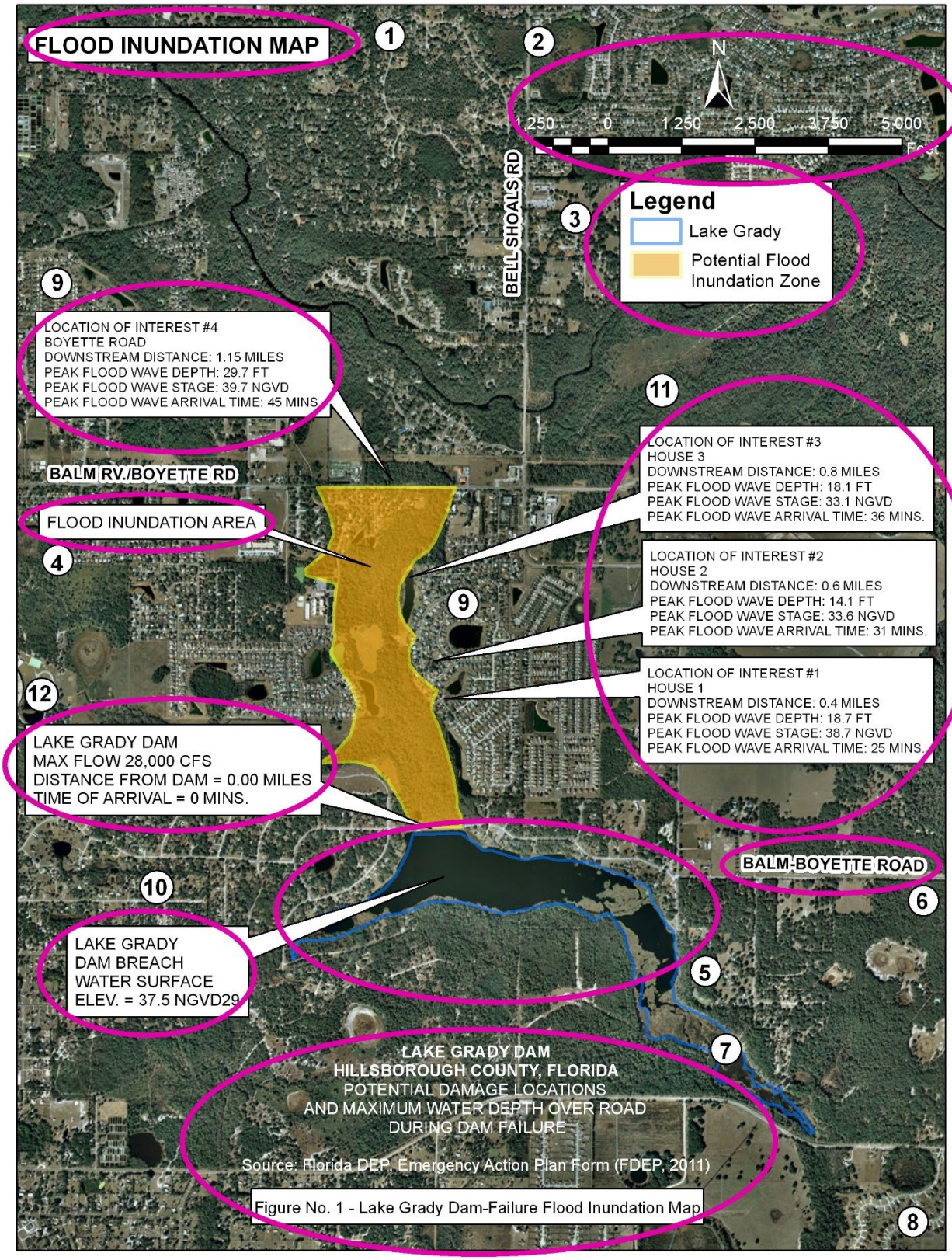
The actual results of the SIMS calculations are presented above. As mentioned above, it is customary to add an additional two feet to the peak flood wave depths and stages shown on the SIMS to provide a protective estimate. Also, the peak flood wave arrival times may be rounded down to the nearest minute.

Simplified Inundation Maps

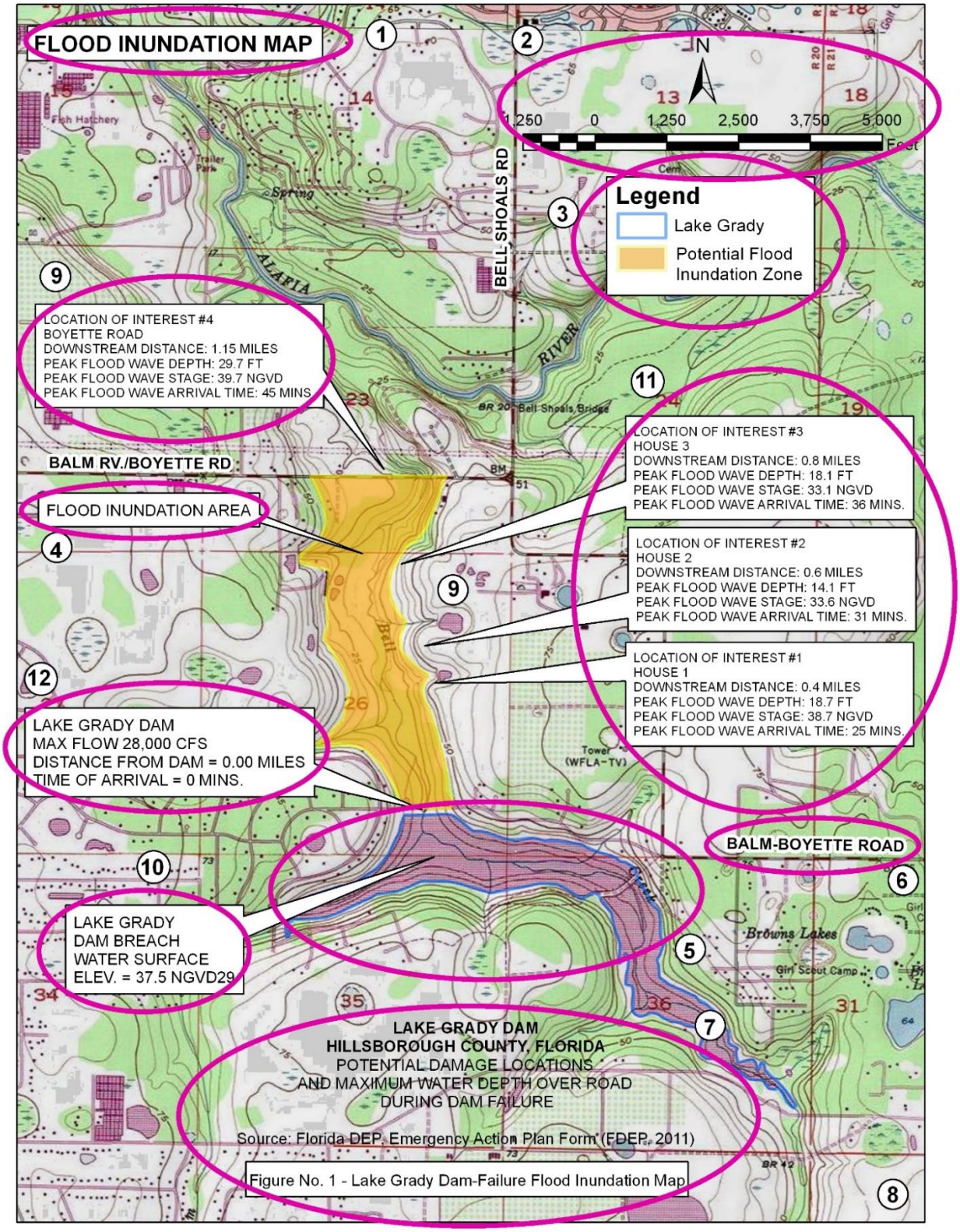
Create an inundation map or maps using either a topographic map or aerial map or both showing the shared and unique SIMS components described in the introduction of Appendix A. The shared map components consist of a quick reference map, a north arrow and scale, a map legend / key, an inundation area, the dam reservoir, roads and highways, title block, and base map. The features that are unique to the SIMS are the callouts containing the peak flood wave depth and stage and peak flood wave arrival time for each location of interest within the inundation area, the dam breach elevation, and points of interest, such as structures within the inundation area and area landmarks.

A disclaimer may be added to the inundation and excavation maps, such as the one that follows: "…the methods, procedures and assumptions used to develop the flooded areas, the limits of flooding shown and flood wave travel times are approximate and should only be used as a guideline for establishing evacuation zones. Actual areas inundated will depend on actual failure of flood conditions and may differ from areas shown on the maps…" (FERC 2007).

Appendix A–3: SIMS Example with Aerial



Appendix A–3: SIMS Example with Quad Map



Appendix A–4: Plan View of Dam

An as-built engineering drawing of the dam's plan view is acceptable to meet this requirement. If the dam owner does not have this plan, ask the WMD or SDSO to see if they have this plan. Distribution of this appendix should be limited to the master EAP and others who need this information, such as the dam owner's engineer, Technical Representative, and SDSO. A plan view of the dam should not be included in all other copies of the EAP.

Appendix A–5: Profile of Principal Spillway

As above, a profile view of the principal spillway may be the as-built engineering drawing. If the dam owner does not have this plan, ask the WMD or SDSO to see if they have this plan. Distribution of this appendix should be limited to the master EAP and others who need this information, such as the dam owner's engineer, Technical Representative, and SDSO. A profile of the principal spillway should not be included in all other copies of the EAP.

Appendix A–6: Reservoir Elevation-Area-Volume and Spillway Capacity Data

The information for the table should be available in the dam design documentation and inundation study. Fill out the information requested in the table; the table may be simplified or modified to accommodate the specific dam components, function, and capacity analysis. This appendix has limited distribution and should only be included in the EAP copies to those who need this information, such as the master EAP, dam owner's engineer, Technical Representative, and SDSO. The reservoir elevation-area-volume and spillway capacity data should not be included in all other copies of the EAP.

Appendix A–7: National Inventory of Dams (NID) Data

The definitions for the terms listed in this table are included in Appendix E: Glossary of Terms. This information may be available if the dam has been inventoried in the NID. Check the NID website, https://nid.usace.army.mil/#/, for available data and confirm the accuracy of any data found. Complete the NID data with available information.

Appendix B: Checklist, Logs, & Report

The following forms are located within this appendix.

- Appendix B-1: Information for Emergency Management.
- Appendix B-2: Action Event Log.
- Appendix B-3: Dam Event Situation Report.

Keep the blank forms in this appendix in the EAP document. Each of these forms will need to be printed or copied and filled out during an event, as described in Section 3.0, Expected Actions. After each form is filled out with the event information, retain the completed forms in the master EAP and provide a copy to each holder of the EAP. Copies of completed forms should be available, if requested.

Appendix B-1: Information for Emergency Management

The following information provides a description of each item to aid in completing this form.

- Time of Call: This is the time the caller completes the call to the Emergency Management office to notify them of an event.
- Caller name/call back phone number/caller represents: This is the name of the caller who contacted the Emergency Management Office, a phone number where the caller can be reached by the Emergency Management office and who the caller represents.
- Time/Date of incident: This is the time and date that the event occurred at the dam.
- Location of incident (dam name, street address, city, county): This is where the event occurred. Enter the dam name, street address, city and county where the event occurred.
- Has dam breakage occurred: (Yes/No): This is to identify if a dam break has occurred as part of the event.
- If no break, is it anticipated and time: This is to identify if a dam break is anticipated as part of the event. If a dam break is anticipated enter the approximate time and date that the break may occur.
- Any threat to population: This is where any threat to population would be identified. Describe the threat and approximate location.
- Evacuation (yes/no), (where & how many): This is to identify if any evacuations are necessary. Describe the location of evacuations and approximately how many evacuations are anticipated.
- Injuries (# and severity): This is to identify any injuries that have already occurred with the event. Identify the number of injuries and describe the severity of the injuries.
- Fatalities (#): This is to identify any fatalities that have occurred as a result of the event. Identify the number of fatalities that have occurred.
- What agencies are on the scene: This is to identify if any agencies have reported to the scene as a result of the event. Identify all agencies on the scene.
- Any assistance requested: This is to identify any assistance needed from Emergency Management or assistance from other agencies already requested. Identify any assistance needed from Emergency Management as a result of the event.
- Who has been notified: This is to identify all parties/agencies that have already been notified of the event.
- Water capacity of the dam: This is to identify the water capacity of the dam. Identify the amount of water capacity of the dam involved in the event.
- Staging location: This is to identify the location where any agencies and/or parties are meeting and staging to assist with the event. Identify the area that has been designated as the staging location for all parties/agencies.
- Estimated time for repairs: This is to identify the amount of time needed to make the repairs to the dam that will allow the dam to function normally. Identify the amount of time that is estimated to do the necessary repairs.

Appendix B-2: Action Event Log

The information to complete on this form serves to document the event circumstances and progression. Additional pages may be necessary for a long event or for different event levels. The weather conditions to record should include the temperature, precipitation, wind conditions, and named storm, if applicable. The descriptions of the actions and progression of the incident should be summarized with key details. Use extra pages, if necessary.

Appendix B-3: Dam Event Situation Report

This form, Appendix B-3: *Dam Event Situation Report*, is to be completed after the event has been terminated as part of the deactivation of the EAP. It is not recommended to include speculative information, particularly as to the areas impacted by dam flooding (flooding may also be attributed to a storm event) and the possible cause of the event. Complete the form with the information available. Additional information may be added later as it becomes known by initialing and dating the entries.

Appendix C: Resources Available

This form is referenced in Section 3.4, *Locally Available Equipment, Labor, and Materials*. Use this form to document the available resources and include it as Appendix C in the EAP Template. Update the form as necessary and include the updated form in the revisions of the EAP. List existing contractual agreements and budgets to facilitate obtaining these resources in an emergency.

Appendix D: Supplementary Information

The appendices listed below contain the forms to document information necessary to the distribution and maintenance of the EAP, and training on its use. Include the forms in the EAP and print or copy them, as needed.

- Appendix D-1: Record of Holders of Control Copies of this EAP.
- Appendix D-2: Concurrences.
- Appendix D-3: Record of Revisions Made to EAP.
- Appendix D-4: Record of Training.
- Appendix D-5: Simulated Event Exercises.

Appendix D-1: Record of Holders of Control Copies of this EAP

The use of this form is described in Section 5.1, *EAP Distribution*. It is to be used to record the EAP recipients each time the EAP is distributed.

Appendix D-2: Concurrences
This form is cited in Section 5.1, *EAP Distribution,* where instructions on its use are detailed. As mentioned, email responses may also serve to confirm receipt of the EAP and acceptance of a role and its associated responsibilities. Each email should be printed out and saved in the hardcopy master EAP and filed digitally with the electronic master EAP.

Appendix D-3: Record of Revisions Made to EAP
Instructions for use of this form are provided in Section 5.2 *EAP Annual Review and Updating*. The description of the revisions should be brief but thorough to indicate what was revised. Ideally, all of the EAP components should be reviewed annually. If a component was not reviewed, consider including a side note in that revision record to that effect (e.g., downstream development and inundation maps were not evaluated).

Appendix D-4: Record of Training Attendees
Use this table to document training, as instructed in Section 5.3, *Training*. An attendance report, with the names of the attendees and duration of attendance for virtual attendees may also be printed out for each training session and included in the hardcopy master EAP and filed digitally with the electronic master EAP. Note the Instructor on the attendance record.

Appendix D-5: Simulated Event Exercise
A simulated event exercise should be conducted minimally every five years and annually for High Hazard Potential dams, per Section 5.4, *EAP Exercises*. A virtual attendance report may also supplement in-person records. Note the type of exercise conducted; there are five types discussed by the Federal Energy Regulatory Commission (see website https://www.ferc.gov/sites/default/files/2020-04/chap6.pdf).

Appendix E Glossary of Terms

Include the Glossary with the terms provided and include additional terms, as necessary, for any additions to the fixed text of the EAP Template.