Virginia Dam Owner's Handbook

Virginia Department of Conservation & Recreation

VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION
Dam Safety and Floodplain Management Program
600 E. Main St., 24th Floor | Richmond, VA 23219 | 804-371-6095

(DCR-VSWCB-034) (03/14)

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Virginia Department of Conservation & Recreation

(DCR-VSWCB-034) (03/14)

VIRGINIA DAM OWNER'S HANDBOOK

2014

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VIRGINIA DAM OWNER'S HANDBOOK, 2ND EDITION

TABLE OF CONTENTS

General Information TAB

Dam Owner's Responsibilities in Virginia

2014

Dam Owner Responsibilities in Virginia 2014

Contents

Dam Owner Responsibilities in Virginia – 2014

What Dams Are Regulated?

The definition of "Impounding Structure or dam" in the Regulations defines dams that are regulated through the Virginia Department of Conservation and Recreation, Division of Dam Safety & Floodplain Management (VA DCR Dam Safety & FM) as "all dams that are six feet or greater in height and that create an impoundment capacity of 50 acre-feet or greater" and "all dams that are 25 feet or greater in height and create an impoundment capacity of 15 acre-feet or greater" with exceptions of dams already regulated or owned by the Federal Government and the exception of dams with approved mining or quarry permits through the Virginia Department of Mines, Minerals, and Energy. Dams that are used for agriculture purposes may be exempt if they comply with the criteria provided in the document provided by VA DCR Dam Safety & FM called "Agricultural Exemption Guidance."

How are Dams Regulated?

All owners of regulated dams are required to have a Certificate to Operate and Maintain (O&M Certificate) their dam through VA DCR Dam Safety & FM. The requirements on how to obtain and maintain an O&M Certificate are detailed in the Regulations. In general, the O&M Certificate renewal application set of documents should include:

1. Current Annual Inspection Report prepared by the Dam Owner's professional engineer.
2. Current Emergency Action Plan or Emergency Preparedness Plan
3. Application for Operation and Maintenance
4. Certificate Application Fee Form and Fee.

One set of each of these documents are sent to the Dam Safety Regional Engineer (See Map for determination of the Dam Safety Engineer for your dam) except for the Certificate Application Fee Form and Fee are sent to the address on the form.

These should be sent to VA DCR Dam Safety & FM at least ninety days prior to the expiration of current O&M Certificates or as soon as possible for first time O&M Certificate applications. First time Certificates have additional requirements and a dam owner should contact the Regional Dam Safety Engineer to help determine what is needed.

Regular Operation and Maintenance Certificates

A Regular O&M Certificate is generally issued for a six year period, and expires six years later on the last day of the month for the month it is issued unless conditions or new information on the dam during the six years warrants converting the Certificate to a Conditional Certificate. The Dam Safety Regional Engineer reviews the documents submitted by the owner for the O&M Certificate Application and if in the opinion of the

Dam Safety Regional Engineer the documents are complete, applicable for the dam, and meet the minimum regulatory requirements, the regional engineer passes a recommendation for issuance of a O&M Certificate for the dam by VA DCR as delegated by the Virginia Soil and Water Conservation Board. Upon approval, the DCR Director issues the O&M Certificate.

The O&M Certificate application must be prepared with the assistance of a Professional Engineer Licensed in the State of Virginia, and the contents must address all the items listed in the regulations. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided a form to assist in addressing all the required items called: DCR199-099 – Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures.

Conditional Operation and Maintenance Certificates

Conditional Certificates are issued when one or more of the minimum standards indicated in the regulations, referenced materials, or guidance documents has not been met. A Conditional O&M Certificate is for a period of up to 2 years, and expires last day of the month for the month indicated.

The Dam Safety Regional Engineer reviews the documents submitted by the owner for the Conditional O&M Certificate Application and if in the opinion of the Dam Safety Regional Engineer the documents are complete and applicable for the dam, the regional engineer passes a recommendation for issuance of a Conditional O&M Certificate for the dam to VA DCR and includes a list of deficiencies that need to be corrected in order for the dam to comply with the minimum standards and lists dates by when the corrections must be made. Upon approval, the DCR Director issues the Conditional O&M Certificate. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided a form to assist in addressing all the required items called: DCR199-099 – Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures.

Inspections Required

Inspections are required at the frequency detailed in the Regulations, as part of the O&M certificate process. Note that a Professional Engineer provided by the owner is required at times to perform the inspections, and at other times, the owner may perform the required inspection without a Professional Engineer. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided a form to address all the required items called: DCR199-098 – Annual Inspection Report for Virginia Regulated Impounding Structures.

Annually the inspection reports must be sent to the Dam Safety Regional Engineer for the current O&M Certificate to remain valid.

Emergency Action Plans & Emergency Preparedness Plans

Emergency Action Plans (EAP) or Emergency Preparedness Plans (EPP) are required with the submittal of the O&M Application, at a minimum of once every 6 years, or when updates are needed due to changes in the watershed of the dam, changes to the dam, or changes downstream of the dam as detailed in the Regulations. The EAP or EPP must be kept current in order for the current O&M Certificate to remain valid.

Dam Break Inundation Zone Mapping is a requirement to be included with the EAP and EPP. A Table Top Exercise is required at least once every 6 years and a Drill is required each year that a Table Top Exercise is not done.

To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided a form to address all the required items in the EPP called: DCR199-103 – Emergency Preparedness Plan for Low Hazard Virginia Regulated Impounding Structures. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided information on preparation of the EAP in the Emergency Action Plan section of this handbook.

Fees Required for Certificates, Extensions, Incremental Damage Analysis Review Fees, and New Dam Construction Permits

Fees required are detailed in the regulations. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM have provided a form to assist in fee submittal process called "DCR199-192 – Department of Conservation and Recreation Certificate and Permit Application Fee Form." The second page of this form is a table summarizing the applicable fees. Please note that the fees and form are sent to the address on the fee form, NOT to the Dam Safety Regional Engineer. It is helpful in the processing of the Application for you to send copies of the information contained in the fee form to the Dam Safety Regional Engineer.

Note that the fees for Incremental Damage Analysis Review are addressed in the regulations as: "Should the department determine that outside expertise to assist with the review of an incremental damage analysis is necessary, the applicant shall be responsible for the cost of such outside expertise. Such costs shall be agreed upon in advance by the department and the applicant."

Hazard Classification of Dams

As indicated in the Regulations: "For the purpose of this chapter, hazards pertain to potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities." The Hazard Classification of a dam determines the minimum spillway capacity requirements, minimum frequency of inspections by a Professional Engineer, and the amount of the Application Fees that must be submitted.

The types of downstream features in affected areas that determine Hazard Classification are detailed in the Regulations. They are:

> "1. High Hazard Potential is defined where an impounding structure failure will cause probable loss of life or serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-

volume urban streets, or other high-volume roadways.
2. Significant Hazard Potential is defined where an impounding structure failure may cause the loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways.
3. Low Hazard Potential is defined where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. "No expected loss of life" means no loss of human life is anticipated."

To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM has provided an information sheet included in the Guidance Document section of this handbook titled "Dam Classification Information." A Guidance Document is provided discussing items downstream of a dam affecting Hazard Classification titled "Roadways On or Below a Dam - Guidance." Additional Guidance on hazard Classification is in the process of being drafted and approved.

Dam Break Inundation Zone Mapping

Dam Break Inundation Zone Computer Modeling and Mapping is required for all regulated dams for Hazard Classification (Exception for dams determined to be Special Criteria Low Hazard as described in the Regulations). The Inundation Zone is the area that encompasses the affected downstream features should a dam break regardless of the current condition of the dam. This Dam Break Inundation Zone is determined using a computer model simulated dam break prepared by a Professional Engineer. The potentially impacted features such as homes, roads, commercial buildings etc. dictate and result in the Hazard Classification designations.

Dam Break Inundation Zone Mapping is required to be used in the EAP and should be used in the EPP. The Owner of a regulated dam is required to provide the Inundation Zone Mapping to the local County or City authority for inclusion into municipal mapping.

The computer model simulated dam break can be used for an Incremental Damage Analysis to determine if the minimum required spillway capacity could be lowered without increasing the hazard downstream to people or facilities. If the Owner of a dam elects to have this work done, it must be done by a Professional Engineer.

Maintenance Requirements on a Dam

To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM has provided a guidance document titled "Vegetation / Erosion on Dams Guidance." This document indicates the frequency of mowing and the removal of unacceptable vegetation such as briars and other woody vegetation. It is Virginia State Law that requires all woody vegetation be removed from a dam and from within 25' of the dam.

The general maintenance requirements for any dam will vary according to the type and condition of the dam. The ongoing maintenance requirements for all regulated dams must be detailed in the O&M Application.

A Regional Dam Safety Engineer, upon finding a dam is not maintained to the minimum safety standards or cannot be inspected, could recommend that a Regular O&M application be denied, or recommend there to be immediate action taken by the State of Virginia for severe cases.

Construction of a New Dam

The regulatory requirements for construction of a new dam can be found in the Regulations. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM has provided a form called: "Design Report for the Construction and Alteration of Virginia Regulated Impounding Structures." All documents must be submitted to the Regional Dam Safety Engineer for Review and Approval for proposed new dams. The Application Fee and completed fee form must be sent to the address listed on the Application Fee Form.

Alteration of an Existing Dam

The regulatory requirements for the alteration of an existing regulated dam are found in the Regulations. To assist the Dam Owner and the owner's Professional Engineer, VA DCR Dam Safety & FM has provided a form called: "Design Report for the Construction and Alteration of Virginia Regulated Impounding Structures." All documents must be submitted to the Regional Dam Safety Engineer for Review and Approval for proposed alterations of existing dams.

Almost any change to a dam including the dam spillways, embankment, or controls must have an approved alteration permit prior to commencing with the proposed alteration. It is advisable for the dam owner to consult with the Regional Dam Safety Engineer before doing work on the dam other than grass cutting and light brush removal.

Obtaining Services of a Professional Engineer

VA DCR Dam Safety & FM maintains a list of engineers and engineering firms that have indicated to VA DCR Dam Safety & FM that they would like to be listed as doing work on dams. This list can be provided to a Dam Owner via e-mail or regular mail upon request.

Dam Safety Regions

Virginia Department of Conservation & Recreation

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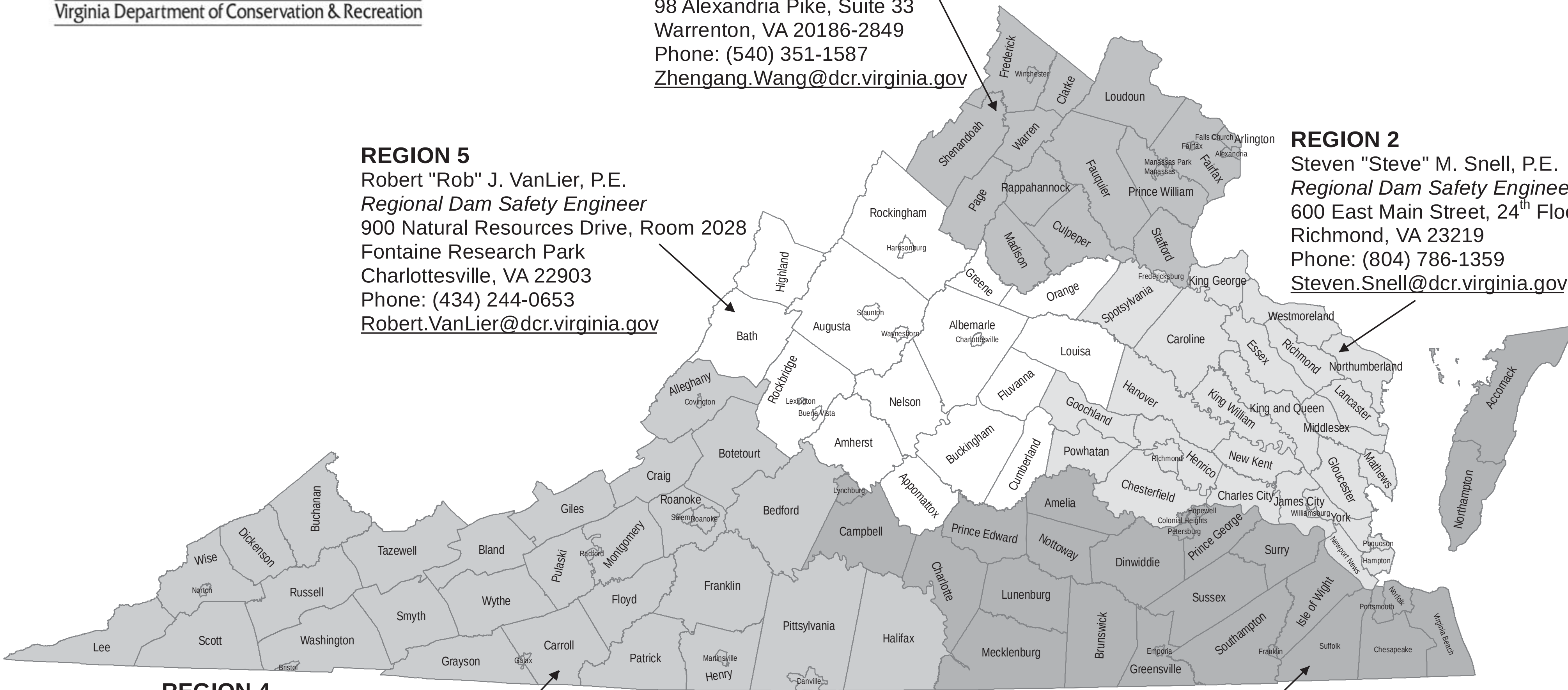

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December 4^{th}, 2014

Regulations and Laws TAB

COMMONWEALTH of VIRGINIA

Virginia Impounding Structure Regulations

(Dam Safety)

Department of Conservation and Recreation
600 E. Main Street, 24th Floor
Richmond, VA 23219-2094
(804) 371-6095

November 8, 2012

Virginia Department of Conservation & Recreation

Codes are read as:

4 VAC 50 20 ---

- --- : Section
- 20 : Chapter
- 50 : Agency
- VAC : Virginia Administrative Codes
- 4 : Titles (Natural Resources)

VIRGINIA SOIL AND WATER CONSERVATION BOARD

CHAPTER 20 – IMPOUNDING STRUCTURE REGULATIONS

TABLE OF CONTENTS

VIRGINIA SOIL AND WATER CONSERVATION BOARD

CHAPTER 20

IMPOUNDING STRUCTURE REGULATIONS

Part I - General

4VAC50-20-10. Authority.

This chapter is promulgated by the Virginia Soil and Water Conservation Board in accordance with the provisions of the Dam Safety Act, Article 2, Chapter 6, Title 10.1 (§ 10.1-604 et seq.), of the Code of Virginia.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 1.1, eff. February 1, 1989.

4VAC50-20-20. General provisions.

A. This chapter provides for the proper and safe design, construction, operation and maintenance of impounding structures to protect public safety. This chapter shall not be construed or interpreted to relieve the owner or operator of any impoundment or impounding structure of any legal duties, obligations or liabilities incident to ownership, design, construction, operation or maintenance.

B. Approval by the board of proposals for an impounding structure shall in no manner be construed or interpreted as approval to capture or store waters. For information concerning approval to capture or store waters, see Chapter 8 (§ 62.1-107) of Title 62.1 of the Code of Virginia, and other provisions of law as may be applicable.

C. In promulgating this chapter, the board recognizes that no impounding structure can ever be completely "fail-safe," because of incomplete understanding of or uncertainties associated with natural (earthquakes and floods) and manmade (sabotage) destructive forces; with material behavior and response to those forces; and with quality control during construction.

D. All engineering analyses required by this chapter, including but not limited to, plans, specifications, hydrology, hydraulics and inspections shall be conducted or overseen by and bear the seal of a professional engineer licensed to practice in Virginia.

E. Design, inspection and maintenance of impounding structures shall be conducted utilizing competent, experienced, engineering judgment that takes into consideration factors including but not limited to local topography and meteorological conditions.

F. The forms noted in this chapter are available from the department at the department's website.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 1.2, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-30. Definitions.

The following words and terms when used in this chapter shall have the following meanings unless the context clearly indicates otherwise:

"Acre-foot" means a unit of volume equal to 43,560 cubic feet or 325,853 gallons (equivalent to one foot of depth over one acre of area).

"Agricultural purpose" means the production of an agricultural commodity as defined in § 3.2-3900 of the Code of Virginia that requires the use of impounded waters.

"Agricultural purpose dams" means impounding structures which are less than 25 feet in height or which create a maximum impoundment smaller than 100 acre-feet, and operated primarily for agricultural purposes.

"Alteration" means changes to an impounding structure that could alter or affect its structural integrity. Alterations include, but are not limited to, changing the height or otherwise enlarging the dam, increasing normal pool or principal spillway elevation or physical dimensions, changing the elevation or physical dimensions of the emergency spillway, conducting necessary structural repairs or structural maintenance, or removing the impounding structure. Structural maintenance does not include routine maintenance.

"Alteration permit" means a permit required for any alteration to an impounding structure.

"Annual average daily traffic" or "AADT" means the total volume of vehicle traffic of a highway or road for a year divided by 365 days and is a measure used in transportation planning and transportation engineering of how busy a road is.

"Board" means the Virginia Soil and Water Conservation Board.

"Conditional Operation and Maintenance Certificate" means a certificate required for impounding structures with deficiencies.

"Construction" means the construction of a new impounding structure.

"Construction permit" means a permit required for the construction of a new impounding structure.

"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

"Department" means the Virginia Department of Conservation and Recreation.

"Design flood" means the calculated volume of runoff and the resulting peak discharge utilized in the evaluation, design, construction, operation and maintenance of the impounding structure.

"Director" means the Director of the Department of Conservation and Recreation or his designee.

"Drill" means a type of emergency action plan exercise that tests, develops, or maintains skills in an emergency response procedure. During a drill, participants perform an in-house exercise to verify telephone numbers and other means of communication along with the owner's response. A drill is considered a necessary part of ongoing training.

"Emergency Action Plan or EAP" means a formal document that recognizes potential impounding structure emergency conditions and specifies preplanned actions to be followed to minimize loss of life and property damage. The EAP specifies actions the owner must take to minimize or alleviate emergency conditions at the impounding structure. It contains procedures and information to assist the owner in issuing early warning and notification messages to responsible emergency management authorities. It shall also contain dam break inundation zone maps as required to show emergency management authorities the critical areas for action in case of emergency.

"Emergency Action Plan Exercise" means an activity designed to promote emergency preparedness; test or evaluate EAPs, procedures, or facilities; train personnel in emergency management duties; and demonstrate operational capability. In response to a simulated event, exercises should consist of the performance of duties, tasks, or operations very similar to the way they would be performed in a real emergency. An exercise may include but not be limited to drills and tabletop exercises.

"Emergency Preparedness Plan" means a formal document prepared for Low Hazard impounding structures that provides maps and procedures for notifying owners of downstream property that may be impacted by an emergency situation at an impounding structure.

"Existing impounding structure" means any impounding structure in existence or under a construction permit prior to July 1, 2010.

"Freeboard" means the vertical distance between the maximum water surface elevation associated with the spillway design flood and the top of the impounding structure.

"Height" means the hydraulic height of an impounding structure. If the impounding structure spans a stream or watercourse, height means the vertical distance from the natural bed of the stream or watercourse measured at the downstream toe of the impounding structure to the top of the impounding structure. If the impounding structure does not span a stream or watercourse, height means the vertical distance from the lowest elevation of the downstream limit of the barrier to the top of the impounding structure.

"Impounding structure" or "dam" means a man-made structure, whether a dam across a watercourse or structure outside a watercourse, used or to be used to retain or store waters or other materials. The term includes: (i) all dams that are 25 feet or greater in height and that create an impoundment capacity of 15 acre-feet or greater, and (ii) all dams that are six feet or greater in height and that create an impoundment capacity of 50 acre-feet or greater. The term "impounding structure" shall not include: (a) dams licensed by the State Corporation Commission that are subject to a safety inspection program; (b) dams owned or licensed by the United States government; (c) dams operated primarily for agricultural purposes which are less than 25 feet in height or which create a maximum impoundment capacity smaller than 100 acre-feet; (d) water or silt retaining dams approved pursuant to § 45.1-222 or 45.1-225.1 of the Code of Virginia; or (e) obstructions in a canal used to raise or lower water.

"Impoundment" means a body of water or other materials the storage of which is caused by any impounding structure.

"Life of the impounding structure" and "life of the project" mean that period of time for which the impounding structure is designed and planned to perform effectively, including the time required to remove the structure when it is no longer capable of functioning as planned and designed.

"Maximum impounding capacity" means the volume of water or other materials in acre-feet that is capable of being impounded at the top of the impounding structure.

"New construction" means any impounding structure issued a construction permit or otherwise constructed on or after July 1, 2010.

"Normal or typical water surface elevation" means the water surface elevation at the crest of the lowest ungated outlet from the impoundment or the elevation of the normal pool of the impoundment if different than the water surface elevation at the crest of the lowest ungated outlet. For calculating sunny day failures for flood control impounding structures, stormwater detention impounding structures, and related facilities designed to hold back volumes of water for slow release, the normal or typical water surface elevation shall be measured at the crest of the auxiliary or emergency spillway.

"Operation and Maintenance Certificate" means a certificate required for the operation and maintenance of all impounding structures.

"Owner" means the owner of the land on which an impounding structure is situated, the holder of an easement permitting the construction of an impounding structure and any person or entity agreeing to maintain an impounding structure. The term "owner" may include the Commonwealth or any of its political subdivisions, including but not limited to sanitation district commissions and authorities, any public or private institutions, corporations, associations, firms or companies organized or existing under the laws of this Commonwealth or any other state or country, as well as any person or group of persons acting individually or as a group.

"Planned land use" means land use that has been approved by a locality or included in a master land use plan by a locality, such as in a locality's comprehensive land use plan.

"Spillway" means a structure to provide for the controlled release of flows from the impounding structure into a downstream area.

"Stage I Condition" means a flood watch or heavy continuous rain or excessive flow of water from ice or snow melt.

"Stage II Condition" means a flood watch or emergency spillway activation or impounding structure overtopping where a failure may be possible.

"Stage III Condition" means an emergency spillway activation or impounding structure overtopping where imminent failure is probable.

"Sunny day dam failure" means the failure of an impounding structure with the initial water level at the normal reservoir level, usually at the lowest ungated principal spillway elevation or the typical operating water level.

"Tabletop Exercise" means a type of emergency action plan exercise that involves a meeting of the impounding structure owner and the state and local emergency management officials in a conference room environment. The format is usually informal with minimum stress involved. The exercise begins with the description of a simulated event and proceeds with discussions by the participants to evaluate the EAP and response procedures and to resolve concerns regarding coordination and responsibilities.

"Top of the impounding structure" means the lowest point of the nonoverflow section of the impounding structure.

"Watercourse" means a natural channel having a well-defined bed and banks and in which water normally flows.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 1.3, eff. February 1, 1989; amended, Virginia Register Volume 18, Issue 14, eff. July 1, 2002; Volume 24, Issue 25, eff. September 26, 2008; Volume 27, Issue 6, eff. December 22, 2010; Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-40. Hazard potential classifications of impounding structures.

A. Impounding structures shall be classified in one of three hazard classifications as defined in subsection B of this section and Table 1.

B. For the purpose of this chapter, hazards pertain to potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. Hazard potential classifications of impounding structures are as follows:

1. High Hazard Potential is defined where an impounding structure failure will cause probable loss of life or serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways, except those having an AADT volume of 400 vehicles or less in accordance with 4VAC50-20-45.

2. Significant Hazard Potential is defined where an impounding structure failure may cause the loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to,

secondary highways, low-volume urban streets, service roads, or other low-volume roadways, except those having an AADT volume of 400 vehicles or less in accordance with 4VAC50-20-45.

3. Low Hazard Potential is defined where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. "No expected loss of life" means no loss of human life is anticipated.

C. To support the appropriate hazard potential classification, dam break analysis shall be conducted by the owner's engineer or the department in accordance with one of the following alternatives and utilizing procedures set out in 4VAC50-20-54.

1. The owner of an impounding structure that does not currently hold a regular or conditional certificate from the board, or the owner of an impounding structure that is already under certificate but the owner believes that a condition has changed downstream of the impounding structure that may reduce its hazard potential classification, may request in writing that the department conduct a simplified dam break inundation zone analysis to determine whether the impounding structure has a low hazard potential classification. The owner shall pay a fee to the department in accordance with 4VAC50-20-395 for conducting each requested analysis. The department shall address requests in the order received and shall strive to complete analysis within 90 days; or

2. The owner may propose a hazard potential classification that shall be subject to approval by the board. To support the proposed hazard potential classification, an analysis shall be conducted by the owner's engineer and submitted to the department. The hazard potential classification shall be certified by the owner.

D. Findings of the analysis conducted pursuant to subsection C of this section shall result in one of the following actions:

1. For findings by the department resulting from analyses conducted in accordance with subdivision C 1 of this section:

a. If the department finds that the impounding structure appears to have a low hazard potential classification, the owner may be eligible for general permit coverage in accordance with 4VAC50-20-103.

b. If the department finds that the impounding structure appears to have a high or significant hazard potential classification, the owner's engineer shall provide further analysis in accordance with the procedures set out in 4VAC50-20-54 and this chapter. The owner may be eligible for grant assistance from the Dam Safety, Flood Prevention and Protection Assistance Fund in accordance with Article 1.2 (§ 10.1-603.16 et seq.) of Chapter 6 of Title 10.1 of the Code of Virginia.

2. For findings by the owner's engineer resulting from analyses conducted in accordance with subdivision C 2 of this section:

a. If the engineer finds that the impounding structure has a low hazard potential classification, the owner may be eligible for general permit coverage in accordance with 4VAC50-20-103; or

b. If the engineer finds that the impounding structure appears to have a high or significant hazard potential classification, then the owner shall comply with the applicable certification requirements set out in this chapter.

E. An incremental damage analysis in accordance with 4VAC50-20-52 may be utilized as part of a hazard potential classification by the owner's engineer.

F. Impounding structures shall be subject to reclassification by the board as necessary.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 1.4, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008; Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-45. Hazard potential classifications based on low volume roadways.

A. All impacted public and private roadways downstream or across an impounding structure shall be considered in determining hazard potential classification. To determine whether a road is impacted by a dam failure, one of the following methodologies shall be utilized:

1. Section IV, Part D of the United States Department of Interior, Bureau of Reclamation's ACER Technical Memorandum No. 11, 1988;

2. An approach to determining impacts to roadways found in any document that is on the list of acceptable references set out in 4VAC50-20-320. The owner's engineer shall reference the methodology utilized in their submittal to the department; or

3. An approach to determine any roadway that would be overtopped, at any depth, by a dam failure under any flood or nonflood condition, including but not limited to probable maximum flood, spillway design flood, or flood from sunny day dam failure, as determined using analysis procedures set out in 4VAC50-20-54.

In all cases, an owner may use an incremental damage analysis conducted in accordance with 4VAC50-20-52 to further refine what roads should be considered impacted.

B. In certain cases, an impounding structure may qualify for a low hazard potential classification in spite of a potential impact to a downstream public or private roadway. If a roadway is found to be impacted in accordance with subsection A of this section, and other factors such as downstream residences, businesses, or other concerns as set forth in this chapter that would raise the hazard potential classification do not exist, such classification may be adjusted in accordance with this section dependent on vehicle traffic volume, based on AADT.

C. For the purposes of determining AADT volume, one of the following techniques may be utilized using data obtained within the last year except as otherwise set out in subdivision 1 of this subsection:

1. The AADT volumes available in the most recent published Daily Traffic Volume Estimates from the Virginia Department of Transportation (VDOT) for the road segment nearest the impounding structure may be utilized. This information is available from VDOT at http://www.virginiadot.org/info/ct-TrafficCounts.asp;

2. Data developed by a local government may be utilized where the locality conducts its own traffic counts;

3. Where AADT volumes are not available from VDOT or a locality, an Average Daily Traffic trip rate that meets the standards set forth in the Institute for Traffic Engineers (ITE) Trip Generation information report, 8th Edition, 2008 (available for ordering online at http://www.ite.org/emodules/scriptcontent/orders/ProductDetail.cfm?pc=IR-016F) may be utilized if practicable; or

4. In all cases, average daily traffic volumes may also be established by a traffic count that meets VDOT standards and is conducted or overseen by the owner's engineer or otherwise approved by the department's regional engineer.

D. Where it can be demonstrated that a public or private roadway has limited usage and that the hazard potential classification is being determined based solely upon impacts to roadways, the roadway may be considered to be "limited use" and the impounding structure may be considered a low hazard potential impounding structure despite the presence of the roadway. Such roadways, located either across or below an impounding structure, are those that result in an AADT volume of 400 vehicles or less.

Where a downstream analysis finds that multiple limited use roadways may be impacted by an impounding structure failure, the traffic volumes of those limited use roadways, determined in accordance with subsection B of this section, shall be combined for the purposes of determining the impounding structure's hazard potential classification unless it can be demonstrated that the traffic using each of the roadways is composed of substantially the same vehicle trips, such that the combined number of individual vehicle trips utilizing all of the roadways would result in an AADT of 400 or less.

E. Although a roadway may be considered to have a "limited use" in accordance with subsection D of this section, the Emergency Preparedness Plan for the low hazard impounding structure shall clearly outline a reliable and timely approach for notification of the proper local emergency services by the dam owner regarding the hazards of continued use of the road during an emergency condition.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-50. Performance standards required for impounding structures.

A. In accordance with the definitions provided by § 10.1-604 of the Code of Virginia and 4VAC50-20-30, an impounding structure shall be regulated if the impounding structure is 25 feet or greater in height and creates a maximum impounding capacity of 15 acre-feet or greater, or the impounding structure is six feet or greater in height and creates a maximum impounding capacity of 50 acre-feet or greater and is not otherwise exempt from regulation by the Code of Virginia. Impounding structures exempted from this chapter are those that are:

1. Licensed by the State Corporation Commission that are subject to a safety inspection program;

2. Owned or licensed by the United States government;

3. Operated primarily for agricultural purposes that are less than 25 feet in height or that create a maximum impoundment capacity smaller than 100 acre-feet;

4. Water or silt-retaining dams approved pursuant to § 45.1-222 or 45.1-225.1 of the Code of Virginia; or

5. Obstructions in a canal used to raise or lower water.

Impounding structures of regulated size and not exempted shall be constructed, operated and maintained such that they perform in accordance with their design and purpose throughout the life of the project. For impounding structures, the spillway(s) capacity shall perform at a minimum to safely pass the appropriate spillway design flood as determined in Table 1. For the purposes of utilizing Table 1, Hazard Potential Classification shall be determined in accordance with 4VAC50-20-40.

TABLE 1 Impounding Structure Regulations			
Applicable to all impounding structures that are 25 feet or greater in height and that create a maximum impounding capacity of 15 acre-feet or greater, and to all impounding structures that are six feet or greater in height and that create a maximum impounding capacity of 50 acre-feet or greater and is not otherwise exempt from regulation by the Code of Virginia.			
Hazard Potential Class of Dam	Spillway Design Flood (SDF)[B] for New Construction[F]	Spillway Design Flood (SDF)[B] for Existing Impounding Structures[F, G]	Minimum Threshold for Incremental Damage Analysis
High	PMF[C]	0.9 PMP[H]	100-YR[D]
Significant	.50 PMF	.50 PMF	100-YR[D]
Low	100-YR[D]	100-YR[D]	50-YR[E]

B. The spillway design flood (SDF) represents the largest flood that need be considered in the evaluation of the performance for a given project. The impounding structure shall perform so as to safely pass the appropriate SDF. Reductions in the established SDF may be evaluated through the use of incremental damage analysis pursuant to 4VAC50-20-52. The SDF established for an impounding structure shall not be less than those standards established elsewhere by state law or regulations, including but not limited to the Virginia Stormwater Management Program (VSMP) Permit Regulations (4VAC50-60). Due to potential for future development in the dam break inundation zone that would necessitate higher spillway design flood standards or other considerations, owners may find it advisable to consider a higher spillway design flood standard than is required.

C. PMF: Probable Maximum Flood is the flood that might be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The PMF is derived from the current probable maximum precipitation (PMP) available from the National Weather Service, NOAA. In some cases, a modified PMF may be calculated utilizing local topography, meteorological conditions, hydrological conditions, or PMP values supplied by NOAA. Any deviation in the application of established developmental procedures must be explained and justified by the owner's engineer. The owner's engineer must develop PMF hydrographs for 6-, 12-, and 24-hour durations. The hydrograph that creates the largest peak outflow is to be used to determine capacity for nonfailure and failure analysis. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

D. 100-Yr: 100-year flood represents the flood magnitude expected to be equaled or exceeded on the average of once in 100 years. It may also be expressed as an exceedence probability with a 1.0% chance of being equaled or exceeded in any given year. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

E. 50-Yr: 50-year flood represents the flood magnitude expected to be equaled or exceeded on the average of once in 50 years. It may also be expressed as an exceedence probability with a 2.0% chance of being equaled or exceeded in any given year. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

F. For the purposes of Table 1 "Existing impounding structure" and "New construction" are defined in 4VAC50-20-30.

G. An existing impounding structure as defined in 4VAC50-20-30, that is currently classified as high hazard, or is subsequently found to be high hazard through reclassification, shall only be required to pass the flood resulting from 0.6 PMP instead of the flood resulting from the 0.9 PMP SDF if the dam owner meets the requirements set out in 4VAC50-20-53.

H. PMP: Probable maximum precipitation means the theoretically greatest depth of precipitation for a given duration that is meteorologically possible over a given size storm area at a particular geographical location at a particular time of year with no allowance made for future long-term climatic trends. In practice, this is derived over flat terrain by storm transposition and moisture adjustment to observed storm patterns. In Virginia, the 0.9 PMP is meant to characterize the maximum recorded rainfall event within the Commonwealth.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 1.5, eff. February 1, 1989; amended, Virginia Register Volume 18, Issue 14, eff. July 1, 2002; Volume 24, Issue 25, eff. September 26, 2008; Errata, 25:3 VA.R. 542 October 13, 2008; amended, Virginia Register Volume 27, Issue 6, eff. December 22, 2010.

4VAC50-20-51. Special criteria for certain low hazard impounding structures.

A. Notwithstanding the requirements of this chapter, should the failure of a low hazard potential impounding structure cause no expected loss of human life and no economic damage to any property except property owned by the impounding structure owner, then the owner may follow the below requirements instead of the requirements specified in this chapter:

1. No map required pursuant to 4VAC50-20-54 shall be required to be developed for the impounding structure should a licensed professional engineer certify that the impounding structure is a low hazard potential impounding structure and eligible to utilize the provisions of this section;

2. The spillway design flood for the impounding structure is recommended as a minimum 50-year flood; however, no specific spillway design flood shall be mandatory for an impounding structure found to qualify under the requirements of this section;

3. No emergency preparedness plan prepared pursuant to 4VAC50-20-177 shall be required. However, the impounding structure owner shall notify the local emergency services coordinator in the event of a failure or emergency condition at the impounding structure;

4. An owner shall perform inspections of the impounding structure annually in accordance with the requirements of 4VAC50-20-105. No inspection of the impounding structure by a licensed professional engineer shall be required, however, so long as the owner certifies at the time of operation and maintenance certificate renewal that conditions at the impounding structure and downstream are unchanged since the last inspection conducted by a licensed professional engineer; and

5. No certificate or permit fee established in this chapter shall be applicable to the impounding structure.

B. Any owner of an impounding structure electing to utilize the requirements of subsection A of this section shall otherwise comply with all other requirements of this chapter applicable to low hazard impounding structures.

C. The owner shall notify the department immediately of any change in circumstances that would cause the impounding structure to no longer qualify to utilize the provisions of this section.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-52. Incremental damage analysis.

A. The proposed potential hazard classification for an impounding structure may be lowered based on the results of an incremental damage analysis utilizing one of the following methodologies:

1. Section III of the United States Department of Interior, Bureau of Reclamation's ACER Technical Memorandum No. 11, 1988. An impact shall be deemed to occur where there are one or more lives in jeopardy as a result of a dam failure; or

2. An approach to determining hazard classification found in any document that is on the list of acceptable references set out in 4VAC50-20-320. The owner's engineer shall reference the methodology utilized in the submittal to the department.

B. The proposed spillway design flood for the impounding structure may be lowered based on the results of an incremental damage analysis. Once the owner's engineer has determined the required spillway design flood through application of Table 1, further analysis may be performed to evaluate the limiting flood condition for incremental damages. Site-specific conditions should be recognized and considered. In no situation shall the allowable reduced level be less than the level at which the incremental increase in water surface elevation downstream due to failure of an impounding structure is no longer considered to present an additional downstream threat. This engineering analysis will need to present water surface elevations at each structure that may be impacted downstream of the dam. An additional downstream threat to persons or property is presumed to exist when water depths exceed two feet or when the product of water depth (in feet) and flow velocity (in feet per second) is greater than seven.

The spillway design flood shall also not be reduced below the minimum threshold values as determined by Table 1.

C. The proposed potential hazard classification for the impounding structure and the required spillway design flood shall be subject to reclassification by the board as necessary to reflect the incremental damage assessment, changed conditions at the impounding structure, and changed conditions in the dam break inundation zone.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-53. Special criteria for reduced SDF requirement for certain high hazard dams.

A. An existing impounding structure that is currently classified as high hazard, or is subsequently found to be high hazard through reclassification, shall be allowed to pass the flood resulting from 0.6 PMP instead of the flood resulting from 0.9 PMP SDF if the dam owner certifies annually that such impounding structure meets each of the following conditions:

1. The owner has a current emergency action plan that is approved by the board and that is developed and updated in accordance with 4VAC50-20-175;

2. The owner has exercised the emergency action plan in accordance with 4VAC50-20-175 and conducts a table-top exercise at least once every two years;

3. The department has verification that both the local organization for emergency management and the Virginia Department of Emergency Management have on file current emergency action plans and updates for the impounding structure;

4. The conditions at the impounding structure are monitored on a daily basis and as dictated by the emergency action plan;

5. The impounding structure is inspected at least annually by a professional engineer and all observed deficiencies are addressed within 120 days of such inspection. Such inspection reports shall be completed in accordance with 4VAC50-20-105 E and be submitted to the department with the owner's certification;

6. The owner has a dam break inundation zone map developed in accordance with the regulations that is acceptable to the department;

7. The owner is insured in an amount that will substantially cover the costs of downstream property losses to others that may result from a dam failure; and

8. The owner has the impounding structure's emergency action plan posted on his website, or upon the request of the owner, the department or another state agency responsible for providing emergency management services to citizens agrees to post the plan on its website. If the department or another state agency agrees to post the plan on its website, the owner shall provide the plan in a format suitable for posting.

A dam owner who meets the conditions of subdivisions 1 through 8 of this subsection, but has not provided record drawings to the department for his impounding structure, shall submit a complete record report developed in accordance with 4VAC50-20-70 J, excluding the required submittal of the record drawings.

B. The dam owner must retain documents for a six-year period that supports the certification of the elements set out in subsection A.

Statutory Authority

§10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 27, Issue 6, eff. December 22, 2010.

4VAC50-20-54. Dam break inundation zone mapping.

A. Dam break inundation zone maps and analyses shall be provided to the department, except as provided for in 4VAC50-20-51, to meet the requirements set out in 4VAC50-20-40, 4VAC50-20-175, and 4VAC50-20-177, as applicable. In accordance with subsection G of this section, a simplified dam break inundation zone map and analysis may be completed by the department and shall be provided to the impounding structure's owner to assist such owner in complying with the requirements of this chapter. All analyses shall be completed in accordance with 4VAC50-20-20 D.

B. The location of the end of the inundation mapping should be indicated where the water surface elevation of the dam break inundation zone and the water surface elevation of the spillway design flood during an impounding structure nonfailure event converge to within one foot of each other. The inundation maps shall be supplemented with water surface profiles showing the peak water surface elevation prior to failure and the peak water surface elevation after failure.

C. All inundation zone map(s) shall be signed and sealed by a licensed professional engineer.

D. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered in determining the classification.

E. For determining the hazard potential classification, an analysis including, but not limited to, those hazards created by flood and nonflood dam failures shall be considered. At a minimum, the following shall be provided to the department:

1. A sunny day dam break analysis utilizing the volume retained at the normal or typical water surface elevation of the impounding structure;

2. A dam break analysis utilizing the spillway design flood with a dam failure;

3. An analysis utilizing the spillway design flood without a dam failure; and

4. A dam break analysis utilizing the probable maximum flood with a dam failure.

F. To meet the Emergency Action Plan requirements set out in 4VAC50-20-175 and the Emergency Preparedness Plan requirements set out in 4VAC50-20-177, all owners of impounding structures shall provide dam break inundation zone map(s) representing the impacts that would occur with both a sunny day dam failure and a probable maximum flood with a dam failure.

1. The map(s) shall be developed at a scale sufficient to graphically display downstream inhabited areas and structures, roads, public utilities that may be affected, and other pertinent structures within the identified inundation area. In coordination with the local organization for emergency management, a list of downstream inundation zone property owners and occupants, including telephone numbers may be plotted on the map or may be provided with the map for reference during an emergency.

2. Each map shall include the following statement: "The information contained in this map is prepared for use in notification of downstream property owners by emergency management personnel."

Should the department prepare a dam break inundation zone map and analysis in response to a request received pursuant to 4VAC50-20-40 C, the owner shall utilize this map to prepare a plan in accordance with this subsection.

G. Upon receipt of a written request in accordance with 4VAC50-20-40 C and receipt of a payment in accordance with 4VAC50-20-395, the department shall conduct a simplified dam break inundation zone analysis. In conducting the analysis, a model acceptable to the department shall be utilized. The analysis shall result in maps produced as Geographic Information System shape files for viewing and analyzing and shall meet the other analysis criteria of this section.

Upon completion of the analysis, the department shall issue a letter to the owner communicating the results of the analysis including the dam break inundation zone map, stipulating the department's finding regarding hazard potential classification based on the information available to the department, and explaining what the owner needs to do procedurally with this information to be compliant with the requirements of the Dam Safety Act (§ 10.1-604 et seq.) and this chapter.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended, Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-58. Local government notifications.

For each certificate issued, the impounding structure owner shall send a copy of the certificate to the appropriate local government(s) with planning and zoning responsibilities. A project description and the map(s) required under 4VAC50-20-54 showing the area that could be affected by the impounding structure failure shall be submitted with the certificate. The department will provide a standard form cover letter for forwarding the certificate copy and accompanying materials.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-59. Reporting.

For the purposes of categorizing and reporting information to national and other dam safety databases, impounding structure size shall be classified as noted in Table 2.

Table 2
Impounding Structure Regulations

Maximum Impounding Capacity (Ac-Ft)	Height (Ft)
Large ≥ 50,000	≥ 100
Medium ≥ 1,000 & < 50,000	≥ 40 & < 100
Small ≥ 15 & < 1,000	≥ 6 & < 40

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

Part II
Permit Requirements

4VAC50-20-60. Required permits.

A. No person or entity shall construct or begin to construct a new impounding structure until the board has issued a construction permit.

B. No person or entity shall alter or begin to alter an existing impounding structure until the board has issued an alteration permit. If an owner or the owner's engineer has determined that circumstances are impacting the integrity of the impounding structure that could result in the imminent failure of the impounding structure, temporary repairs may be initiated prior to approval from the board. The owner shall notify the department within 24 hours of identifying the circumstances impacting the integrity of the impounding structure. Such emergency notification shall not relieve the owner of the need to obtain an alteration permit as soon as may be practicable, nor shall the owner take action beyond that necessary to address the emergency situation.

C. When the owner submits an application to the board for any permit to construct or alter an impounding structure, the owner shall also inform the local government jurisdiction or jurisdictions that might be affected by the permit application.

D. In evaluating construction and alteration permit applications the director shall use the design criteria and standards referenced in 4VAC50-20-320.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 2.1, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-70. Construction permits.

A. Prior to preparing the complete design report for a Construction Permit, applicants may submit a preliminary design report to the department to determine if the project concept is acceptable to the department. The preliminary design report should contain, at a minimum, a general description of subdivisions 1 through 12 of subsection B of this section and subdivisions 1 and 2 of this subsection:

1. Proposed design criteria and a description of the size of the impounding structure, ground cover conditions, extent of current upstream development within the watershed and the hydraulic, hydrological and structural features, geologic conditions and the geotechnical engineering assumptions used to determine the foundation, impoundment rim stability and materials to be used.

2. Preliminary drawings of a general nature, including cross sections, plans and profiles of the impounding structure, proposed pool levels and types of spillway(s).

B. An applicant for a Construction Permit shall submit a design report. A form for the design report is available from the department (Design Report for the Construction or Alteration of Virginia Regulated Impounding Structures). The design report shall be prepared in accordance with 4VAC50-20-240. The design report is a required element of a complete application for a Construction Permit and shall include the following information:

1. Project information including a description of the proposed construction, name of the impounding structure, inventory number if available, name of the reservoir, and the purpose of the reservoir.

2. The proposed hazard potential classification in conformance with Table 1 of 4VAC50-20-50.

3. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude.

4. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication.

5. Owner's engineer's name, firm, professional engineer Virginia number, mailing address, and business telephone number.

6. Impounding structure data including type of material (earth, concrete, masonry or other) and the following design configurations:

a. Top of impounding structure (elevation);

b. Downstream toe – lowest (elevation);

c. Height of impounding structure (feet);

d. Crest length – exclusive of spillway (feet);

e. Crest width (feet);

f. Upstream slope (horizontal to vertical); and
g. Downstream slope (horizontal to vertical).

7. Reservoir data including the following:
a. Maximum capacity (acre-feet);

b. Maximum pool (elevation);

c. Maximum pool surface area (acres);

d. Normal capacity (acre-feet);

e. Normal pool (elevation);

f. Normal pool surface area (acres); and

g. Freeboard (feet).

8. Spillway data including the type, construction material, design configuration, and invert elevation for the low level drain, the principal spillway, and the emergency spillway.

9. Watershed data including drainage area (square miles); type and extent of watershed development; time of concentration (hours); routing procedure; spillway design flood used and

state source; design inflow hydrograph volume (acre-feet), peak inflow (cfs), and rainfall duration (hours); and freeboard during passage of the spillway design flood (feet).

10. A description of properties located in the dam break inundation zone downstream from the site of the proposed impounding structure, including the location and number of structures, buildings, roads, utilities and other property that would be endangered should the impounding structure fail.

11. Evidence that the local government or governments have been notified of the proposal by the owner to build an impounding structure.

12. Maps showing the location of the proposed impounding structure that include: the county or city in which the proposed impounding structure would be located, the location of roads and access to the site, and the outline of the impoundment. Existing aerial photographs or existing topographic maps may be used for this purpose.

13. A report of the geotechnical investigations of the foundation soils, bedrock, or both and of the materials to be used to construct the impounding structure.

14. Design assumptions and analyses sufficient to indicate that the impounding structure will be stable during its construction and during the life of the impounding structure under all conditions of impoundment operations, including rapid filling, flood surcharge, seismic loadings, and rapid drawdown of the impoundment.

15. Evaluation of the stability of the impoundment rim area to safeguard against impoundment rim slides of such magnitude as to create waves capable of overtopping the impounding structure and evaluation of rim stability during seismic activity.

16. Design assumptions and analyses sufficient to indicate that seepage in, around, through or under the impounding structure, foundation and abutments will be reasonably and practically controlled so that internal or external forces or results thereof will not endanger the stability and integrity of the impounding structure. The design report shall also include information on graded filter design.

17. Calculations and assumptions relative to hydraulic and structural design of the spillway or spillways and energy dissipater or dissipaters. Spillway capacity shall conform to the criteria of Table 1 and 4VAC50-20-52.

18. Provisions to ensure that the impounding structure and appurtenances will be protected against unacceptable deterioration or erosion due to freezing and thawing, wind, wave action, and rain or any combination thereof.

19. Other pertinent design data, assumptions and analyses commensurate with the nature of the particular impounding structure and specific site conditions, including when required by this chapter, a plan and water surface profile of the dam break inundation zone.

20. A description of the techniques to be used to divert stream flow during construction so as to prevent hazard to life, health and property, including a detailed plan and procedures to maintain a stable impounding structure during storm events, a drawing showing temporary diversion devices, and a description of the potential impoundment during construction. Such diversion plans shall also be in accordance with applicable environmental laws.

21. A plan for project construction monitoring and quality control testing to confirm that construction materials and performance standards meet the design requirements set forth in the specifications.

22. Plans and specifications as required by 4VAC50-20-310.

23. Certification by the owner's engineer that the information provided pursuant to this subsection is true and correct in their professional judgment. Such certification shall include the engineer's signature, printed name, Virginia number, date, and the engineer's Virginia seal.

24. Owner's signature certifying receipt of the information provided pursuant to this subsection.

C. A plan of construction is a required element of a complete permit application for a Construction Permit and shall include:

1. A construction sequence with milestones.

2. Elements of the work plan that should be considered include, but are not limited to, foundation and abutment treatment, stream or river diversion, excavation and material fill processes, phased fill and compaction, testing and control procedures, construction of permanent spillway and drainage devices.

3. The erosion and sediment control plan, as approved by the local government, which minimizes soil erosion and sedimentation during all phases of construction.

4. The stormwater management plan or stormwater management facility plan, as approved by the local government, if the impounding structure is a stormwater management best management practice.

D. A Temporary Emergency Action Plan is a required element of a complete application for a Construction Permit and shall include:

1. A notification list of state and local emergency response agencies;

2. Provisions for notification of potentially affected residences and structures;

3. Construction site evacuation routes; and

4. Any other special notes particular to the project.

E. Within 120 days of receipt of a complete Construction Permit Application the board shall act on the application. If the application is not acceptable, the director shall inform the applicant within 60 days of receipt and shall explain what changes are required for an acceptable application. A complete Construction Permit Application consists of the following:

1. A final design report, submitted on the department form (Design Report for the Construction or Alteration of Virginia Regulated Impounding Structures), with attachments as needed, and certified by the owner and the owner's engineer;

2. A plan of construction that meets the requirements of subsection C of this section; and

3. A Temporary Emergency Action Plan that meets the requirements of subsection D of this section.

F. Prior to and during construction the owner shall provide the director with any proposed changes from the approved design, plans, specifications, or plan of construction. Approval shall be obtained from the director prior to the construction or installation of any changes that will affect the integrity or impounding capacity of the impounding structure.

G. The Construction Permit shall be valid for the plan of construction specified in the Construction Permit Application.

H. Construction must commence within two years after the permit is issued. If construction does not commence within two years after the permit is issued, the permit shall expire, except that the applicant may petition the board for extension of the two-year period and the board may extend such period for good cause with an appropriately updated plan of construction and Temporary Emergency Action Plan.

I. The board, the director, or both may take any necessary action consistent with the Dam Safety Act (§ 10.1-604 et seq. of the Code of Virginia) if any terms of this section or of the permit are violated, if the activities of the owner are not in accordance with the approved plans and specifications, if construction is conducted in a manner hazardous to downstream life or property, or for other cause as described in the Act.

J. Within 90 days after completion of the construction of an impounding structure, the owner shall submit:

1. A complete set of record drawings signed and sealed by a licensed professional engineer and signed by the owner:

2. A complete Record Report (Record Report for Virginia Regulated Impounding Structures) signed and sealed by a licensed professional engineer and signed by the owner that includes:

a. Project information including the name and inventory number of the structure, name of the reservoir, and whether the report is associated with a new or old structure;

b. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;

c. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;

d. Information on the design report, including who it was prepared by, the date of design report preparation, whether it was for new construction or for an alteration, and the permit issuance date;

e. Owner's engineer's name, firm, professional engineer Virginia number, mailing address, and business telephone number;

f. Impounding structure data including type of material (earth, concrete, masonry or other) and the following configurations:

(1) Top of impounding structure (elevation);

(2) Downstream toe – lowest (elevation);

(3) Height of impounding structure (feet);

(4) Crest length – exclusive of spillway (feet);

(5) Crest width (feet);

(6) Upstream slope (horizontal to vertical); and

(7) Downstream slope (horizontal to vertical).
g. Reservoir data including the following:

(1) Maximum capacity (acre-feet);

(2) Maximum pool (elevation);

(3) Maximum pool surface area (acres);

(4) Normal capacity (acre-feet);
(5) Normal pool (elevation);

(6) Normal pool surface area (acres); and
(7) Freeboard (feet).

h. Spillway data including the type, construction material, design configuration, and invert elevation for the low level drain, the principal spillway, and the emergency spillway; a description of the low level drain and principal spillway including dimensions, trash guard information, and orientation of intake and discharge to impounding structure if looking downstream; and a description of the emergency spillway including dimensions and orientation to impounding structure if looking downstream;

i. Watershed data including drainage area (square miles); type and extent of watershed development; time of concentration (hours); routing procedure; spillway design flood used and state source; design inflow hydrograph volume (acre-feet), peak inflow (cfs), and rainfall duration (hours); and freeboard during passage of the spillway design flood (feet);

j. Impounding structure history including the date construction was completed, who it was designed by and the date, who it was built by and the date, who performed inspections and dates, description of repairs, and confirmation as to whether the impounding structure has ever been overtopped;

k. A narrative describing the impounding structure procedures for operation, maintenance, filling, emergency action plan implementation, and structure evaluation;

l. A narrative describing the hydraulic and hydrologic data on the spillway design flood, hydrologic records, flood experience, flood potential, reservoir regulation, and comments or recommendations regarding these attributes;

m. A narrative describing stability of the foundation and abutments, embankment materials, and a written evaluation of each;

n. A complete set of record drawings signed and sealed by a licensed professional engineer and signed by the owner;

o. Certification by the owner's engineer that the information provided pursuant to subdivision J 2 of this section is true and correct in their professional judgment. Such certification shall include the engineer's signature, printed name, Virginia number, date, and the engineer's Virginia seal; and

p. Owner's signature certifying receipt of the information provided pursuant to subdivision J 2 of this section.

3. Certification from the licensed professional engineer who has monitored construction of the impounding structure during construction that, to the best of the engineer's judgment, knowledge and belief, the impounding structure and its appurtenances were constructed in conformance with the plans, specifications, drawings and other requirements approved by the board;

4. Operation and Maintenance Certificate Application (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures) in accordance with 4VAC50-20-105; and

5. Emergency Action Plan or Emergency Preparedness Plan in accordance with 4VAC50-20-175 or 4VAC50-20-177.

K. Upon completion of construction, the impoundment may be filled upon board issuance of an Operation and Maintenance Certificate.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 2.2, eff. February 1, 1989; amended, Virginia Register Volume 18, Issue 14, eff. July 1, 2002; Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-80. Alterations permits.

A. Alterations which would potentially affect the structural integrity of an impounding structure include, but are not limited to, changing the height or otherwise enlarging the dam, increasing normal pool or principal spillway elevation or physical dimensions, changing the elevation or physical dimensions of the emergency spillway, conducting necessary repairs or structural maintenance, or removing the impounding structure. Structural maintenance does not include routine maintenance.

B. An applicant for an Alteration Permit shall submit a design report. A form for the design report is available from the department (Design Report for the Construction or Alteration of Virginia Regulated Impounding Structures). The design report shall be prepared in accordance with 4VAC50-20-240. The design report shall include, but not be limited to, the following information:

1. Project information including a description and benefits of the proposed alteration, name of the impounding structure, inventory number if available, name of the reservoir, and the purpose of the reservoir.

2. The hazard potential classification in conformance with Table 1 in 4VAC50-20-50.

3. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude.

4. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication.

5. Owner's engineer's name, firm, professional engineer Virginia number, mailing address, and business telephone number.

6. Impounding structure data including type of material (earth, concrete, masonry or other) and the following configurations (note both existing and design configurations for each):

a. Top of impounding structure (elevation);

b. Downstream toe – lowest (elevation);

c. Height of impounding structure (feet);

d. Crest length – exclusive of spillway (feet);

e. Crest width (feet);

f. Upstream slope (horizontal to vertical); and

g. Downstream slope (horizontal to vertical).

7. Reservoir data including the following (note both existing and design configurations for each):

a. Maximum capacity (acre-feet);

b. Maximum pool (elevation);

c. Maximum pool surface area (acres);

d. Normal capacity (acre-feet);

e. Normal pool (elevation);

f. Normal pool surface area (acres); and

g. Freeboard (feet).

8. Spillway data including the type, construction material, design configuration, and invert elevation for the low level drain, the principal spillway, and the emergency spillway.

9. Watershed data including drainage area (square miles); type and extent of watershed development; time of concentration (hours); routing procedure; spillway design flood used and state source; design inflow hydrograph volume (acre-feet), peak inflow (cfs), and rainfall duration (hours); and freeboard during passage of the spillway design flood (feet).

10. Evidence that the local government has been notified of the alteration and repair plan.

11. Plans and specifications as required by 4VAC50-20-310. The plan view of the impounding structure site should represent all significant structures and improvements that illustrate the location of all proposed work.

12. A report of the geotechnical investigations of the foundation soils, bedrock, or both in the areas affected by the proposed alterations and of the materials to be used to alter the impounding structure.

13. Design assumptions and analyses sufficient to indicate that the impounding structure will be stable during the alteration of the impounding structure under all conditions of reservoir operations.

14. Calculations and assumptions relative to design of the improved spillway or spillways, if applicable.

15. Provisions to ensure that the impounding structure and appurtenances during the alteration will be protected against unacceptable deterioration or erosion due to freezing and thawing, wind, wave action and rain or any combination thereof.

16. Other pertinent design data, assumptions and analyses commensurate with the nature of the particular impounding structure and specific site conditions, including when required by this chapter, a plan and water surface profile of the dam break inundation zone.

17. If applicable, a description of the techniques to be used to divert stream flow during alteration work so as to prevent hazard to life, health and property, including a detailed plan and procedures to maintain a stable impounding structure during storm events, a drawing showing temporary diversion devices, and a description of the potential impoundment during the alteration. Such diversion plans shall be in accordance with the applicable environmental laws.

18. A plan for project construction monitoring and quality control testing to confirm that materials used in the alteration work and that performance standards meet the design requirements set forth in the specifications.

19. Certification by the owner's engineer that the information provided pursuant to this subsection is true and correct in their professional judgment. Such certification shall include the engineer's signature, printed name, Virginia number, date, and the engineer's Virginia seal.

20. Owner's signature certifying receipt of the information provided pursuant to this subsection.

C. A plan of construction is a required element of complete permit application and shall include:

1. A construction sequence with milestones.

2. Elements of the work plan that should be considered include, but are not limited to, foundation and abutment treatment, excavation and material fill processes, phased fill and compaction, testing and control procedures, construction of permanent spillway and drainage devices, if applicable.

3. The erosion and sediment control plan, as approved by the local government, which minimizes soil erosion and sedimentation during all phases of construction.

D. Within 120 days of receipt of a complete Alteration Permit Application, the board shall act on the application. If the application is not acceptable, the director shall inform the applicant within 60 days of receipt and shall explain what changes are required for an acceptable application. A complete Alteration Permit Application consists of the following:

1. A final design report with attachments as needed, and certified by the owner;

2. A plan of construction that meets the requirements of subsection C of this section;

3. Any necessary interim provisions to the current Emergency Action Plan or Emergency Preparedness Plan. Interim provisions shall be submitted to the local organization for emergency management, the Virginia Department of Emergency Management, and the department; and

4. If the owner is requesting the deregulation of an impounding structure, the application shall specify whether the impounding structure is to be removed so that the impounding structure is incapable of storing water, either temporarily or permanently; or whether the impounding structure is to be altered in such a manner that either the height or storage capacity of the impounding structure causes the impounding structure to be of less than regulated size.

E. During the alteration work, the owner shall provide the director with any proposed changes from the approved design, plans, specifications, or a plan of construction. Approval shall be obtained from the director prior to the alteration or installation of any changes that will affect the integrity or impounding capacity of the impounding structure.

F. The Alteration Permit shall be valid for the construction sequence with milestones specified in the approved Alteration Permit Application.

G. Work identified in the Alteration Permit must commence within the time frame identified in the Alteration Permit. If work does not commence within the prescribed time frame, the permit shall expire, except that the applicant may petition the board for extension of the prescribed time frame and the board may extend such period for good cause with an updated construction sequence with milestones.

H. The board, the director, or both may take any necessary action consistent with the Dam Safety Act (§ 10.1-604 et seq. of the Code of Virginia) if any terms of this section or of the permit are violated, if the activities of the owner are not in accordance with the approved plans and specifications, if the alteration is conducted in a manner hazardous to downstream life or property, or for other cause as described in the Act.

I. Within 90 days after completion of the alteration of an impounding structure, the owner shall submit a complete Record Report. A form for the Record Report is available from the department (Record Report for Virginia Regulated Impounding Structures). The Record Report shall be signed and sealed by a licensed professional engineer and signed by the owner and shall be sent to the department indicating that the modifications made to the structural features of the impounding structure have been completed. This report is not required when the Alteration Permit has been issued for the removal of an impounding structure. The Record Report shall include the following:

1. Project information including the name and inventory number of the structure, name of the reservoir, and whether the report is associated with a new or old structure;

2. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;

3. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;

4. Information on the design report, including who it was prepared by, the date of design report preparation, whether it was for new construction or for an alteration, and the permit issuance date;

5. Owner's engineer's name, firm, professional engineer Virginia number, mailing address, and business telephone number;

6. Impounding structure data including type of material (earth, concrete, masonry or other) and the following configurations:

a. Top of impounding structure (elevation);

b. Downstream toe – lowest (elevation);

c. Height of impounding structure (feet);

d. Crest length – exclusive of spillway (feet);

e. Crest width (feet);

f. Upstream slope (horizontal to vertical); and

g. Downstream slope (horizontal to vertical).

7. Reservoir data including the following:

a. Maximum capacity (acre-feet);

b. Maximum pool (elevation);

c. Maximum pool surface area (acres);

d. Normal capacity (acre-feet);

e. Normal pool (elevation);

f. Normal pool surface area (acres); and

g. Freeboard (feet).

8. Spillway data including the type, construction material, design configuration, and invert elevation for the low level drain, the principal spillway, and the emergency spillway; a description of the low level drain and principal spillway including dimensions, trash guard information, and orientation of intake and discharge to impounding structure if looking downstream; and a description of the emergency spillway including dimensions and orientation to impounding structure if looking downstream;

9. Watershed data including drainage area (square miles); type and extent of watershed development; time of concentration (hours); routing procedure; spillway design flood used and state source; design inflow hydrograph volume (acre-feet), peak inflow (cfs), and rainfall duration (hours); and freeboard during passage of the spillway design flood (feet);

10. Impounding structure history including the date construction was completed, who it was designed by and the date, who it was built by and the date, who performed inspections and dates, description of repairs, and confirmation as to whether the impounding structure has ever been overtopped;

11. A narrative describing the impounding structure procedures for operation, maintenance, emergency action plan implementation, and structure evaluation;

12. A narrative describing the hydraulic and hydrologic data on the spillway design flood, hydrologic records, flood experience, flood potential, reservoir regulation, and comments or recommendations regarding these attributes;

13. A narrative describing stability of the foundation and abutments, embankment materials, and a written evaluation of each;

14. A complete set of record drawings signed and sealed by a licensed professional engineer and signed by the owner;

15. Certification by the owner's engineer that the information provided pursuant to this subsection is true and correct in their professional judgment. Such certification shall include the engineer's signature, printed name, Virginia number, date, and the engineer's Virginia seal; and

16. Owner's signature certifying receipt of the information provided pursuant to this subsection.

J. For altered impounding structures, a certification from a licensed professional engineer who has monitored the alteration of the impounding structure that, to the best of the engineer's judgment, knowledge, and belief, the impounding structure and its appurtenances were altered in conformance with the plans, specifications, drawings and other requirements approved by the board.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 2.3, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-90. Transfer of permits.

A. Prior to the transfer of ownership of a permitted impounding structure the permittee shall notify the director in writing and the new owner shall file a transfer notification with the department. A form for the transfer notification is available from the department (Transfer of Impounding Structure Notification form Past Owner to New Owner). The new owner shall amend the existing permit application as necessary and shall certify to the director that he is aware of and will comply with all of the requirements and conditions of the permit.

B. The transfer notification shall include the following required information:

1. Project information including the name and inventory number of the structure, name of the reservoir, and impoundment hazard classification;

2. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;

3. Type of certificates and permits to be transferred including effective date and expiration date of all certificates and permits;

4. Past owner's name, mailing address, and residential and business telephone numbers;

5. New owner's name, mailing address, and residential and business telephone numbers;

6. Request to transfer certification statement signed and dated by the past owner;

7. Certification of compliance with permit or certificate with all said terms and conditions signed and dated by the new owner; and

8. Contact information updates for Emergency Action Plan or Emergency Preparedness Plan provided by the new owner. Such updates shall include the name, mailing address, and residential and business telephone numbers for the impounding structure owner, impounding structure operator, rainfall and staff gage observer, and alternate observer.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 2.4, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-100. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 3.1, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-101. General permit requirements for low hazard potential impounding structures.

Any impounding structure owner whose registration statement is approved by the board will receive the following permit and shall comply with the requirements in it. If the failure of a low hazard potential impounding structure is not expected to cause loss of human life or economic damage to any property except property owned by the owner, the owner may follow the special criteria established for certain low hazard impounding structures in accordance with 4VAC50-20-51 in lieu of coverage under the general permit.

General Permit No.: Dam Safety 1
Effective Date: (Date of Issuance of Coverage)
Expiration Date: (6 years following Date of Issuance of Coverage)
GENERAL PERMIT FOR OPERATION OF A LOW HAZARD POTENTIAL IMPOUNDING STRUCTURE

In compliance with the provisions of the Dam Safety Act and attendant regulations, owners of an impounding structure covered by this permit are authorized to operate and maintain a low hazard potential impounding structure. The owner shall be subject to the following requirements as set forth herein.

1. The spillway design of the owner's impounding structure shall be able to safely pass a 100-year flood. When appropriate, the spillway design flood requirement may be further reduced to the 50-year flood in accordance with an incremental damage analysis conducted by the owner's engineer.

2. The owner shall develop and maintain an emergency preparedness plan in accordance with 4VAC50-20-177. The owner shall update and resubmit the emergency preparedness plan immediately upon becoming aware of necessary changes to keep the plan workable.

3. The owner shall perform an annual inspection of the impounding structure. The owner shall maintain such records and make them available to the department upon request. The department also shall conduct inspections as necessary in accordance with 4VAC50-20-180.

4. The owner shall ensure that the impounding structure is properly and safely maintained and operated and shall have the following documents available for inspection upon request of the department:

a. An operating plan and schedule including narrative on the operation of control gates and spillways and the impoundment drain;

b. For earthen embankment impounding structures, a maintenance plan and schedule for the embankment, principal spillway, emergency spillway, low-level outlet, impoundment area, downstream channel, and staff gages; and

c. For concrete impounding structures, a maintenance plan and schedule for the upstream face, downstream face, crest of dam, galleries, tunnels, abutments, spillways, gates and outlets, and staff gages.

Impounding structure owners shall not permit growth of trees and other woody vegetation and shall remove any such vegetation from the slopes and crest of embankments and the emergency spillway area, and within a distance of 25 feet from the toe of the embankment and abutments of the dam.

5. The owner shall file a dam break inundation zone map developed in accordance with 4VAC50-20-54 with the department and with the offices with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides.

6. The owner shall notify the department immediately of any change in circumstances that would cause the impounding structure to no longer qualify for coverage under the general permit. In the event of a failure or an imminent failure of the impounding structure, the owner shall immediately notify the local emergency services coordinator, the Virginia Department of Emergency Management, and the department. The department shall take actions in accordance

with § 10.1-608 or 10.1-609 of the Code of Virginia, depending on the degree of hazard and the imminence of failure caused by the unsafe condition.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-102. Registering for coverage under the general permit for low hazard potential impounding structures.

A. Pursuant to § 10.1-605.3, an impounding structure owner may seek general permit coverage from the board for a low hazard potential impounding structure in lieu of obtaining a Low Hazard Potential Regular Operation and Maintenance Certificate in accordance with 4VAC50-20-105 or a Conditional Operation and Maintenance Certificate for Low Hazard Potential impounding structures in accordance with 4VAC50-20-150.

B. An owner shall submit a complete and accurate registration statement in accordance with the requirements of this section prior to the issuance of coverage under the general permit. A complete registration statement shall include the following:

1. The name and address of the owner;

2. The location of the impounding structure;

3. The height of the impounding structure;

4. The volume of water impounded;

5. An Emergency Preparedness Plan prepared in accordance with 4VAC50-20-101;

6. The applicable fee for the processing of registration statements as set out in 4VAC50-20-375;

7. A dam break inundation zone map completed in accordance with 4VAC50-20-54 and evidence that such map has been filed with the offices with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides; and

8. A certification from the owner that the impounding structure (i) is classified as low hazard pursuant to a determination by the department or the owner's professional engineer in accordance with § 10.1-604.1 and this chapter; (ii) is, to the best of his knowledge, properly and safely constructed and currently has no observable deficiencies; and (iii) shall be maintained and operated in accordance with the provisions of the general permit.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-103. Transitioning from regular or conditional certificates to general permit coverage for low hazard potential impounding structures.

A. Holders of a regular certificate to operate a low hazard potential impounding structure shall be eligible for general permit coverage upon the expiration of their regular certificate. In lieu of a regular certificate renewal, registration coverage materials pursuant to 4VAC50-20-102 shall be submitted to the department 90 days prior to the expiration of the regular certificate.

B. Holders of a conditional certificate to operate a low hazard potential impounding structure shall be eligible for general permit coverage upon satisfying the registration requirements for a general permit pursuant to 4VAC50-20-102.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-104. Maintaining general permit coverage for low hazard potential impounding structures.

Provided that an impounding structure's hazard potential classification does not change, an owner's coverage under the general permit shall be for a six-year term after which time the owner shall reapply for coverage by filing a new registration statement and paying the necessary fee. No inspection of the impounding structure by a licensed professional engineer shall be required if the owner certifies at the time of general permit coverage renewal that conditions at the impounding structure and downstream are unchanged. If such certification is made, the owner is not required to submit an updated dam break inundation zone map.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

Part III
Certificate Requirements

4VAC50-20-105. Regular Operation and Maintenance Certificates.

A. A Regular Operation and Maintenance Certificate is required for an impounding structure. Such six-year certificates shall include the following based on hazard classification:

1. High Hazard Potential Regular Operation and Maintenance Certificate;

2. Significant Hazard Potential Regular Operation and Maintenance Certificate; or

3. Low Hazard Potential Regular Operation and Maintenance Certificate.

B. The owner of an impounding structure shall apply for the renewal of the six-year Regular Operation and Maintenance Certificate 90 days prior to its expiration. If a Regular Operation and Maintenance Certificate is not renewed as required, the board shall take appropriate enforcement action.

C. Any owner of an impounding structure that does not have a Regular Operation and Maintenance Certificate or any owner renewing a Regular Operation and Maintenance Certificate shall file an Operation and Maintenance Certificate Application. A form for the application is available from the department (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures). Such application shall be signed by the owner and signed and sealed by a licensed professional engineer. The following information shall be submitted on or with the application:

1. The application shall include the following required information:

a. The name of structure and inventory number;

b. The proposed hazard potential classification;

c. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;

d. An operating plan and schedule including a narrative on the operation of control gates and spillways and the impoundment drain;

e. For earthen embankment impounding structures, a maintenance plan and schedule for the embankment, principal spillway, emergency spillway, low-level outlet, impoundment area, downstream channel, and staff gages;

f. For concrete impounding structures, a maintenance plan and schedule for the upstream face, downstream face, crest of dam, galleries, tunnels, abutments, spillways, gates and outlets, and staff gages;

g. An inspection schedule for operator inspection, maintenance inspection, technical safety inspection, and overtopping situations;

h. A schedule including the rainfall amounts, emergency spillway flow levels or storm event that initiates the Emergency Action or Preparedness Plan and the frequency of observations;

i. A statement as to whether or not the current hazard potential classification for the impounding structure is appropriate and whether or not additional work is needed to make an appropriate hazard potential designation;

j. For newly constructed or recently altered impounding structures, a certification from a licensed professional engineer who has monitored the construction or alteration of the impounding structure that, to the best of the engineer's judgment, knowledge, and belief, the impounding structure and its appurtenances were constructed or altered in conformance with the plans, specifications, drawings and other requirements approved by the board;

k. Certification by the owner's engineer that the Operation and Maintenance Certificate Application information provided pursuant to subdivision 1 of this subsection is true and correct in their professional judgment. Such certification shall include the engineer's signature, printed name, Virginia number, date, and the engineer's Virginia seal; and

l. Owner's signature certifying the Operation and Maintenance Certificate Application information provided pursuant to subdivision 1 of this subsection and that the operation and maintenance plan and schedule shall be conducted in accordance with this chapter.

2. An Inspection Report (Annual Inspection Report for Virginia Regulated Impounding Structures) in accordance with subsection E of this section;

3. An Emergency Action Plan in accordance with 4VAC50-20-175 or an Emergency Preparedness Plan in accordance with 4VAC50-20-177 and evidence that the required copies of such plan have been submitted to the local organization for emergency management and the Virginia Department of Emergency Management;

4. Any additional analysis determined necessary by the director, the board or the owner's engineer to address public safety concerns. Such additional analysis may include, but not be limited to, seismic stability, earthen spillway integrity, adequate freeboard allowance, stability

assessment of the impoundment's foundation, potential liquefaction of the embankment, overturning or sliding of a concrete structure and other structural stress issues; and

5. If applicable, a current certification from the dam owner in accordance with 4VAC50-20-53.

D. If the Operation and Maintenance Certificate Application submittal is found to be not complete, the director shall inform the applicant within 30 days and shall explain what changes are required for an acceptable submission. Within 60 days of receipt of a complete application the board shall act upon the application. Upon finding that the impounding structure as currently operating is in compliance with this chapter, the board shall issue a Regular Operation and Maintenance Certificate. Should the board find that the impounding structure as currently operating is not in compliance with this chapter, the board may deny the permit application or issue a Conditional Operation and Maintenance Certificate in accordance with 4VAC50-20-150.

E. Inspections shall be performed on an impounding structure annually.

1. Inspection Reports (Annual Inspection Report for Virginia Regulated Impounding Structures) signed and sealed by a licensed professional engineer shall be submitted to the department in accordance with the following schedule:

a. For a High Hazard Potential impounding structure, every two years;

b. For a Significant Hazard Potential impounding structure, every three years;

c. For a Low Hazard Potential impounding structure, every six years; or

d. For a High Hazard Potential impounding structure, annually in accordance with 4VAC50-20-53, where applicable.

In years when an Inspection Report signed and sealed by a licensed professional engineer is not required, an owner shall submit the Annual Inspection Report for Virginia Regulated Impounding Structures.

2. The Inspection Report shall include the following required information:

a. Project information including the name and inventory number of structure, name of the reservoir, and purpose of the reservoir;

b. City or county where the impounding structure is located;

c. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;

d. Owner's engineer's name, firm, professional engineer Virginia number, mailing address, and business telephone number;

e. Inspection observation of the impounding structure including the following:

(1) Earthen embankment information including any embankment alterations; erosion; settlement, misalignments or cracks; seepage and seepage flow rate and location;

(2) Upstream slope information including notes on woody vegetation removed, rodent burrows discovered, and remedial work performed;

(3) Intake structure information including notes on deterioration of concrete structures, exposure of rebar reinforcement, need to repair or replace trash rack, any problems with debris in the reservoir, and whether the drawdown valve operated;

(4) Abutment contacts including notes on seepage and seepage flow rate and location;

(5) Earthen emergency spillway including notes on obstructions to flow and plans to correct, rodent burrows discovered, and deterioration in the approach or discharge channel;

(6) Concrete emergency spillway including notes on the deterioration of the concrete, exposure of rebar reinforcement, any leakage below concrete spillway, and obstructions to flow and plans to correct;

(7) Downstream slope information including notes on woody vegetation removed, rodent burrows discovered, whether seepage drains are working, and any seepage or wet areas;

(8) Outlet pipe information including notes on any water flowing outside of discharge pipe through the impounding structure and a description of any reflection or damage to the pipe;

(9) Stilling basin information including notes on the deterioration of the concrete, exposure of rebar reinforcement, deterioration of the earthen basin slopes, repairs made, and any obstruction to flow;

(10) Gates information including notes on gate malfunctions or repairs, corrosion or damage, and whether any gates were operated and if so how often and to what extreme;

(11) Reservoir information including notes on new developments upstream of the dam, slides or erosion of lake banks, and general comments to include silt, algae, or other influence factors;

(12) Instruments information including any reading of instruments and any installation of new instruments; and

(13) General information including notes on new development in the downstream dam break inundation zone that would impact hazard classification or spillway design flood requirements, the maximum stormwater discharge or peak elevation during the previous year, whether general maintenance was performed and when, and actions that need to be completed before the next inspection.

f. Evaluation rating of the impounding structure and appurtenances (excellent, good, or poor), general comments, and recommendations;

g. Certification by the owner and date of inspection; and

h. Certification and seal by the owner's engineer and date of inspection, as applicable.

F. The owner of an impounding structure shall notify the department immediately of any change in the use of the area downstream that would impose hazard to life or property in the event of failure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended, Virginia Register Volume 27, Issue 6, eff. December 22, 2010.

4VAC50-20-110. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 3.2, eff. February 1, 1989; repealed, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-120. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 3.3, eff. February 1, 1989; repealed, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-125. Delayed effective date for Spillway Design Flood requirements for impounding structures.

A. If an impounding structure has been determined to have an adequate spillway capacity prior to September 26, 2008, and is currently operating under a Regular Operation and Maintenance Certificate, but will now require spillway modifications due to changes in these regulations, the owner shall submit to the board an Alteration Permit Application in accordance with 4VAC50-20-80 to address spillway capacity at the time of the expiration of their Regular Operation and Maintenance Certificate or by September 26, 2011, whichever is later. The Alteration Permit Application shall contain a construction sequence with milestones for completing the necessary improvements within five years of Alteration Permit issuance. The board may approve an extension of the prescribed time frame for good cause. Should the owner be able to demonstrate that no spillway capacity change is necessary, the impounding structure may be found to be in compliance with this chapter.

B. In accordance with 4VAC50-20-105, the owner shall submit the Operation and Maintenance Certificate Application (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures), the Emergency Action Plan or Emergency Preparedness Plan, and the Inspection Report (Annual Inspection Report for Virginia Regulated Impounding Structures) 90 days prior to the expiration of the Regular Operation and Maintenance Certificate.

C. If circumstances warrant more immediate repairs to the impounding structure, the board may direct alterations to the spillway to be completed sooner.

D. During this delay period, owners are required to address other deficiencies that may exist that are not related to the spillway design flood.

E. Any impounding structure owner who, as of September 26, 2008, held an Alteration Permit or Construction Permit under the requirements of this chapter that were effective prior to that date, who has maintained this permit as valid, and who completes all requirements of such permit and any applicable Conditional Operation and Maintenance Certificate by September 26, 2011, shall not be required to meet new requirements of this chapter that became effective on September 26, 2008, until the completion of the first six-year certificate cycle following completion of all requirements of his permit and any applicable certificates. During this six-year period, the owner may be issued a Regular Operation and Maintenance Certificate should the impounding structure otherwise be eligible for such certificate.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended Virginia Register Volume 28, Issue 5, eff. December 22, 2011.

4VAC50-20-130. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 3.4, eff. February 1, 1989; repealed, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-140. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 3.5, eff. February 1, 1989; repealed, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-150. Conditional operation and maintenance certificate.

A. During the review of any Operation and Maintenance Certificate Application (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures) completed in accordance with 4VAC50-20-105 should the director determine that the impounding structure has nonimminent deficiencies, the director may recommend that the board issue a Conditional Operation and Maintenance Certificate.

B. The Conditional Operation and Maintenance Certificate for High, Significant, and Low Hazard Potential impounding structures shall be for a maximum term of two years. This certificate will allow the owner to continue normal operation and maintenance of the impounding structure, and shall require that the owner correct the deficiencies on a schedule approved by the board.

C. A Conditional Certificate may be extended in accordance with the procedures of 4VAC50-20-155 provided that Inspection Reports (Annual Inspection Report for Virginia Regulated Impounding Structures) are on file, and the board determines that the owner is proceeding with the necessary corrective actions.

D. Once the deficiencies are corrected, the board shall issue a Regular Operation and Maintenance Certificate based upon the impounding structure's meeting the requirements of 4VAC50-20-105.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 3.6, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-155. Extension of Operation and Maintenance Certificates.

The board may extend an Operation and Maintenance Certificate for impounding structures provided that the owner submits a written request justifying an extension, the amount of time needed to comply with the requirements set out in the current Operation and Maintenance

Certificate, and any required fees. The owner must have demonstrated substantial and continual progress towards meeting the requirements of the certificate in order to receive an extension.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-160. Additional operation and maintenance requirements.

A. The owner of an impounding structure shall not, through action or inaction, cause or allow such structure to impound water following receipt of a written report from the owner's engineer that the impounding structure will not safely impound water.

B. In accordance with § 10.1-609.2 of the Code of Virginia, impounding structure owners shall not permit the growth of trees and other woody vegetation and shall remove any such vegetation from the slopes and crest of embankments and the emergency spillway area, and within a distance of 25 feet from the toe of the embankment and abutments of the dam.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 3.7, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-165. Agricultural exemption.

A. Impounding structures operated primarily for agricultural purposes that are less than 25 feet in height or that create a maximum impoundment capacity smaller than 100 acre-feet are exempt from the Impounding Structure Regulations.

B. An owner covered by an agricultural exemption pursuant to § 10.1-604 of the Code of Virginia and 4VAC50-20-30 may validate such exemption by submitting an Agricultural Exemption Report (Agricultural Exemption Report for Impounding Structures). The Agricultural Exemption Report shall include the following information:

1. Project information including the name and inventory number of the structure and name of the reservoir;

2. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;

3. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;

4. The impounding structure height in feet and the maximum impounding capacity in acre-feet;

5. A list of the agricultural functions for which the impoundment supplies water;

6. The date of validation; and

7. The owner's signature validating that the impoundment is operated primarily for agricultural purposes and is exempt from the regulations.

C. The Agricultural Exemption Report may be verified by the department through a site visit.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-170. Transfer of certificates.

A. Prior to the transfer of ownership of an impounding structure the certificate holder shall notify the director in writing and the new owner shall file a transfer notification with the department. A form for the transfer notification is available from the department (Transfer of Impounding Structure Notification from Past Owner to New Owner). The new owner may elect to continue the existing operation and maintenance certificate for the remaining term or he may apply for a new certificate in accordance with 4VAC50-20-105. If the owner elects to continue the existing certificate, he shall certify to the director that he is aware of and will comply with all of the requirements and conditions of the certificate.

B. The transfer notification shall include the following required information:

1. Project information including the name and inventory number of the structure, name of the reservoir, and impoundment hazard classification;

2. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;

3. Type of certificates and permits to be transferred including effective date and expiration date of all certificates and permits;

4. Past owner's name, mailing address, and residential and business telephone numbers;

5. New owner's name, mailing address, and residential and business telephone numbers;

6. Request to transfer certification statement signed and dated by the past owner;

7. Certification of compliance with permit or certificate with all said terms and conditions signed and dated by the new owner; and

8. Contact information updates for Emergency Action Plan or Emergency Preparedness Plan provided by the new owner. Such updates shall include the name, mailing address, and residential and business telephone numbers for the impounding structure owner, impounding structure operator, rainfall and staff gage observer, and alternate observer.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 3.8, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-175. Emergency Action Plan (EAP) for High and Significant Hazard Potential impounding structures.

A. In order to protect life during potential emergency conditions at an impounding structure, and to ensure effective, timely action is taken should an impounding structure emergency occur, an EAP shall be required for each High and Significant Hazard Potential impounding structure. The EAP shall be coordinated with the Department of Emergency Management in accordance with § 44-146.18 of the Code of Virginia. The EAP required by these regulations shall be incorporated into local and interjurisdictional emergency plans pursuant to § 44-146.19 of the Code of Virginia.

B. It is the impounding structure owner's responsibility to develop, maintain, exercise, and implement a site-specific EAP.

C. An EAP shall be submitted every six years. The EAP shall be submitted with the owner's submittal of their Regular Operation and Maintenance Certificate application (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures).

D. The owner shall update and resubmit the EAP immediately upon becoming aware of necessary changes to keep the EAP workable. Should an impounding structure be reclassified, an EAP in accordance with this section shall be submitted.

E. A drill shall be conducted annually for each high or significant hazard impounding structure. To the extent practicable, the drill should include a face-to-face meeting with the local emergency management agencies responsible for any necessary evacuations to review the EAP and ensure the local emergency management agencies understand the actions required during an emergency. Except as set out in 4VAC50-20-53, a table-top exercise shall be conducted once every six years, although more frequent table-top exercises are encouraged. Drills and table-top exercises for multiple impounding structures may be performed in combination if the involved parties are the same. Owners shall certify to the department annually that a drill, a table-top exercise, or both has been completed and provide any revisions or updates to the EAP or a statement that no revisions or updates are needed.

F. Impounding structure owners shall test existing monitoring, sensing, and warning equipment at remote or unattended impounding structures at least twice per year or as performed by the Virginia Department of Emergency Management pursuant to § 10.1-609.1 of the Code of Virginia and maintain a record of such tests.

G. An EAP shall contain the following seven basic elements unless otherwise specified in this subsection.

1. Notification chart. A notification chart shall be included for all classes of impounding structures that shows who is to be notified, by whom, and in what priority. The notification chart shall include contact information providing 24-hour telephone coverage for all responsible parties including, but not limited to, the impounding structure operator or manager, state and local emergency management officials, local police or sheriffs' departments, and the owner's engineer. The notification chart shall also identify the process by which downstream property owners will be notified, and what party or parties will be responsible for making such notifications.

2. Emergency Detection, Evaluation, and Classification. The EAP shall include a discussion of the procedures for timely and reliable detection, evaluation, and classification of emergency situations considered to be relevant to the project setting and impounding features. Each relevant emergency situation is to be documented to provide an appropriate course of action based on the urgency of the situation. Where appropriate, situations should address impounding structure failures that are imminent or in progress, a situation where the potential for impounding structure failure is rapidly developing, and a situation where the threat is slowly developing.

3. Responsibilities. The EAP shall specify responsibilities for EAP-related tasks. The EAP shall also clearly designate the responsible party for making the decision that an emergency condition no longer exists at the impounding structure. The EAP shall include procedures and the

responsible parties for notifying to the extent possible any known local occupants, owners, or lessees of downstream properties potentially impacted by the impounding structure's failure.

4. Preparedness. The EAP shall include a section that describes preparedness actions to be taken both before and following development of emergency conditions.

5. Dam Break Inundation Maps. The EAP shall include dam break inundation maps developed in accordance with 4VAC50-20-54.

6. Appendices. The appendices shall contain information that supports and supplements the material used in the development and maintenance of the EAP such as analyses of impounding structure failure floods; plans for training, exercising, updating, and posting the EAP; and other site-specific concerns.

7. Certification. The EAP shall include a section that identifies all parties with assigned responsibilities in the EAP pursuant to subdivision 3 of this subsection. This will include certification that the EAP has been received by these parties. The preparer's name, title, and contact information shall be printed in this section. The preparer's signature shall also be included in the certification section. The local organization for emergency management shall provide the owner and the department with any deficiencies they may note.

H. The development of the EAP shall be coordinated with all entities, jurisdictions, and agencies that would be affected by an impounding structure failure or that have statutory responsibilities for warning, evacuation, and postflood actions. Consultation with state and local emergency management officials at appropriate levels of management responsible for warning and evacuation of the public shall occur to ensure that there is awareness of their individual and group responsibilities. The owner shall also coordinate with the local organization for emergency management to identify properties that upon failure of the impounding structure would result in economic impacts.

I. The EAP, or any updates to an existing EAP, shall be submitted to the department, the local organization for emergency management, and the Virginia Department of Emergency Management. Two copies shall be provided to the department.

J. The following format shall be used as necessary to address the requirements of this section.

Title Page/Cover Sheet

Table of Contents

I. Certifications

II. Notification Flowchart

III. Statement of Purpose

IV. Project Description

V. Emergency Detection, Evaluation, and Classification

VI. General Responsibilities Under the EAP

A. Impounding Structure Owner Responsibilities

B. Responsibility for Notification

C. Responsibility for Evacuation

D. Responsibility for Termination and Follow-Up

E. EAP Coordinator Responsibility

VII. Preparedness

VIII. Inundation Maps

IX. Appendices

A. Investigation and Analyses of Impounding Structure Failure Floods

B. Plans for Training, Exercising, Updating, and Posting the EAP

C. Site-Specific Concerns

Statutory Authority
§ 10.1-605 of the Code of Virginia.
Historical Notes
Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended, Virginia Register Volume 27, Issue 6, eff. December 22, 2010.

4VAC50-20-177. Emergency Preparedness Plan for Low Hazard impounding structures.

Low Hazard impounding structures shall provide information for emergency preparedness to the department, the local organization for emergency management and the Virginia Department of Emergency Management. A form for the submission is available from the department (Emergency Preparedness Plan for Low Hazard Virginia Regulated Impounding Structures). The information shall include, but not be limited, to the following:

1. Name and location information for the impounding structure including city or county and latitude and longitude;

2. Name of owner and operator and associated contact information including residential and business telephone numbers and other means of communication;

3. Contact information for relevant emergency responders including the following:

a. Local dispatch center or centers governing the impounding structure's dam break inundation zone; and

b. City or county emergency services coordinator's name or names;

4. Procedures for notifying downstream property owners or occupants potentially impacted by the impounding structure's failure;

5. A dam break inundation zone map completed in accordance with 4VAC50-20-54 and evidence that:

a. Such map has been filed with the offices with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides; and

b. Required copies of such plan have been submitted to the local organization for emergency management and the Virginia Department of Emergency Management; and

6. Certification of the accuracy of the plan by the owner.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended, Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

Part IV
Procedures

4VAC50-20-180. Inspections.

A. The director may make inspections during construction, alteration or operation and maintenance as deemed necessary to ensure that the impounding structure is being constructed, altered or operated and maintained in compliance with the permit or certificate issued by the board. The director shall provide the owner a copy of the findings of these inspections. The department's inspection does not relieve the owner from the responsibility of providing adequate inspection during construction, alteration, or operation and maintenance. During the maintenance, construction, or alteration of any impounding structure or reservoir, the director shall require the owner to perform, at the owner's expense, such work or tests as necessary to obtain information sufficient to enable the director to determine whether conformity with the plans and specifications approved by the certificate is being secured.

B. Periodic inspections during construction or alteration shall be conducted under the direction of a licensed professional engineer who shall provide for monitoring, review of contractor submittals, and appropriate confirmatory testing of all facets of construction affecting the safety of the impounding structure in accordance with the construction or alteration permit issued by the board.

C. Required inspections during operation and maintenance shall be conducted under the supervision of a licensed professional engineer at intervals designated under 4VAC50-20-105.

D. Every owner shall provide for an inspection by a licensed professional engineer after overtopping of the impounding structure or after flows cause damage to the emergency spillway. A copy of the findings of each inspection with the engineer's recommendations shall be filed with the board within a reasonable period of time not to exceed 30 days subsequent to completion of the inspection.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.1, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-190. Right to informal fact-finding proceeding or hearing.

Any owner aggrieved by an action taken by the director or by the board without hearing, or by inaction of the director or the board, under the provisions of this chapter, may demand in writing an informal fact-finding proceeding pursuant to § 2.2-4019 of the Code of Virginia or a formal hearing pursuant to § 2.2-4020 of the Code of Virginia. A formal hearing may be granted only with the consent of the board.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.2, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-195. Judicial review.

Any owner aggrieved by a decision of the director, department, or board regarding the owner's impounding structure shall have the right to judicial review of the final decision pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq. of the Code of Virginia).

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-200. Enforcement.

The provisions of this chapter may be enforced by the board, the director, or both in any manner consistent with the provisions of the Dam Safety Act (§ 10.1-604 et seq. of the Code of Virginia). Failure to comply with the provisions of the general permit issued in accordance with 4VAC50-20-103 may result in enforcement actions, including penalties assessed in accordance with §§ 10.1-613.1 and 10.1-613.2.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.3, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008; Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-210. Consulting committee.

A. When the board needs to satisfy questions of safety regarding plans and specifications, construction, alteration, or operation and maintenance, or when requested by the owner, the board may appoint a consulting committee to report to it with respect to those questions of the impounding structure's safety. Such a committee shall consist of two or more consultants, none of whom have been associated with the impounding structure.

B. The costs and expenses incurred by the consulting committee, if appointed at the request of an owner, shall be paid by the owner.

C. The costs and expenses incurred by the consulting committee, if initiated by the board, shall be paid by the board.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.4, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-220. Unsafe conditions.

A. No owner shall maintain an unsafe impounding structure. Designation of an impounding structure as unsafe shall be made in accordance with § 10.1-607.1 of the Code of Virginia.

B. Imminent danger.

1. If an owner or the owner's engineer has determined that circumstances are impacting the integrity of the impounding structure that could result in the imminent failure of the impounding structure, temporary repairs may be initiated prior to approval from the board. The owner shall notify the department within 24 hours of identifying the circumstances impacting the integrity of the impounding structure. Such emergency notification shall not relieve the owner of the need to obtain an alteration permit as soon as may be practicable, nor shall the owner take action beyond that necessary to address the emergency situation.

2. When the director finds that an impounding structure is unsafe and constitutes an imminent danger to life or property, he shall immediately notify the Virginia Department of Emergency Management and confer with the owner who shall activate the Emergency Action Plan or Emergency Preparedness Plan if appropriate to do so. The owner of an impounding structure found to constitute an imminent danger to life or property shall take immediate corrective action to remove the imminent danger as required by § 10.1-608 of the Code of Virginia.

C. Nonimminent danger. The owner of an impounding structure who has been issued findings and recommendations, by the board, for the correction of deficiencies that may threaten life or property if not corrected, shall undertake to implement the recommendations for correction of deficiencies according to a schedule of implementation contained in that report as required by § 10.1-609 of the Code of Virginia. A dam owner may submit to the board his own plan, consistent with this chapter, to address the recommendations for correction of deficiencies and the schedule of implementation contained in the department's safety inspection report. The board shall determine if the submitted plan and schedule are sufficient to address deficiencies.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.5, eff. February 1, 1989; amended, Virginia Register Volume 18, Issue 14, eff. July 1, 2002; Volume 24, Issue 25, eff. September 26, 2008; Volume 27, Issue 6, eff. December 22, 2010.

4VAC50-20-230. Complaints.

A. Upon receipt of a complaint alleging that the person or property of the complainant is endangered by the construction, alteration, maintenance or operation of an impounding structure, the director shall cause an inspection of the structure, unless the data, records and inspection reports on file with the board are found adequate to determine if the complaint is valid.

B. If the director finds that an unsafe condition exists, the director shall proceed under the provisions of §§ 10.1-608 and 10.1-609 of the Code of Virginia to render the extant condition safe.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 4.6, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

Part V
Design Requirements

4VAC50-20-240. Design of structures.

A. The owner shall complete all necessary investigations prior to submitting the design report (Design Report for the Construction or Alteration of Virginia Regulated Impounding Structures). The design report shall contain those components outlined in 4VAC50-20-70 for construction activities or those outlined in 4VAC50-20-80 for alteration activities. The scope and degree of precision required is a matter of engineering judgment based on the complexities of the site and the hazard potential classification of the proposed structure.

B. Surveys shall be made with sufficient accuracy to locate the proposed construction site and to define the total volume of storage in the impoundment. Locations of center lines and other horizontal and vertical controls shall be shown on a map of the site. The area downstream and upstream from the proposed impounding structure shall be investigated in order to delineate the areas and extent of potential damage in case of failure or backwater due to flooding.

C. The drainage area shall be determined. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area. The most severe of these conditions shall be included in the design calculations which shall be submitted as part of the design report.

D. The geotechnical engineering investigation shall consist of borings, test pits and other subsurface explorations necessary to adequately define the existing conditions. The investigations shall be performed so as to appropriately define the soil, rock and ground water conditions.

E. All construction materials shall be adequately researched and selected so as to ensure that their as constructed behavior will reasonably conform to design criteria. If on-site materials are to be utilized, they shall be located and determined to be adequate in quantity and quality.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.1, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-250. (Repealed.)

Historical Notes

Derived from VR625-01-00 § 5.2, eff. February 1, 1989; repealed, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-260. Spillway design.

A. Every impounding structure shall have a spillway system with adequate capacity to discharge the design flood without endangering the safety of the impounding structure.

B. Vegetated earth or an unlined emergency spillway may be approved when the applicant demonstrates that it will pass the spillway design flood without jeopardizing the safety of the impounding structure (such as by allowance of overtopping of a structure not designed to permit overtopping). In no case shall impounding structure owners permit the growth of trees and other woody vegetation in the emergency spillway area.

C. Lined emergency spillways shall include design criteria calculations, plans and specifications for suitable energy dissipators and for spillways that include crest control structures, chutes, walls, panel lining, sills, blocks, and miscellaneous details. All joints shall be reasonably water-tight and placed on a foundation capable of sustaining applied loads without undue deformation. Provision shall be made for handling under seepage and uplift pressures from the foundation which might adversely affect the structural integrity and structural stability of the impounding structure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.3, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-270. Principal spillways and outlet works.

A. It will be assumed that principal spillways and regulating outlets provided for special functions will operate to normal design discharge capabilities during the spillway design flood, provided appropriate analyses show:

1. That control gates and structures are suitably designed to operate reliably under maximum heads for durations likely to be involved and risks of blockage by debris are minimal;

2. That access roads and passages to gate regulating controls would be safely passable by operating personnel under spillway design flood conditions; and

3. That there are no substantial reasons for concluding that outlets would not operate safely to full design capacity during the spillway design flood.

B. If there are reasons to doubt that any of the above basic requirements might not be adequately met under spillway design flood conditions, the "dependable" discharge capabilities of regulating outlets shall be assumed to be less than 100% of design capacities, generally as outlined in the following subsections C through G of this section.

C. Any limitations in safe operating heads, maximum velocities to be permitted through structures or approach channels, or other design limitations shall be observed in establishing "dependable" discharge rating curves to be used in routing the spillway design flood hydrograph through the reservoir.

D. If intakes to regulating outlets are likely to be exposed to significant quantities of floating debris, sediment depositions or ice hazards prior to or during major floods, the dependable discharge capability during the spillway design flood shall be assumed to be zero.

E. If access roads or structural passages to operating towers or controls are likely to be flooded or otherwise unusable during the spillway design flood, the dependable discharge capability of regulating outlets will be assumed to be zero for the periods of time during which such conditions might exist.

F. Any deficiencies in discharge performance likely to result from delays in the operation of gates before attendants could be reasonably expected to reach the control must be taken into account when estimating "dependable" discharge capabilities assumptions in routing the spillway design flood through the impoundment. Reports on design studies shall indicate the allowances made for possible delays in initiating gate operations. Normally, for projects located in small basins, where critical spillway design flood inflows may occur within several hours after intense precipitation, outflows through any regulating outlets that must be opened after the flood begins shall be assumed to be zero for an appropriate period of time subsequent to the beginning of intense rainfall.

G. All gates, valves, conduits and concrete channel outlets shall be designed and constructed to prevent significant erosion or damage to the impounding structure or to the downstream outlet or channel.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.4, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-280. Drain requirements.

All new impounding structures regardless of their hazard potential classification, shall include a device to permit draining of the impoundment within a reasonable period of time as determined by the owner's licensed professional engineer. Existing drains on impounding structures shall be kept operational. When practicable, existing impounding structures shall be retrofitted with devices to permit draining.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.5, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-290. Life of the impounding structure.

Components of the impounding structure, the outlet works, drain system and appurtenances shall be durable and maintained or replaced in keeping with the design and planned life of the impounding structure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.6, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-300. Additional design requirements.

A. Flood routings shall start at or above the elevation of the crest of the lowest ungated outlet. Freeboard determination and justification must be addressed by the owner's engineer.

B. All elements of the impounding structure shall conform to sound engineering practice. Safety factors, design standards and design references that are used shall be included with the design report.

C. Inspection devices may be required by the director for use by inspectors, owners or the director in conducting inspections in the interest of structural integrity during and after completion of construction and during the life of the impounding structure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.7, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-310. Plans and specifications.

The plans and specifications for a proposed impounding structure required in 4VAC50-20-70 for construction activities and in 4VAC50-20-80 for alteration activities shall consist of a detailed engineering design report (Design Report for the Construction or Alteration of Virginia Regulated Impounding Structures) and engineering drawings and specifications, with the following as a minimum:

1. The name of the project; the name of the owner; classification of the impounding structure as set forth in this chapter; designated access to the project and the location with respect to highways, roads, streams and existing impounding structures and impoundments that would affect or be affected by the proposed impounding structure.

2. Cross-sections, plans, profiles, logs of test borings, laboratory and in situ test data, drawings of principal and emergency spillways, impounding structures, outlet works, drain system and appurtenances, and other project components in sufficient detail to indicate clearly the extent and complexity of the work to be performed.

3. Contract drawings should include, but not be limited to, foundation and abutment treatment, stream or river diversion, excavation and material fill processes, phased fill and compaction and drainage devices.

4. The erosion and sediment control plan, as approved by the local government, which minimizes soil erosion and sedimentation during all phases of construction or alteration.

5. Technical specifications, as may be required to describe the materials, performance, and methods of the construction and construction quality control for the project.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.8, eff. February 1, 1989; amended, Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-320. Acceptable design procedures and references.

To ensure consistency of approach, within the major engineering disciplines of hydrology, hydraulics, soils and foundations, structures, and general civil design, criteria and approaches from multiple sources shall not be mixed for developing the design of a given feature or facility without approval of the director. In all cases the owner's engineer shall identify the source of the criteria.

The following are acceptable as design procedures and references:

1. The design procedures, manuals and criteria used by the United States Army Corps of Engineers.

2. The design procedures, manuals and criteria used by the United States Department of Agriculture, Natural Resources Conservation Service.

3. The design procedures, manuals and criteria used by the United States Department of the Interior, Bureau of Reclamation.

4. The design procedures, manuals and criteria used by the United States Department of Commerce, National Weather Service.

5. The design procedures, manuals and criteria used by the United States Federal Energy Regulatory Commission.

6. Other design procedures, manuals and criteria that are accepted as current, sound engineering practices, as approved by the director prior to the design of the impounding structure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from VR625-01-00 § 5.9, eff. February 1, 1989; amended, Virginia Register Volume 18, Issue 14, eff. July 1, 2002; Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-330. Other applicable dam safety references.

A. Manuals, guidance, and criteria used by the Federal Emergency Management Agency, including the following:

1. Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners, U.S. Department of Homeland Security, Federal Emergency Management Agency, October 1998, Reprinted January 2004; FEMA 64 or as revised.

2. Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams, U.S. Department of Homeland Security, Federal Emergency Management Agency, October 1998, Reprinted April 2004; FEMA 94 or as revised.

B. Manuals, guidance, and forms provided by the department. Such materials may be located on the department's website at: http://www.dcr.virginia.gov.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

Part VI
Fees

4VAC50-20-340. Authority to establish fees.

Under § 10.1-613.5 of the Code of Virginia, the board is authorized to establish and collect application fees to be used for the administration of the dam safety program, including actions taken in accordance with §§ 10.1-608, 10.1-609, and 10.1-613 of the Code of Virginia. The fees will be deposited into the Dam Safety Administrative Fund.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008; amended, Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-350. Fee submittal procedures.

A. Effective September 26, 2008, fees for all application submittals required pursuant to 4VAC50-20-370 through 4VAC50-20-390 are due prior to issuance of a certificate or permit. No application for an Operation and Maintenance Certificate or a Construction Permit will be acted upon by the board without full payment of the required fee per § 10.1-613.5 of the Code of Virginia.

B. Fees shall be paid by check, draft or postal money order payable to the Treasurer of Virginia, or submitted electronically (if available), and must be in U.S. currency, except that agencies and institutions of the Commonwealth of Virginia may submit Interagency Transfers for the amount of the fee. All fees shall be sent to the following address (or submitted electronically, if available): Virginia Department of Conservation and Recreation, Division of Finance, Accounts Payable, 203 Governor Street, 4th Floor, Richmond, Virginia 23219.

C. All fee payments shall be accompanied by the following information:

1. Applicant name, address and daytime phone number.

2. The name of the impounding structure, and the impounding structure location.

3. The type of application or report submitted.

4. Whether the submittal is for a new permit or certificate issuance or permit or certificate reissuance.

5. The amount of fee submitted.

6. Impounding structure identification number, if applicable.

D. No permit fees remitted to the department shall be subject to refund except as credits provided for in 4VAC50-20-390 C.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-360. Fee exemptions.

Impounding structures owned by Virginia Soil and Water Conservation Districts shall be exempt from all fees associated with this part in accordance with § 10.1-613.5 of the Code of Virginia.

There will be no fee assessed for a low hazard impounding structure exempted from fees pursuant to 4VAC50-20-51 or for the decommissioning of an impounding structure.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-370. Construction Permit application fees.

A. Any application form submitted pursuant to 4VAC50-20-70 for permitting a proposed impounding structure construction after September 26, 2008, shall be accompanied by a payment as determined in subsection B of this section.

B. Fees shall be as follows:

1. $2,500 for High or Significant Hazard Potential impounding structures.

2. $1,000 for Low Hazard Potential impounding structures.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-375. Fee for coverage under the general permit for low hazard impounding structures.

The fee for processing registration statements from impounding structure owners seeking to obtain coverage under the general permit for low hazard impounding structures shall be $300.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-380. Regular Operation and Maintenance Certificate application fees.

A. Any application for a six-year Regular Operation and Maintenance Certificate after September 26, 2008, except as otherwise exempted, shall be accompanied by a payment as determined in subsection B of this section.

B. Fees for High, Significant, or Low Hazard Potential impounding structures shall be as follows:

1. $600 for High Hazard Potential.

2. $600 for Significant Hazard Potential.

3. $300 for Low Hazard Potential.

C. Fees for extension of Regular Operation and Maintenance Certificates shall be $250 per year or portion thereof.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-390. Conditional Operation and Maintenance Certificate application fee.

A. Fees for issuance of a Conditional Operation and Maintenance Certificate shall be as follows:

1. For a certificate for more than one year but no more than two years: $300.

2. For a certificate for one year or less: $150.

B. The fee for an extension of a Conditional Operation and Maintenance Certificate shall be $250 per year or portion thereof.

C. The board may allow a partial credit towards the Regular Operation and Maintenance Certificate fee if the owner of the impounding structure has completed, to the director's satisfaction, the conditions of the Conditional Certificate prior to its expiration.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

4VAC50-20-395. Simplified dam break inundation zone analysis fee.

Pursuant to authority provided in § 10.1-604.1 A 1 of the Code of Virginia and in accordance with 4VAC50-20-40 C, when the department receives a request from the owner of a dam to conduct a simplified dam break inundation zone analysis, the owner shall submit a fee of $2,000 prior to the department conducting such analysis. The fee shall be submitted in accordance with 4VAC50-20-350 B and C as applicable. The fee shall be deposited into the Dam Safety Administrative Fund to be used to cover the partial cost of such analysis. Once the analysis has commenced, no analysis fee remitted to the department shall be subject to refund.

If the department attains additional efficiencies in its analysis process, the department is authorized to reduce this fee to a level commensurate with the costs.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 29, Issue 2, eff. November 8, 2012.

4VAC50-20-400. Incremental Damage Analysis review fees.

Should the department determine that outside expertise to assist with the review of an incremental damage analysis is necessary, the applicant shall be responsible for the cost of such outside expertise. Such costs shall be agreed upon in advance by the department and the applicant.

Statutory Authority

§ 10.1-605 of the Code of Virginia.

Historical Notes

Derived from Virginia Register Volume 24, Issue 25, eff. September 26, 2008.

Virginia Department of Conservation & Recreation

VIRGINIA DAM SAFETY ACT - TABLE OF CONTENTS

Code Section

Page Number

VIRGINIA DAM SAFETY ACT

§ 10.1-604. Definitions.

As used in this article, unless the context requires a different meaning:

"Alteration" means changes to an impounding structure that could alter or affect its structural integrity. Alterations include, but are not limited to, changing the height or otherwise enlarging the dam, increasing normal pool or principal spillway elevation or physical dimensions, changing the elevation or physical dimensions of the emergency spillway, conducting necessary repairs or structural maintenance, or removing the impounding structure.

"Board" means the Soil and Water Conservation Board.

"Construction" means the construction of a new impounding structure.

"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

"Height" means the structural height of a dam which is defined as the vertical distance from the natural bed of the stream or watercourse measured at the downstream toe of the dam to the top of the dam.

"Impounding structure" means a man-made structure, whether a dam across a watercourse or other structure outside a watercourse, used or to be used to retain or store waters or other materials. The term includes: (i) all dams that are twenty-five feet or greater in height and that create an impoundment capacity of fifteen acre-feet or greater, and (ii) all dams that are six feet or greater in height and that create an impoundment capacity of fifty acre-feet or greater. The term "impounding structure" shall not include: (a) dams licensed by the State Corporation Commission that are subject to a safety inspection program; (b) dams owned or licensed by the United States government; (c) dams operated primarily for agricultural purposes which are less than twenty-five feet in height or which create a maximum impoundment capacity smaller than 100 acre-feet; (d) water or silt retaining dams approved pursuant to § 45.1-222 or § 45.1-225.1; or (e) obstructions in a canal used to raise or lower water.

"Owner" means the owner of the land on which a dam is situated, the holder of an easement permitting the construction of a dam and any person or entity agreeing to maintain a dam.

"Watercourse" means a natural channel having a well-defined bed and banks and in which water normally flows.

(1982, c. 583, § 62.1-115.1; 1986, c. 9; 1988, c. 891; 2001, c. 92; 2006, c. 30.)

§ 10.1-604.1. Determination of hazard potential classification.

A. The hazard potential classification for an impounding structure shall be determined by one of the following procedures:

1. The owner of an impounding structure that does not currently hold a regular or conditional certificate from the Board, or the owner of an impounding structure that is already under certificate but the owner believes that a condition has changed downstream of the impounding structure that may reduce its hazard potential classification, may request that the Department conduct a simplified dam break inundation zone analysis to determine whether the impounding structure has a low hazard potential classification. The owner shall pay 50 percent of the cost of the analysis. If the Department finds that the impounding structure has a low hazard potential classification, the owner shall be eligible for general permit coverage in accordance with § 10.1-605.3. If the Department finds that the impounding structure appears to be a high or significant hazard potential structure, the owner's engineer shall provide further analysis in accordance with § 10.1-606.2 and the criteria set out in the Impounding Structure Regulations (4 VAC 50-20). The owner may be eligible for grant assistance in accordance with § 10.1-603.19.

2. The owner may propose a hazard potential classification that shall be subject to approval by the Board. To support the proposed hazard classification, an analysis shall be conducted by the owner's engineer and shall comply with the criteria set out in the Impounding Structure Regulations (4 VAC 50-20). If the engineer finds that the impounding structure has a low hazard potential classification, the owner shall be eligible for general permit coverage in accordance with § 10.1-605.3.

An impounding structure's hazard potential classification's determination shall include an analysis of those hazards created by flood and nonflood dam failures. In conducting the hazard potential classification, the Department or the owner's engineer may utilize an incremental damage analysis. When considering the failure of the impounding structure under a flood condition, such engineers shall only consider those hazards that exceed those created by the flood event.

B. Any owner aggrieved by a decision of the Department regarding his impounding structure shall have the right to judicial review of the final decision pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

C. The Board may adopt regulations in accordance with § 10.1-605 to establish a simplified methodology for dam break inundation zone analysis.

(2011, c. 637.)

§ 10.1-605. Promulgation of regulations by the Board; guidance document.

A. The Board shall adopt regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated. Dam safety regulations promulgated by the State Water Control Board shall remain in full force until amended in accordance with applicable procedures.

B. The Board's Impounding Structure Regulations shall not require any impounding structure in existence or under a construction permit prior to July 1, 2010, that is currently classified as high hazard, or is subsequently found to be high hazard through reclassification, to upgrade its spillway to pass a rainfall event greater than the maximum recorded within the Commonwealth, which shall be deemed to be 90 percent of the probable maximum precipitation.

1. Such an impounding structure shall be determined to be in compliance with the spillway requirements of the regulations provided that (i) the impounding structure will pass two-thirds of the reduced probable maximum precipitation requirement described in this subsection and (ii) the dam owner certifies annually and by January 15 that such impounding structure meets each of the following conditions:

a. The owner has a current emergency action plan that is approved by the Board and that is developed and updated in accordance with the regulations;

b. The owner has exercised the emergency action plan in accordance with the regulations and conducts a table-top exercise at least once every two years;

c. The Department has verification that both the local organization for emergency management and the Virginia Department of Emergency Management have on file current emergency action plans and updates for the impounding structure;

d. That conditions at the impounding structure are monitored on a daily basis and as dictated by the emergency action plan;

e. The impounding structure is inspected at least annually by a professional engineer and all observed deficiencies are addressed within 120 days of such inspection;

f. The owner has a dam break inundation zone map developed in accordance with the regulations that is acceptable to the Department;

g. The owner is insured in an amount that will substantially cover the costs of downstream property losses to others that may result from a dam failure; and

h. The owner shall post the dam's emergency action plan on his website, or upon the request of the owner, the Department or another state agency responsible for providing emergency management services to citizens agrees to post the plan on its website. If the Department or another state agency agrees to post the plan on its website, the owner shall provide the plan in a format suitable for posting.

2. A dam owner who meets the conditions of subdivisions 1 a through 1 h, but has not provided record drawings to the Department for his impounding structure, shall submit a complete record report developed in accordance with the construction permit requirements of the Impounding Structure Regulations, excluding the required submittal of the record drawings.

3. A dam owner who fails to submit certifications required by subdivisions 1 a through 1 h in a timely fashion shall not enjoy the presumption that such impounding structure is deemed to be in compliance with the spillway requirements of the Board's Impounding Structure Regulations (4 VAC 50-20).

4. Any dam owner who has submitted the certifications required by subdivisions 1 a through 1 h shall make (i) such certifications, (ii) the emergency action plan required by subdivision 1 a, and (iii) the certificate of insurance required by subdivision 1 g available, upon request and within five business days, to any person. A dam owner may comply with the requirements of this subdivision by providing the same information on a website and directing the requestor to such website. A dam owner who fails to comply with this subdivision shall be subject to a civil penalty pursuant to § 10.1-613.2.

C. The Board's regulations shall establish an incremental damage analysis procedure that permits the spillway design flood requirement for an impounding structure to be reduced to the level at which dam failure shall not significantly increase downstream hazard to life or property, provided that the spillway design flood requirement shall not be reduced to below the 100-year flood event for high or significant hazard impounding structures, or to below the 50-year flood event for low hazard potential impounding structures.

D. The Board shall consider the impact of limited-use or private roadways with low traffic volume and low public safety risk that are downstream from or across an impounding structure in the determination of the hazard potential classification of an impounding structure.

(1982, c. 583, § 62.1-115.2; 1986, c. 9; 1988, c. 891; 2010, cc. 249, 270; 2011, c. 323.)

§ 10.1-605.1. Delegation of powers and duties.

The Board may delegate to the Director or his designee any of the powers and duties vested in the Board by this article, except the adoption and promulgation of regulations. Delegation shall not remove from the Board authority to enforce the provisions of this article. At each meeting of the Board, the Director shall identify those impounding structures that are currently classified as high hazard and determined noncompliant with the spillway requirements of the Board's Impounding Structure Regulations (4 VAC 50-20) or with statutory presumption provided by subsection B of § 10.1-605.

(2006, c. 30; 2011, c. 323.)

§ 10.1-605.2. Certain regulations affecting impounding structures.

The Virginia Soil and Water Conservation Board shall, in accordance with the Administrative Process Act (§ 2.2-4000 et seq.), adopt regulations that consider the impact of downstream limited-use or private roadways with low traffic volume and low public safety risk on the determination of the hazard potential classification of an impounding structure under the Dam Safety Act (§ 10.1-604 et seq.).

(2010, c. 41.)

§ 10.1-605.3. General permit for certain impounding structures.

A. The Board shall develop a general permit for the regulation of low hazard potential impounding structures in accordance with § 10.1-605.

B. The regulations shall include the following:

1. A registration statement requiring:

a. The name and address of the owner;

b. The location of the impounding structure;

c. The height of the impounding structure;

d. The volume of water impounded; and

e. A certification from the owner that the impounding structure (i) is classified as low hazard pursuant to a determination by the Department or the owner's professional engineer in accordance with § 10.1-604.1; (ii) is, to the best of his knowledge, properly and safely constructed and currently has no observable deficiencies; and (iii) shall be maintained and operated in accordance with the provisions of the general permit.

2. A spillway design flood requirement of the 100-year flood. When appropriate, the spillway design flood requirement may be reduced to the 50-year flood in accordance with an incremental damage analysis.

3. A simplified emergency preparedness plan that provides:

a. Name and location information for the impounding structure;

b. Name of owner and operator and associated contact information;

c. Contact information for relevant emergency responders;

d. Procedures for notifying downstream property owners or occupants; and

e. Identification of any downstream roadways that would be impacted by a failure.

4. An annual inspection of the impounding structure by the owner. No inspection of the impounding structure by a licensed professional engineer shall be required if the owner certifies at the time of general permit coverage renewal that conditions at the impounding structure and downstream are unchanged.

5. Procedures for seeking and issuing coverage under the general permit.

6. A six-year term of coverage under the general permit after which time the owner shall reapply for coverage by filing a new registration statement. The Board may, by regulation, establish a fee for the processing of registration statements.

C. The owner shall notify the Department immediately of any change in circumstances that would cause the impounding structure to no longer qualify for coverage under the general permit. In the event of a failure or an imminent failure at the impounding structure, the owner shall immediately notify the local emergency services coordinator, the Department of Emergency Management, and the Department. The Department shall take actions in accordance with § 10.1-608 or 10.1-609, depending on the degree of hazard and the imminence of failure caused by the unsafe condition.

D. Failure to comply with the provisions of the general permit may result in penalties assessed in accordance with §§ 10.1-613.1 and 10.1-613.2.

E. In order to qualify for the provisions of § 10.1-606.3, a dam owner eligible for a general permit shall file a dam break inundation map with the Department and with the offices with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides in accordance with § 10.1-606.2.

F. If the failure of a low hazard potential impounding structure is not expected to cause loss of human life or economic damage to any property except property owned by the owner, the owner may follow the special criteria established for certain low hazard impounding structures in the Impounding Structure Regulations (4 VAC 50-20) in lieu of coverage under the general permit.

(2011, c. 637.)

§ 10.1-606. Local advisory committee.

When requested by the governing body of any affected county or city, the Board shall provide for the creation of a local advisory committee to advise the Board on impoundments within that locality. The advisory committee shall include, but not be limited to, representation of the owner and each affected county or city. Prior to the issuance of any permits under this article, the Board shall advise any existing local advisory committee of any affected jurisdiction for which a permit is being sought, and request comments from the committee on the permit application. No permit shall be issued until at least sixty days after such a local advisory committee has been so advised.

(1982, c. 583, § 62.1-115.3; 1984, c. 240; 1988, c. 891.)

§ 10.1-606.2. Mapping of dam break inundation zones.

A. An owner of an impounding structure shall prepare a map of the dam break inundation zone for the impounding structure in accordance with criteria set out in the Virginia Impounding Structure Regulations (4VAC 50-20). Existing maps prepared by the locality in accordance with these regulations may be used for this purpose.

B. All maps prepared in accordance with subsection A shall be filed with the Department of Conservation and Recreation and with the offices with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides.

C. Owners of impounding structures may be eligible for matching grants of up to 50 percent from the Dam Safety, Flood Prevention and Protection Assistance Fund and other sources of funding available to the Director to assist in the development of dam break inundation zone maps and for conducting incremental damage assessments in accordance with the Virginia Impounding Structure Regulations.

D. All properties identified within the dam break inundation zone shall be incorporated by the owner into the dam safety emergency action plan of that impounding structure so as to ensure the proper notification of persons downstream and other affected persons or property owners in the event of an emergency condition at the impounding structure.

(2008, c. 491.)

§ 10.1-606.3. Requirement for development in dam break inundation zones.

A. For any development proposed within the boundaries of a dam break inundation zone that has been mapped in accordance with § 10.1-606.2, the locality shall, as part of a preliminary plan review pursuant to § 15.2-2260, or as part of a plan review pursuant to § 15.2-2259 if no preliminary review has been conducted, (i) review the dam break inundation zone map on file with the locality for the affected impounding structure, (ii) notify the dam owner, and (iii) within 10 days forward a request to the Department of Conservation and Recreation to make a determination of the potential impacts of the proposed development on the spillway design flood standards required of the dam. The Department shall notify the dam owner and the locality of its determination within 45 days of the receipt of the request. Upon receipt of the Department's determination, the locality shall complete the review in accordance with § 15.2-2259 or 15.2-2260. If a locality has not received a determination within 45 days of the Department's receipt of the request, the Department shall be deemed to have no comments, and the locality shall complete its review. Such inaction by the Department shall not affect the Board's authority to regulate the impounding structure in accordance with this article.

If the Department determines that the plan of development would change the spillway design flood standards of the impounding structure, the locality shall not permit development as defined in § 15.2-2201 or redevelopment in the dam break inundation zone unless the developer or subdivider agrees to alter the plan of development so that it does not alter the spillway design flood standard required of the impounding structure or he contributes payment to the necessary upgrades to the affected impounding structure pursuant to § 15.2-2243.1.

The developer or subdivider shall provide the dam owner and all affected localities with information necessary for the dam owner to update the dam break inundation zone map to reflect any new development within the dam break inundation zone following completion of the development.

The requirements of this subsection shall not apply to any development proposed downstream of a dam for which a dam break inundation zone map is not on file with the locality as of the time of the official submission of a development plan to the locality.

B. The locality is authorized to map the dam break inundation zone in accordance with criteria set out in the Virginia Impounding Structure Regulations (4VAC 50-20) and recover the costs of such mapping from the owner of an impounding structure for which a dam break inundation zone map is not on file with the locality and a map has not been prepared by the impounding structure owner.

C. This section shall not be construed to supersede or conflict with the authority granted to the Department of Mines, Minerals and Energy for the regulation of mineral extraction activities in the Commonwealth as set out in Title 45.1. Nothing in this section shall be interpreted to permit the impairment of a vested right in accordance with § 15.2-2307.

(2008, c. 491.)

§ 10.1-606.4. Notice to the public.

A. When applying to the Department for a permit under the Virginia Impounding Structure Regulations (4 VAC 50-20) to construct a new high or significant hazard potential impounding structure, the applicant shall provide localities that lie within the inundation zone with copies of the construction permit request and the dam break inundation zone map.

B. When submitting the application to the Department, the permit applicant shall publish a notice in a newspaper of general circulation in the affected localities summarizing the permit request and providing the address of locations where copies of the construction permit request and the dam break inundation zone map may be examined. The applicant shall provide copies of the published notice to the Department and to the local government offices with plat and plan approval authority or zoning responsibilities as designated by the locality.

C. The Department may hold, on behalf of the Virginia Soil and Water Conservation Board, a public hearing on safety issues associated with the construction permit application for the impounding structure.

D. The Department may require a permit applicant to provide other forms of reasonable notice, such as the placement of a sign on the proposed site, to ensure that affected parties have been informed.

E. The permit applicant shall send, by certified mail, to each property owner within the dam break inundation zone, a summary of the permit request and the addresses of locations where the map of the dam break inundation zone may be viewed. In the case of a condominium or cooperative, such information shall be sent to each property owner or the owners' association. The permit applicant may rely upon real estate assessment records to identify property owners. If requested by the Department, the applicant shall provide a list of the persons to whom notice has been sent.

(2008, c. 491; 2011, c. 637.)

§ 10.1-607. Safety inspections.

No one shall maintain a dam which unreasonably threatens the life or property of another. The Board shall cause safety inspections to be made of impounding structures on such schedule as it deems appropriate. The time of the initial inspection and the frequency of reinspection shall depend on such factors as the condition of the structure and its size, type, location and downstream hazard potential. The owners of dams found to have deficiencies which could threaten life or property if not corrected shall take the corrective actions needed to remove such deficiencies within a reasonable time. All safety inspections shall be conducted by or under the supervision of a licensed professional engineer. Each report shall bear the seal and signature of the licensed professional engineer responsible for the inspection.

The Board shall be responsible for the inspection and reinspection of flood control dams where the maintenance and operation of the dam is the responsibility of a soil and water conservation district and where the permit for operation of the impounding structure is held by such a district.

(1982, c. 583, § 62.1-115.4; 1986, c. 209; 1988, c. 891; 2000, c. 14.)

§ 10.1-607.1. Criteria for designating a dam as unsafe.

A. Designation of a dam as unsafe shall be based on one or more of the following findings:

1. The dam has serious deficiencies in its design or construction or has a physical condition that if left unaddressed could result in a failure that may result in loss of life or significant damage to downstream property.

2. The design, construction, operation, or maintenance of the dam is such that its expected performance during flooding conditions threatens the structural integrity of the dam.

B. After completion of the safety inspections pursuant to § 10.1-607, or as otherwise informed of an unsafe condition, the Department shall take actions in accordance with § 10.1-608 or 10.1-609 depending on the degree of hazard and imminence of failure caused by the unsafe condition.

(2006, c. 30; 2010, c. 270.)

§ 10.1-608. Unsafe dams presenting imminent danger.

When the Director finds an unsafe dam constituting an imminent danger to life or property, he shall immediately notify the Department of Emergency Management and confer with the owner. The owner of a dam found to constitute an imminent danger to life or property shall take immediate corrective action. If the owner does not take appropriate and timely action to correct the danger found, the Governor shall have the authority to take immediate appropriate action, without the necessity for a hearing, to remove the imminent danger. The Attorney General may bring an action against the owner of the impounding structure for the Commonwealth's expenses in removing the imminent danger. There shall be a lien upon the owner's real estate for the Commonwealth's expenses in removing the imminent danger. The owner may avoid the Commonwealth's costs, and recover any damages, upon proving that the dam was known to be safe at the time such action was taken, and that the owner had provided or offered to immediately provide such proof to the Director before the action complained of was taken. Nothing herein shall in any way limit any authority existing under the Emergency Services and Disaster Law (§ 44-146.13 et seq.).

(1982, c. 583, § 62.1-115.5; 1986, c. 9; 1988, c. 891.)

§ 10.1-609. Unsafe dams presenting nonimminent danger.

A. Within a reasonable time after completion of a safety inspection of an impounding structure authorized by § 10.1-607, the Board shall issue a report to the owner of the impounding structure containing its findings and recommendations for correction of any deficiencies which could threaten life or property if not corrected. Owners who have been issued a report containing recommendations for correction of deficiencies shall undertake to implement the recommendations contained in the report according to the schedule of implementation contained in the report. If an owner fails or refuses to commence or diligently implement the recommendations for correction of deficiencies according to the schedule contained in an issued report, the Director shall have the authority to issue an administrative order directing the owner to commence implementation and completion of such recommendations according to the schedule contained in the report with modifications as appropriate. Within thirty days after being served by personal service or by mail with a copy of an order issued pursuant to this section, any owner shall have the right to petition the Board for a hearing. As part of his petition, a dam owner may submit to the Board his own plan, consistent with regulations adopted pursuant to §

10.1-605, to address the recommendations for correction of deficiencies and the schedule of implementation contained in the report. The Board shall determine if the submitted plan and schedule are sufficient to address deficiencies. A timely filed petition shall stay the effect of the administrative order.

The hearing shall be conducted before the Board or a designated member thereof pursuant to § 2.2-4019. The Board shall have the authority to affirm, modify, amend or cancel the administrative order. Any owner aggrieved by a decision of the Board after a hearing shall have the right to judicial review of the final Board decision pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

B. The provisions of subsection A of this section notwithstanding, if the Director determines, after the report is issued, that changed circumstances justify reclassifying the deficiencies of an impounding structure as an imminent danger to life or property, the Director may proceed directly under § 10.1-613 for enforcement of his order, and the owner shall have the opportunity to contest the fact based upon which the administrative order was issued.

C. The Director, upon a determination that there is an unsafe condition at an impounding structure, is authorized to cause the lowering or complete draining of such impoundment until the unsafe condition has been corrected at the owner's expense and prior to any authorization to refill.

An owner who fails to comply with the provisions contained in an administrative order of the Department shall be subject to procedures set out in § 10.1-613 and the penalties authorized under §§ 10.1-613.1 and 10.1-613.2.

D. No persons, other than those authorized to maintain an impounding structure, shall interfere with the operation of an impounding structure.

(1982, c. 583, § 62.1-115.6; 1986, cc. 9, 615; 1988, c. 891; 1999, c. 110; 2006, c. 30; 2010, c. 270.)

§ 10.1-609.1. Installation of IFLOWS gauges.

A soil and water conservation district responsible for the maintenance and operation of a flood control dam shall be permitted to install Integrated Flood Observing and Warning Systems (IFLOWS) gauges and associated equipment, or a device approved by the Department of

Emergency Management, while awaiting funds to make structural modifications to correct emergency spillway capacity deficiencies in the dam, identified by the Board in a report issued pursuant to § 10.1-609, when any of the following conditions exist: (i) funds are not available to make such structural modifications to the dam, (ii) the completion of such structural modifications requires the acquisition of additional property or easements by exercise of the power of eminent domain, or (iii) funds for the IFLOWS equipment or an equivalent device have been appropriated by the General Assembly. Installation of IFLOWS gauges or similar devices shall not affect the regulated status of the dam under the Virginia Dam Safety Act (§ 10.1-604 et seq.). Any IFLOWS gauges and associated equipment shall be installed in a manner approved by the Department of Emergency Management and shall be operated and maintained by the Department of Emergency Management.

(1993, c. 709.)

§ 10.1-609.2. Prohibited vegetation.

Dam owners shall not permit the growth of trees and other woody vegetation and shall remove any such vegetation from the slopes and crest of embankments and the emergency spillway area, and within a distance of 25 feet from the toe of the embankment and abutments of the dam. Owners failing to maintain their dam in accordance with this section shall be subject to enforcement pursuant to § 10.1-613.

(2006, c. 30.)

§ 10.1-610. Right of entry.

The Board and its agents and employees shall have the right to enter any property at reasonable times and under reasonable circumstances to perform such inspections and tests or to take such other actions it deems necessary to fulfill its responsibilities under this article, including the inspection of dams that may be subject to this article, provided that the Board or its agents or employees make a reasonable effort to obtain the consent of the owner of the land prior to entry. If entry is denied, the Board or its designated agents or employees may apply to any magistrate whose territorial jurisdiction encompasses the property to be inspected or entered for a warrant authorizing such investigation, tests or other actions. Such warrant shall issue if the magistrate finds probable cause to believe that there is a dam on such property which is not known to be safe.

(1982, c. 583, § 62.1-115.7; 1988, c. 891; 2005, c. 117.)

§ 10.1-610.1. Monitoring progress of work.

A. During the maintenance, construction, or alteration of any dam or reservoir, the Department shall make periodic inspections for the purpose of securing conformity with the approved plans and specifications. The Department shall require the owner to perform at his expense such work or tests as necessary to obtain information sufficient to enable the Department to determine whether conformity with the approved plans and specifications is being secured.

B. If, after any inspections, investigations, or examinations, or at any time as the work progresses, or at any time prior to issuance of a certificate of approval, it is found by the Director that project modifications or changes are necessary to ensure conformity with the approved plans and specifications, the Director may issue an administrative order to the owner to comply with the plans and specifications. Within 15 calendar days after being served by personal service or by mail with a copy of an order issued pursuant to this section, any owner shall have the right to petition the Board for a hearing. A timely filed petition shall stay the effect of the administrative order. The hearing shall be conducted before the Board or a designated member of the Board pursuant to § 2.2-4019. The Board shall have the authority to affirm, modify, amend, or cancel the administrative order. Any owner aggrieved by a decision of the Board after a hearing shall have the right to judicial review of the final Board decision pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

C. Following the Board hearing, subject to judicial review of the final decision of the Board, if conditions are revealed that will not permit the construction of a safe dam or reservoir, the certificate of approval may be revoked. As part of the revocation, the Board may compel the owner to remove the incomplete structure sufficiently to eliminate any safety hazard to life or property.

(2006, c. 30.)

§ 10.1-611. Dam safety coordination.

The Board shall coordinate all impoundment safety activities in the Commonwealth, which shall include, but not be limited to: (i) the maintenance of an inventory of all impoundment structures and of all other similar structures that are not regulated under this article to the extent the Board deems necessary; (ii) the maintenance of a repository for record drawings of all such structures to the extent the Board deems necessary; (iii) the maintenance of an inventory of safety inspection reports for each such structure to the extent the Board deems necessary; and (iv) the maintenance of a secondary repository for all dam safety emergency action plans, which are primarily filed with the Department of Emergency Management. The Board shall consult with the Department of Emergency Management in its planning for impoundment safety and shall provide technical assistance in the preparation, updating, and execution of dam safety emergency action plans. It shall establish uniform maintenance-of-records requirements and uniform inspection standards to be applied to all impounding structures in the Commonwealth and to be recommended for all other similar structures. It may inspect or cause to be inspected state-owned or state-licensed dams on a cost-reimbursable basis at the request of the state agency owning the state-owned dam or of the licensor of the state-licensed dam.

(1982, c. 583, § 62.1-115.8; 1986, c. 9; 1988, c. 891; 2012, cc. 70, 230.)

§ 10.1-611.1. Soil and Water Conservation District Dam Maintenance, Repair, and Rehabilitation Fund established; Department to manage; Board to expend moneys; regulations.

A. There is hereby created in the state treasury a special nonreverting fund to be known as the Soil and Water Conservation District Dam Maintenance, Repair, and Rehabilitation Fund, hereafter referred to as "the Fund." The Fund shall be comprised of moneys appropriated to the Fund by the General Assembly and any other moneys designated for deposit to the Fund from any source, public or private. The Fund shall be established on the books of the Comptroller and the moneys shall be paid into the state treasury and credited to the Fund. Interest earned on moneys in the Fund shall remain in the Fund and be credited to it. Any moneys remaining in the Fund, including interest thereon, at the end of each fiscal year shall not revert to the general fund but shall remain in the Fund. Moneys in the Fund shall be used solely for (i) the maintenance and repair of any dams owned by soil and water conservation districts and (ii) the rehabilitation and major repair of Class I and Class II dams owned by soil and water conservation districts, in order to bring such dams into compliance with regulations promulgated pursuant to Article 2 (§ 10.1-604 et seq.) of Chapter 6 of this title. Expenditures from the Fund made under clause (ii) of this subsection may include, but are not limited to, the following repairs to the infrastructure of a dam: increasing the height of a dam, modifying the spillway, and reducing wave erosion of a dam's inside face. Expenditures and disbursements from the Fund shall be made by the State Treasurer on warrants issued by the Comptroller upon written request signed by the Director of the Department of Conservation and Recreation.

B. The Fund shall be administered and managed by the Department of Conservation and Recreation, subject to the right of the Board, following consultation with the Department of Conservation and Recreation, to direct the distribution of moneys in the Fund to particular soil and water conservation districts.

C. The Board is authorized to promulgate regulations for the proper administration of the Fund. Such regulations may include, but are not limited to, the type and amount of financial assistance, the terms and conditions of the assistance, and project eligibility criteria.

(1997, c. 356; 2000, cc. 23, 205.)

§ 10.1-612. Technical Advisory Committee.

The Board shall establish an Impoundment Safety Technical Advisory Committee to provide technical review. The Committee may make recommendations to the Board.

(1982, c. 583, § 62.1-115.9; 1988, c. 891.)

§ 10.1-612.1. Temporary stop work order; hearing; injunctive relief.

A. The Director may issue a temporary stop work order on a construction or alteration project if he finds that an owner is constructing or altering a dam without having first obtained the necessary certificate of approval, or if the activities are not in accordance with approved plans and specifications. The order shall include written notice to the owner of the date, time, and location where the owner may appear at a hearing before the Board or a designated member thereof pursuant to § 2.2-4019 to show cause why the temporary order should be vacated. The hearing shall be held within 15 calendar days of the date of the order, unless the owner consents to a longer period.

B. Following the hearing, the Board may affirm or cancel the temporary order and may issue a final order directing that immediate steps be taken to abate or ameliorate any harm or damage arising from the violation. The owner may seek judicial review of the final decision of the Board pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

C. If the violation continues after the Board has issued a final decision and order pursuant to subsection B or a temporary order issued by the Director pursuant to subsection A, the Board may apply for an injunction from the appropriate court. A decision to seek injunctive relief does not preclude other forms of relief, enforcement, or penalties against the owner.

(2006, c. 30.)

§ 10.1-613. Enforcement.

Any person or legal entity failing or refusing to comply with an order issued pursuant to this article may be compelled to comply with the order in a proceeding instituted in any appropriate court by the Board. The Board shall bring suit in the name of the Commonwealth in any court of competent jurisdiction to enjoin the unlawful construction, modification, operation, or maintenance of any dam regulated under this article. Such court may require the removal or modification of any such dam by mandatory injunction. If the court orders the removal of the dam, the owner shall be required to bear the expenses of such removal.

Should the Board be required to implement and carry out the action, the Board shall charge the owner for any expenses associated with the action, and if the repayment is not made within 90 days after written demand, the Board may bring an action in the proper court to recover this expense. The Board shall file an action in the court having jurisdiction over any owner or the owner's property for the recovery of such costs. A lien in the amount of such costs shall be automatically created on all property owned by any such owner at or proximate to such dam or reservoir.

(1982, c. 583, § 62.1-115.10; 1988, c. 891; 2006, c. 30.)

§ 10.1-613.1. Criminal penalties.

A. It is unlawful for any owner to knowingly:

1. Operate, construct, or alter a dam without an approval as provided in this article;

2. Violate the terms of an approval, order, regulation, or requirement of the Board or Director under this article; or

3. Obstruct, hinder, or prevent the Board or its designated agents or employees from performing duties under this article.

A violation of any provision of this subsection or this article is a Class 3 misdemeanor.

B. Each day that any such violation occurs after notice of the original violation is served upon the violator by the Board or its designated agents or employees by registered mail shall constitute a separate offense. Upon conviction, the violator is subject to a fine not exceeding $500 per day for each day of the offense, not to exceed a total fine of $25,000, with costs imposed at the discretion of the court. In determining the amount of the penalty, the appropriate court shall consider the degree of harm to the public; whether the violation was knowing or willful; the past conduct of the defendant; whether the defendant should have been on notice of the violation; whether the defendant has taken steps to cease, remove, or mitigate the violation; and any other relevant information.

(2006, c. 30.)

§ 10.1-613.2. Civil penalties.

In addition to or in lieu of any other forfeitures, remedies, or penalties authorized by law or regulations, any owner violating any provision of this article may be assessed a civil penalty of up to $500 per day by the Board not to exceed a maximum of $25,000.

In setting the civil penalty amount, the Board shall consider (i) the nature, duration, and number of previous instances of failure by the owner to comply with requirements of law relating to dam safety and the requirements of Board regulations and orders; (ii) the efforts of the owner to correct deficiencies or other instances of failure to comply with the requirements of law relating to dam safety and the requirements of Board regulations and orders that are the subject of the proposed penalty; (iii) the cost of carrying out actions required to meet the requirements of law and Board regulations and orders; (iv) the hazard classification of the dam; and (v) other factors deemed appropriate by the Board.

All civil penalties will be assessed by written penalty notice from the Board and given by certified mail or personal service. The notice shall state the specific reasons for the penalty, the number of days the Department considers the owner in violation, and the total amount due. Within 30 days after receipt of a copy of the order issued pursuant to this section, any owner subject to the civil penalty provisions shall have the right to petition the Board, in writing, for a hearing. A timely filed petition shall stay the effect of the penalty notice.

The hearing shall be conducted before the Board or a designated member thereof pursuant to § 2.2-4019. The Board shall affirm, modify, amend, or cancel the penalty notice within 10 days following the conclusion of the hearing. Any owner aggrieved by a decision of the Board after a hearing shall have the right to judicial review of the final Board decision pursuant to the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

If any civil penalty has not been paid within 45 days after the final Board decision or court order has been served on the violator, the Board shall request the Attorney General to institute a civil action in the court of any county in which the violator resides or has his principal place of business to recover the amount of the assessment.

Civil penalties assessed under this section shall be paid into the Flood Prevention and Protection Assistance Fund, established pursuant to § 10.1-603.17, and shall be used for the administration of the dam safety program, including for the repair and maintenance of dams.

(2006, c. 30.)

§ 10.1-613.3. No liability of Board, Department, employees, or agents.

An owner may not bring an action against the Commonwealth, the Board, the Department, or agents or employees of the Commonwealth for the recovery of damages caused by the partial or total failure of a dam or reservoir, or by the operation of a dam or reservoir, or by an act or omission in connection with:

1. Approval of the construction, alteration, or maintenance of a dam or reservoir, or approval of flood-operations plans during or after construction;

2. Issuance or enforcement of orders relating to maintenance or operation of the dam or reservoir;

3. Control or regulation of the dam or reservoir;

4. Measures taken to protect against failure of the dam or reservoir during an emergency;

5. Investigations or inspections authorized under this article;

6. Use of design and construction criteria prepared by the Department; or

7. Determination of the hazard classification of the dam.

(2006, c. 30.)

§ 10.1-613.4. Liability of owner or operator.

Nothing in this article, and no order, notice, approval, or advice of the Director or Board shall relieve any owner or operator of such a structure from any legal duties, obligations, and liabilities resulting from such ownership or operation. The owner shall be responsible for liability for damage to the property of others or injury to persons, including, but not limited to, loss of life resulting from the operation or failure of a dam. Compliance with this article does not guarantee the safety of a dam or relieve the owner of liability in case of a dam failure.

(2006, c. 30.)

§ 10.1-613.5. Program administration fees; establishment of Dam Safety Administrative Fund.

A. The Board is authorized to establish and collect application fees from any applicant to be deposited into the Dam Safety Administrative Fund established pursuant to subsection B. Permit applications shall not be reviewed without a full payment of the required fee. Virginia Soil and Water Conservation Districts shall be exempt from all fees established pursuant to this section.

B. There is hereby created in the state treasury a special nonreverting fund to be known as the Dam Safety Administrative Fund, hereafter referred to as "the Fund." The Fund shall be established on the books of the Comptroller. The Fund shall consist of permit application fees authorized under subsection A and shall be used for the administration of the dam safety program, including actions taken in accordance with §§ 10.1-608, 10.1-609, and 10.1-613. All such funds shall be paid into the state treasury and credited to the Fund. Interest earned on moneys in the Fund shall remain in the Fund and be credited to it. Any moneys remaining in the Fund, including interest thereon, at the end of each fiscal year shall not revert to the general fund but shall remain in the Fund. Expenditures and disbursements from the Fund shall be made by the State Treasurer on warrants issued by the Comptroller upon written request signed by the Director.

(2006, c. 30; 2010, c. 13.)

Forms TAB

VIRGINIA DAM OWNER'S HANDBOOK, 2ND EDITION

TABLE OF CONTENTS

FORMS

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Date Prepared: ________________
Prepared By: ________________

ANNUAL INSPECTION REPORT FOR VIRGINIA REGULATED IMPOUNDING STRUCTURES

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-105, Virginia Soil and Water Conservation Board

Owner's Information

Name of Dam: ________________ Inventory Number: ________________
Owner's Name: ________________ Location-County/City: ________________
Contact Person (if different from above): ________________
Owner's Address: ________________ Hazard Classification: ________________
Name of reservoir: ________________
Purpose of reservoir: ________________
Telephone No.: (Residential) ________________ (Business) ________________
Other means of communication: ________________

Owner's Engineer

Name of Engineering Firm and Engineer: ________________
Professional Engineer Virginia License Number: ________________
Mailing Address: ________________

Telephone No.: (Business) ________________

Directions: Make note of all pertinent conditions and changes since the last inspection, or, if this is the first inspection, since the filing of a design report.

Date of This Inspection ________________
Date of Last Inspection ________________

1. EMBANKMENT

a. Any alteration made to the embankment? ________________

b. Erosion on embankment? ________________

c. Settlement, misalignment or cracks in embankment? ________________

d. Seepage? If so, seepage flow rate and location (describe any turbidity and observed color within the flow): ________________

2. UPSTREAM SLOPE

a. Woody vegetation discovered? ________________
b. Rodent burrows discovered? ________________
c. Remedial work performed? ________________

3. INTAKE STRUCTURE

a. Deterioration of concrete? ________________
b. Exposure of rebar reinforcement? ________________
c. Is there a need to repair or replace the trash rack? ________________
d. Any problems with debris? ________________
e. Was the drawdown valve operated? ________________

4. ABUTMENT CONTACTS

a. Any seepage? If so, estimate the flow rate and describe the location of the seep or damp areas (describe any turbidity and observed color within the flow): ___

---

5. EARTHEN EMERGENCY SPILLWAY

a. Obstructions to flow? If so, describe plans to correct: ___

b. Rodent burrows discovered? ___

c. Any deterioration in the approach or discharge channel?

---

6. CONCRETE EMERGENCY SPILLWAY

a. Deterioration of concrete? ___

b. Exposed steel reinforcement? ___

c. Any leakage below concrete spillway? ___

d. Obstructions to flow? If so, lists plans to correct: ___

---

7. DOWNSTREAM SLOPE

a. Woody vegetation discovered? ___

b. Rodent burrows discovered? ___

c. Are seepage drains flowing? ___

d. Any seepage or wet areas? ___

---

8. OUTLET PIPE

a. Any water flowing outside of discharge pipe through the Impounding Structure? ___

b. Describe any deflection or damage to the pipe: ___

---

9. STILLING BASIN

a. Deterioration of concrete structures? ___

b. Exposure of rebar reinforcement? ___

c. Deterioration of the basin slopes? ___

d. Repairs made? ___

e. Any obstruction to flow? ___

---

10. GATES

a. Gate malfunctions or repairs? ___

b. Corrosion or damage? ___

c. Were any gates operated? If so, how often and to what extreme? ___

---

11. RESERVOIR/WATERSHED

a. New developments upstream of dam? ___

b. Slides or erosion of lake banks around the rim? ___

c. General comments to include silt, algae or other influence factors: ___

---

12. INSTRUMENTS

a. List all instruments ______________________________
b. Any readings of instruments? ______________________________
c. Any installation of new instruments? ______________________________

13. DOWNSTREAM/HAZARD ISSUES

a. New development in downstream inundation zone? ______________________________
b. Note the maximum storm water discharge or peak elevation during the previous year. ______________________________
c. Was general maintenance performed on dam? If so, when? ______________________________
d. List actions that need to be accomplished before the next inspection: ______________________________

14. OVERALL CONDITION ASSESSMENT OF IMPOUNDING STRUCTURE AND APPURTENANCES

(Check one) ☐ **SATISFACTORY** ☐ **FAIR** ☐ **POOR** ☐ **UNSATISFACTORY** ☐ **NOT RATED**

1. SATISFACTORY
No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.
2. FAIR
No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action.
3. POOR
A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary.
4. UNSATISFACTORY
A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.
5. NOT RATED
The dam has not been inspected, is not under state jurisdiction, or has been inspected but, for whatever reason, has not been rated.

General Comments: ______________________________

Recommendations: ______________________________

CERTIFICATION BY OWNER'S ENGINEER (required only when an inspection by an engineer is required)

I hereby certify that the information provided in this report has been examined by me and found to be true and correct in my professional judgment.

Signed: ______________________________ Virginia Number: ____________

Professional Engineer's Signature Print Name

This ________ day of ____________ , 20 ___ .

Engineer's Virginia Seal:

CERTIFICATION BY OWNER

I hereby certify that the information provided in this report has been examined by me.

Signed: ______________________________

Owner's Signature Print Name

This ________ day of ____________ , 20 ___ .

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

DCR
Virginia Department of Conservation & Recreation

Date Prepared: ______________
Prepared By: ______________

RECORD REPORT FOR VIRGINIA REGULATED IMPOUNDING STRUCTURES

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-70 and 80, Virginia Soil and Water Conservation Board

---

1. **Project Information:**
   a. Name of Impounding Structure: ______________
   b. Inventory Number: ______________
   Other Name (if any): ______________
   c. Name of Reservoir: ______________
   d. Check one: ☐ Old Structure ☐ New Structure

---

2. **Location of Impounding Structure:**
   a. City or County: ______________
   b. Located ______ feet/miles upstream/downstream of Highway Number ______
   c. Name of river or stream: ______________
   d. Latitude: ______________ Longitude: ______________

---

3. **Ownership:**
   a. Owner's Name: ______________
   If a corporation, name of representative: ______________
   b. Mailing Address: ______________
   c. Telephone: (Residential) ______________ (Business) ______________
   d. Other means of communication: ______________

---

4. **Construction/Alteration Design Report:**
   a. Design Report prepared by: ______________
   b. Design Report date: ______________
   c. Check one: ☐ Construction ☐ Alteration Permit #: ______ Date Issued: ______

---

5. **Owner's Engineer:**
   a. Engineering Firm and Engineer: ______________
   b. Professional Engineer Virginia Number: ______________
   c. Mailing Address: ______________
   d. Telephone: (Business) ______________

---

6. **Impounding Structure Data (Identify datum used for all elevations):**
   a. Type of material: earth ☐ concrete ☐ masonry ☐ Other: ______________

	Design Configuration	
b. Top of Impounding Structure Elevation		Feet
c. Downstream Toe Elevation (Lowest)		Feet
d. Height of Impounding Structure		Feet
e. Crest Length (Exclusive of Spillway)		Feet
f. Crest Width		Feet
g. Upstream Slope (Horizontal to Vertical)	H:	V
h. Downstream Slope (Horizontal to Vertical)	H:	V

7. Reservoir Data

	Design Configuration	
a. Maximum Capacity		Acre-feet
b. Maximum Pool Elevation		Feet
c. Maximum Pool Surface Area		Acres
d. Normal Capacity		Acre-feet
e. Normal Pool Elevation		Feet
f. Normal Pool Surface Area		Acres
g. Freeboard (to lowest crest elevation)		Feet

8. Spillway Data

	Type	Construction Material	Design Capacity	Invert Elevation	
a. Low Level Drain					Feet
b. Principal Spillway					Feet
c. Emergency Spillway					Feet

d. Briefly describe the low level drain and principal spillway; include dimensions, trash guards, and orientation of intake and discharge to dam if looking downstream: ______________________

____

____

e. Describe the emergency spillway to include dimensions and orientation to dam if looking downstream:

____

____

9. Watershed Data:

a. Drainage Area: ______________ square miles

b. Type and Extent of Watershed Development: ______________________

____

c. Time of Concentration: ______________ (hours) Routing Procedure: ______________

d. Spillway Design Flood used (mark appropriate box):

______ PMF, source ______________________

______ ½ PMF, source ______________________

______ 100 Year, source ______________________

______ 50 Year, source ______________________

______ Other, source ______________________

e. Design inflow Hydrograph: Volume: ______________ acre-feet

Peak inflow: ______________ cfs

Rainfall duration of design inflow hydrograph: ______________ hours

f. Freeboard during passage of spillway design flood: ______________ feet

10. Impounding Structure History:

a. Date construction completed: ______________________

b. Designed by: ______________________ Date: ______________

c. Built by: ______________________ Date: ______________

d. Inspections by: ______________________ Date: ______________

e. Description of repairs: ______________________

f. Has the impounding structure ever been overtopped? ☐ Yes ☐ No

---

11. Operational Procedures: Provide a narrative describing the following impounding structure procedures:

a. Operation: ______________________

b. Maintenance: ______________________

c. Filling: ______________________

d. Emergency Action Plan Implementation: ______________________

e. Structure Evaluation: ______________________

---

12. Hydraulic/Hydrologic Data: Provide a narrative describing the following hydraulic/hydrologic data:

a. Spillway Design Flood: ______________________

b. Hydrologic records: ______________________

c. Flood experience: ______________________

d. Flood potential: ______________________

e. Reservoir regulation: ______________________

f. Comments/ Recommendations: ______________________

13. Dam Stability: Provide a narrative and evaluation describing impounding structure stability:

a. Foundation/abutments: ______________________________

b. Embankment materials: ______________________________

14. Attachments:

a. Attach Record Drawings signed and sealed by a licensed professional engineer and signed by the owner.

CERTIFICATION BY OWNER'S ENGINEER

I hereby certify that the information provided in this Record Report and the attached Record Drawings have been examined by me and found to be true and correct in my professional judgment.

Signed: ______________________________ Virginia Number: ______________

Professional Engineer's Signature Print Name

This __________ day of ______________ , 20 ____ .

Engineer's Virginia Seal:

CERTIFICATION BY OWNER

I hereby certify that the information provided in this Record Report and the attached Record Drawings have been examined by me.

Signed: ______________________________

Owner's Signature Print Name

This __________ day of ______________ , 20 ____ .

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

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Date Prepared: ________________
Prepared By: ________________

DESIGN REPORT FOR THE CONSTRUCTION OR ALTERATION OF VIRGINIA REGULATED IMPOUNDING STRUCTURES

Note: Any executed Design Report for construction of an impounding structure must be mailed to the appropriate Regional Engineer. In addition, a completed Certificate and Permit Application Fee Form (DCR199-192) and the required fee must be mailed under separate cover to: Virginia Department of Conservation and Recreation, Division of Finance, Accounts Payable, 600 E. Main St., 24th Floor, Richmond, Virginia 23219.

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-240, Virginia Soil and Water Conservation Board

1. Project Information:

a. Proposed Construction: ________________
Proposed Alteration: ________________
b. Name of Impounding Structure: ________________
c. Inventory Number: ________________ (Leave blank if new Construction)
d. Name of Reservoir: ________________
e. Purpose of Reservoir: ________________

2. Impounding Structure Hazard Classification:

a. Hazard Potential Classification Table I Impounding Structure Regulations:
(Check one) ☐ High ☐ Significant ☐ Low

3. Location of Impounding Structure:

a. City or County: ________________
b. Located ________ feet/miles upstream/downstream of Highway Number ________________
c. Name of river or stream: ________________
d. Latitude: ________________ Longitude: ________________

4. Ownership:

a. Owner's Name: ________________
If a corporation, name of representative: ________________
b. Mailing Address: ________________
____
____
c. Telephone: (Residential) ________________ (Business) ________________
d. Other means of communication: ________________

5. Design Engineer:

a. Design Engineer and Design Firm: ________________
b. Design Engineer Virginia License Number: ________________
c. Mailing Address: ________________
____
____
d. Telephone: (Business) ________________

6. Impounding Structure Data:

a. Type of material: earth ________ concrete ________ masonry ________
Other: ____

Note: Identify datum used for elevations.
For new construction, complete the design configuration column.
For alteration, complete both the existing and design configuration columns.

	Existing Configuration	Design Configuration	
b. Top of Dam Elevation			Feet
c. Streambed Elevation at Toe (Lowest)			Feet
d. Height of Impounding Structure			Feet
e. Crest Length (Exclusive of Spillway)			Feet
f. Crest Width			Feet
g. Upstream Slope (Horizontal to Vertical)	____ H: ____ V	____ H: ____ V	
h. Downstream Slope (Horizontal to Vertical)	____ H: ____ V	____ H: ____ V	

7. Reservoir Data	Existing Configuration	Design Configuration	
a. Maximum Capacity			Acre-feet
b. Maximum Pool Elevation			Feet
c. Maximum Pool Surface Area			Acres
d. Normal Capacity			Acre-feet
e. Normal Pool Elevation			Feet
f. Normal Pool Surface Area			Acres
g. Freeboard (to lowest crest elevation)			Feet

8. Spillway Data	Type	Construction Material	Design Configuration	Invert Elevation	
a. Low Level Drain					Feet
b. Principal Spillway					Feet
c. Emergency Spillway					Feet

9. Watershed Data:

a. Drainage Area: ________ square miles

b. Type and Extent of Watershed Development: ____

c. Time of Concentration: ________ (hours)

d. Routing Procedure: ________ Routing Model used: ________

e. Spillway Design Flood used (check and state source):

____ PMF, source ________

____ ½ PMF, source ________

____ 100 Year, source ________

____ Other, source ________

f. Design inflow hydrograph: Volume: ________ acre-feet

Peak inflow: ________ cfs

Rainfall duration of design inflow hydrograph: ________ hours

g. Freeboard during passage of spillway design flood: ________ feet

h. Provide printouts for 6, 12, and 24 hour models

10. Additional Information:

Provide as attachments to the Design Report the following information. Note: For alteration permits the details of this information is to be in accordance with the scope of the proposed alteration:

a. A description of properties located in the dam break inundation zone downstream from the site of the proposed/existing impounding structure, including the location and number of structures, buildings, roads, utilities and other property that would be endangered should the impounding structure fail.
b. Evidence that the local government or governments have been notified of the proposal by the owner to build or alter an impounding structure.
c. Maps showing the location of the impounding structure that include the county or city in which the proposed/existing impounding structure is located, the location of roads and access to the site, and the outline of the impoundment. Existing aerial photographs or existing topographic maps may be used for this purpose.
d. A report of the geotechnical investigations(s) of the foundation soils, bedrock, or both and of the materials to be used to construct or alter the impounding structure.
e. Design assumptions and analyses sufficient to indicate that the impounding structure will be stable during construction or alteration and during the life of the impounding structure under all conditions of impoundment operations, including rapid filling, flood surcharge, seismic loadings, and rapid drawdown of the impoundment.
f. Evaluation of the stability of the impoundment rim area to safeguard against impoundment rim slides of such magnitude as to create waves capable of overtopping the impounding structure and evaluation of rim stability during seismic activity.
g. Design assumptions and analyses sufficient to indicate the seepage in, around, through, or under the impounding structure, foundation, and abutments will be reasonably and practically controlled so that internal or external forces or results thereof will not endanger the stability and integrity of the impounding structure. The design report shall also include information on graded filter design.
h. Calculations and assumptions relative to hydraulic and structural design of the spillway or spillways and energy dissipater or dissipaters. Spillway capacity shall conform to the criteria of Table 1 and 4VAC50-20-52.
i. Provisions to ensure that the impounding structure and appurtenances will be protected against unacceptable deterioration or erosion due to freezing and thawing, wind, wave action, and rain, or any combination thereof.
j. Other pertinent design data, assumptions, and analyses commensurate with the nature of the particular impounding structure and specific site conditions, including when required, a plan and water surface profile of the dam break inundation zone.
k. A description of the techniques to be used to divert stream flow during construction so as to prevent hazard to life, health and property, including a detailed plan and procedures to maintain a stable impounding structure during storm events, a drawing showing temporary diversion devices, and a description of the potential impoundment during construction.
l. A plan for project construction monitoring and quality control testing to confirm that construction materials and performance standards meet the design requirements.
m. Plans and specifications as required by 4VAC50-20-310, signed and sealed by the engineer.

List of attached drawings and specifications:

____
____
____
____

CERTIFICATION BY OWNER'S ENGINEER

I hereby certify that the information provided in this Design Report has been examined by me and found in my professional judgment to be true and correct.

Signed: ____ Virginia Number: ____________

Professional Engineer's Signature Print Name

This __________ day of ______________ , 20 ____ .

Engineer's Virginia Seal:

CERTIFICATION BY OWNER

I hereby certify that I have received this Design Report.

Signed: ____

Owner's Signature Print Name

This __________ Day of ______________ , 20 ____ .

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

Date Prepared: ________________
Prepared By: ________________

EMERGENCY PREPAREDNESS PLAN FOR LOW HAZARD VIRGINIA REGULATED IMPOUNDING STRUCTURES

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-177, Virginia Soil and Water Conservation Board

---

1. Name of Impounding Structure: ________________
   Inventory Number: ________________ City/County: ________________
   Other Name (if any): ________________
   Stream Name: ________________
   Latitude: ________________ Longitude: ________________

---

2. Name of Owner: ________________
   Address: ________________
   Telephone: (Residential) ________________ (Business) ________________
   Other means of communication: ________________
   (Note: 24-hour telephone contact required)

---

3. Name of Impounding Structure Operator: ________________
   Address: ________________
   Telephone: (Residential) ________________ (Business) ________________
   Other means of communication: ________________
   (Note: 24-hour telephone contact required)

   Name of Alternate Operator: ________________
   Telephone: (Residential) ________________ (Business) ________________
   Other means of communication: ________________
   (Note: 24-hour telephone contact required)

---

4. Name of Rainfall and Staff Gage Observer for Dam: ________________
   Address: ________________
   Telephone: (Residential) ________________ (Business) ________________
   Other means of communication: ________________
   (Note: 24-hour telephone contact required)

   Name of Alternate Rainfall and Staff Gage Observer: ________________
   Telephone: (Residential) ________________ (Business) ________________
   Other means of communication: ________________
   (Note: 24-hour telephone contact required)

---

5. 24-Hour Dispatch Center Nearest Impounding Structure – Police/Fire/Sheriff's Department: ________________
   Address: ________________
   24-Hour Telephone: ________________

---

6. Name of City/County Emergency Services Coordinator(s): ________________________________

Address: ________________________________
____
____

Telephone: ________________________________
Other means of communication ________________________________

(Note: 24-hour telephone contact required)

7. Describe the procedure and the responsible parties for notifying to the extent possible any known local occupants, owners, or lessees of downstream properties potentially impacted by the dam's failure.

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8. Discuss the procedures for timely and reliable detection, evaluation, and classification of emergency situations considered to be relevant to the project setting and impounding features. Each relevant emergency situation is to be documented to provide an appropriate course of action based on the urgency of the situation

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9. Attach a simple dam break inundation map, demonstrating the general inundation that would result from an impounding structure failure.

10. If there are public roads downstream from the impounding structure, identify by highway number and distance below dam:

Route # ______	, ______ Miles	Route # ______	, ______ Miles
Route # ______	, ______ Miles	Route # ______	, ______ Miles

Provide name of resident engineer, VA Department of Transportation, (or City/County engineer):
____

Address: ________________________________
____
____

Telephone: (Residential) ______ (Business) ________________
Other means of communication: ________________________________
(Note: 24-hour telephone contact required)

Definitions:

Stage I Condition – A flood watch, or heavy continuous rain or excessive flow of water from ice or snow melt.

Stage II Condition – A flood watch, or emergency spillway activation or dam overtopping/breach may be possible.

Stage III Condition – Emergency spillway activation, dam overtopping or imminent failure is probable.

---

11. Amount of rainfall that will initiate a:

Stage II Condition	____________	Inches per 6 hrs.
	____________	Inches per 12 hrs.
	____________	Inches per 24 hrs.
Stage III Condition	____________	Inches per 6 hrs.
	____________	Inches per 12 hrs.
	____________	Inches per 24 hrs.

The amount of flow in the emergency spillway that will initiate a:

Stage II Condition	____________	Feet (depth of flow)
Stage III Condition	____________	Feet (depth of flow)

Total depth of emergency spillway available before crest of dam is overtopped: ________ Feet

---

12. Does a staff gage exist? ____ Yes ____ No
Staff Gage Location and Description: ______________________________

____

____

Frequency of observations by rainfall/staff gage observer during a:

Stage I Condition	____________	
Stage II Condition	____________	
Stage III Condition	____________	(recommend continuous)

Clearly identify access route and means of monitoring during flood conditions at the dam.

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Note: It is recommended that the Observer remain on post until potentially serious or serious conditions subside.

13. Evacuation Procedures:
   a. The dam owner/operator should notify the local emergency services office (i.e., the city/county 24-hour dispatch center). Phone number should be listed in #5 above.
   b. Once the local emergency services office has been notified of any problem at a dam site, it should take appropriate protective measures in accordance with the local Emergency Operations Plan and this Emergency Preparedness Plan. Local emergency services actions will include:
      (1) Notify the individuals who own downstream property
      (2) Begin Alert, Notification, and Warning
      (3) Immediately evacuating the inundation areas, when stage III conditions warrant.
      (4) Begin Emergency Public Information procedures open emergency shelters.
      (5) Provide Situation Reports to the State Emergency Operations Center (804) 674-2400 or (800) 468-8892.
   c. Once the local government has been notified of a condition requiring evacuation, the dam owner/operator and local government are mutually responsible for effecting evacuation.
      (1) The dam owner/operator will: ____________________

      (2) Local emergency services will: ____________________

   d. Methods for notification and warning to evacuate include:
      Check appropriate method(s)
      _____ (1) Telephone
      _____ (2) Police/fire/sheriff radio dispatch vehicles with loudspeakers, bullhorns, etc.
      _____ (3) Personal runners for door-to-door alerting
      _____ (4) Radio/television broadcasts for areas involved

CERTIFICATION BY OWNER

I certify that a copy of this plan has been filed with ____ (City/County) and ____________________________ (Name), the local Emergency Services Coordinator. Also, that a copy of this form has been filed with the State Department of Emergency Management; that this plan shall be adhered to during the life of the project; and that the information contained herein is current to the best of my knowledge.

Signed: ____

Owner's Signature   Print Name

This __________ day of ______________ , 20 ____ .

Please fill out and mail to:

Virginia Department of Emergency Management
Plans Division
10501 Trade Court
Richmond, Virginia 23236

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

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AGRICULTURAL EXEMPTION REPORT FOR IMPOUNDING STRUCTURES

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-165, Virginia Soil and Water Conservation Board

"Agricultural Purpose dams are dams which are less than 25 feet in height or which create a maximum impoundment smaller than 100 acre-feet operated primarily for agricultural purposes."

---

1. **Project Information:**
   a. Name of Impounding Structure: ______________________
   b. Inventory Number: ______________________
      Other Name (if any): ______________________
   c. Name of Reservoir: ______________________

---

2. **Location of Impounding Structure:**
   a. City or County: ______________________
   b. Located __________ feet/miles upstream/downstream of Highway Number ______________
   c. Name of river or stream: ______________________
   d. Latitude: ______________________ Longitude: ______________________

---

3. **Ownership:**
   a. Owner's Name: ______________________
      If a corporation, name of representative: ______________________
   b. Mailing Address: ______________________
      ____
      ____
   c. Telephone: (Residential) ______________________ (Business) ______________________
   d. Other means of communication: ______________________

---

4. **Impounding Information:**
   a. Impounding structure height ________ feet (measured vertically from top of structure to the streambed at the downstream toe of the dam).
   b. Maximum impounding capacity __________ acre-feet (volume in acre-feet that is capable of being impounded at the top of the impounding structure).

---

5. **Identification of Agricultural Activity. (List the agricultural functions for which the reservoir supplies water).**
   Note: The Regional Engineer may make a site visit to verify the agricultural usage.

____
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____

CERTIFICATION BY OWNER

I hereby certify that the impounding structure named __________________________________ meets the requirements of the Impounding Structure Regulations as a dam operated primarily for agricultural purposes and that it is exempt from regulation and that the above information is correct to the best of my knowledge and belief.

Signed: ____

Owner's Signature Print Name

This _____________ day of ____________________, 20 _____ .

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

Date Prepared: ________________

TRANSFER OF IMPOUNDING STRUCTURE NOTIFICATION FROM PAST OWNER TO NEW OWNER

This application document is for the purpose of transferring current certificates or permits to a new owner. This form does not transfer the ownership of the dam from one owner to another.

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC50-20-90 and 4VAC50-20-170, Virginia Soil and Water Conservation Board

---

1. Project Information:

a. Name of Impounding Structure: ________________

b. Inventory Number: ________________

Other Name (if any): ________________

c. Name of Reservoir: ________________

d. Hazard Potential Classification:

(Check one) ☐ High ☐ Significant ☐ Low

---

2. Location of Impounding Structure:

a. City or County: ________________

b. Located ________ feet/miles upstream/downstream of Highway Number ________

c. Name of river or stream: ________________

d. Latitude: ________________ Longitude: ________________

(degrees, minutes, decimal tenths of minutes) (degrees, minutes, decimal tenths of minutes)

---

3. Transfer Information: Identify status of dam's Virginia Certification: Check appropriate status:

a. Type of transfer(s): ☐ Construction Permit ☐ Alteration Permit ☐ Operation and Maintenance Certificate

b. Effective Date of Permit/Certificate: ________________

c. Expiration Date of Permit/Certificate: ________________

---

4. Past Owner Information:

a. Past Owner's Name: ________________

b. Contact Person (if different from above): ________________

c. Mailing Address: ________________

____

d. Telephone No.: (Residential) ________________ (Business) ________________

---

5. New Owner Information:

a. New Owner's Name: ________________

b. Contact Person (if different from above): ________________

c. Mailing Address: ________________

____

d. Telephone No.: (Residential) ________________ (Business) ________________

EMERGENCY ACTION PLAN/EMERGENCY PREPAREDNESS PLAN UPDATES

I, ______________________ , request that the required forms on file for the above referenced permit/certificate ______________
(New Owner) (Number)
be revised to indicate the new ownership. I specifically request that the Emergency Action Plan or the Emergency Preparedness Plan be amended as follows:

1. Name of Owner: ______________________
   Mailing Address: ______________________
   ____
   Telephone No.: (Residential) ____________ (Business) ____________ (Cell) ____________

2. Name of Dam Operator: ______________________
   Mailing Address: ______________________
   ____
   Telephone No.: (Residential) ____________ (Business) ____________ (Cell) ____________

3. Name of Rainfall or Staff Gage Observer for Dam: ______________________
   Mailing Address: ______________________
   ____
   Telephone No.: (Residential) ____________ (Business) ____________ (Cell) ____________

4. Name of Alternate Observer for Dam: ______________________
   Mailing Address: ______________________
   ____
   Telephone No.: (Residential) ____________ (Business) ____________ (Cell) ____________

PAST/NEW OWNERS' STATEMENTS

I, ______________________ , request to transfer the above referenced permit/certificate ______________
(Past Owner) (Number)
which was effective ______________ and expires ______________ to ______________________ .
(Date) (Date) (New Owner)
I, ______________________ , have reviewed and I am aware of all terms and conditions of the
(New Owner)
permit/certificate ______________ and will comply with all said terms and conditions.
(Number)
I, ______________________ , further certify that ______________ City/County, the local
(New Owner)
Emergency Services Coordinator and the Virginia Department of Emergency Management have been advised of this change in ownership.

Signed: ____
(Past Owner's Signature) (Print Name)

This ____________ day of ______________ , 20 ______ .

Signed: ____
(New Owner's Signature) (Print Name)

This ____________ day of ______________ , 20 ______ .

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

Virginia Department of Conservation & Recreation

Date Prepared: ______________
Prepared By: ______________

OPERATION AND MAINTENANCE CERTIFICATE APPLICATION FOR VIRGINIA REGULATED IMPOUNDING STRUCTURES

Note: Any executed Application for an Operation and Maintenance Certificate must be mailed to the appropriate Regional Engineer. In addition, a completed Certificate and Permit Application Fee Form (DCR199-192) and the required fee must be mailed under separate cover to: Virginia Department of Conservation and Recreation, Division of Finance, Accounts Payable, 600 E. Main St., 24th Floor, Richmond, Virginia 23219.

Reference: Impounding Structures Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-105 and 4VAC 50-20-150, Virginia Soil and Water Conservation Board

---

1. **Name of Dam:** ______________ Inventory Number: ______________
   Other Name (if any): ______________

---

2. **Hazard Potential Classification** (See 4VAC 50-20-40 Hazard Classifications of the Virginia Impounding Structure Regulations):
   (Check one) ☐ HIGH ☐ SIGNIFICANT ☐ LOW

---

3. **Name of Owner(s):** ______________
   If a corporation, name of representative: ______________
   Mailing address: ______________
   Telephone: (Business) ______________ (Residential) ______________
   Other means of communication: ______________

---

4. **Operating Plan and Schedule:**
   Provide a narrative for each item:
   a. Operation of control gates and spillways: ______________
   b. Operation of Impoundment Drain: ______________

---

5. **Maintenance Plan and Schedule:**
   Provide a narrative explaining the Maintenance Plan and Schedule.
   a. Earthen Embankment Impounding Structures:
      (1) embankment: ______________
      (2) principal spillway: ______________
      (3) emergency spillway: ______________
      (4) low level outlet: ______________
      (5) impoundment area: ______________
      (6) downstream channel: ______________
      (7) staff gages: ______________
      (8) other maintenance actions: ______________

b. Concrete Impounding Structures (including masonry and others):

(1) upstream face: ____________________

(2) downstream face: ____________________

(3) crest of dam: ____________________

(4) galleries (tunnels): ____________________

(5) abutments: ____________________

(6) spillways: ____________________

(7) gates and outlets: ____________________

(8) staff gages: ____________________

(9) other maintenance actions: ____________________

6. Inspection schedule (provide appropriate response):

a. Operator inspection (daily, weekly, etc.): ____________________

b. Maintenance inspection (monthly, quarterly, semi-annual, annual): ____________________

c. Technical safety inspection by a professional engineer. (Required for certification update: High Hazard Dams – every two years, Significant Hazard Dams – every three years and Low Hazard Dams – every six years: ____________________

d. Inspection by dam owner or designee (years in which a Professional Engineer does not inspect): ____________________

e. Note: All dams must be inspected by a professional engineer each time a dam is overtopped or significant flows through the emergency spillway are experienced.

7. Emergency Action Plan Schedule:

Provide the events that initiate the Emergency Action Plan.

a. Rainfall amounts, emergency spillway flow levels or storm event: ____________________

b. Frequency of observation: Stage I condition: ________ Stage II condition: ________ Stage III condition: ________

8. State whether or not the current hazard classification for the impounding structure is appropriate and whether or not additional work is needed to make an appropriate hazard designation:

9. For newly constructed or recently altered impounding structures, provide certification from a Professional Engineer who has inspected the impounding structure during construction or alteration that, to the best of the engineer's judgment, knowledge and belief, the impounding structure and its appurtenances have been constructed or altered in conformance with the plans, specifications, drawings and other requirements approved by the Virginia Soil and Water Conservation Board.

OPERATION AND MAINTENANCE PLAN AND SCHEDULE CERTIFICATION BY OWNER

I hereby certify that the operation and maintenance plan and schedule provided herewith will be adhered to during the certification period except in cases of unanticipated emergency requiring departure therefrom in order to mitigate hazards to life and property, at which time my engineer and the Department of Conservation and Recreation will be notified.

Signed: ____

Owner's Signature Print Name

This ____________ day of ________________ , 20 ____ .

CERTIFICATION BY OWNER'S ENGINEER

I hereby certify that the information provided in this form has been examined by me and found in my professional judgment to be true and correct.

Signed: ____ Virginia Number: ______________

Professional Engineer's Signature Print Name

This ____________ day of ________________ , 20 ____ .

Engineer's Virginia Seal:

Remarks: ____

____

____

____

____

Mail the executed form to the appropriate
Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
Regional Engineer

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DEPARTMENT OF CONSERVATION AND RECREATION
CERTIFICATE AND PERMIT APPLICATION FEE FORM

Reference: Impounding Structure Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-340 through 400, Virginia Soil and Water Conservation Board

NOTE:
Fees for all application submittals required pursuant to 4VAC50-20-370 through 4VAC50-20-390 are due prior to issuance of a certificate or permit. No application for an Operation and Maintenance Certification or a Construction Permit will be acted upon by the Board without full payment of the required fee per § 10.1-613.5 of the Code of Virginia.

INSTRUCTIONS:
Submit a separate form for each impounding structure. Fees shall be paid by check, draft, or postal money order payable to the Treasurer of Virginia, and must be in U.S. currency, except that agencies and institutions of the Commonwealth of Virginia may submit Interagency Transfers for the amount of the fee. All fees should note the inventory number of the impounding structure to which it relates, if known, and shall be sent to the following address:

Virginia Department of Conservation and Recreation
Division of Finance
Accounts Payable
600 E. Main St., 24th Floor
Richmond, Virginia 23219

All fee payments shall be accompanied by the following information:
Applicant Name:____
Address:____
____
Daytime Phone:_(____)_______-___________
Name of the dam:____
DCR Dam Safety Dam Inventory Number (5 digit no.):____________________________
Location of the dam (name of county or city):__________________________________
____
Type of Submittal:
____________ Regular Operation and Maintenance Certificate (A)
____________ Conditional Operation and Maintenance Certificate (B)
____________ Construction Permit (C)
____________ Extension of a Regular or Conditional Certificate (D)
____________ Incremental Analysis Review (E)
The amount of fee submitted:____
Note: No permit fees remitted to the Department shall be subject to refund except as credits provided for in 4VAC50-20-390(C).

Any application from submitted pursuant to 4VAC50-20-70 for permitting a proposed impounding structure construction shall be accompanied by a payment:

Construction Permit Application Fee	
High or Significant Potential Impounding Structures	$2,500
Low Hazard Potential Impounding Structures	$1,000

Any application for a six-year Regular Operation and Maintenance Certificate submitted pursuant to 4VAC50-20-105 shall be accompanied by a payment:

Regular Operation and Maintenance Certificate Fees	
High Hazard Potential	$600
Significant Hazard Potential	$600
Low Hazard Potential (except those exempted from fees by 4VAC50-20-51)	$300

The fee for an extension of a Regular Operation and Maintenance Certificate shall be $250 per year or portion thereof.

Any application for a Conditional Operation and Maintenance Certificate submitted pursuant to 4VAC50-20-150 shall be accompanied by a payment:

Conditional Operation and Maintenance Certificate Fees	
More Than One Year But No More Than Two Years	$300
For One Year or Less	$150

The fee for an extension of a Conditional Operation and Maintenance Certificate shall be $250 per year or portion thereof.

Pursuant to 4VAC50-20-390(C), the Board may allow a partial credit towards the Regular Operation and Maintenance Certificate fee if the owner of the impounding structure has completed, to the Director's satisfaction, the conditions of the Conditional Certificate prior to its expiration.

Pursuant to 4VAC50-20-400, should the Department determine that outside expertise to assist with the review of an incremental damage analysis is necessary, the applicant shall be responsible for the cost of such outside expertise. The Department and the applicant shall agree upon such costs in advance.

Date Prepared: ________________
Prepared By: ________________

SIMPLIFIED INUNDATION MAPPING REQUEST FORM

TO BE COMPLETED AND CERTIFIED BY DAM OWNER. PLEASE PRINT

1. **Name of Dam:** ______________________ Inventory Number: ____________

   Other Name (if any): ______________________

2. **Hazard Potential Classification** (See 4VAC 50-20-40 Hazard Classifications of the Virginia Impounding Structure Regulations):
   (Check one) ☐ HIGH ☐ SIGNIFICANT ☐ LOW

3. **Name of Owner(s):** ______________________

   If a corporation, name of representative: ______________________

   Mailing address: ______________________

   Telephone: (Business) ______________ (Residential) ______________

   Other means of communication: ______________________

4. **Current Operation and Maintenance Certificate Information:**
   Type of O&M Certificate:
   (Check one) ☐ Conditional ☐ Regular ☐ No Certificate
   Certificate Issue Date: | Certificate Expiration Date:

OWNER CERTIFICATION STATEMENT

I hereby request a Simplified Inundation Mapping and Hazard Classification analysis from the Division of Dam Safety and Floodplain Management. I understand that if, during any point during the analysis, the Hazard Potential Classification is found to be either High or Significant, I will be required to hire an engineer to perform Mapping and Hazard Potential Classification in accordance with sections 4VAC50-20-54 and 4VAC50-20-40 of the Impounding Structure Regulations. I also understand that my request shall not be processed until my fee is received and I will not receive a refund of the fee associated with this request.

Signed: ______________________ ______________________
Owner's Signature Print Name

This __________ day of ______________, 20 ____.

Note: Completed forms must be mailed to the following address:

Department of Conservation and Recreation
Division of Dam Safety and Floodplain Management
600 E. Main St., 24th Floor
Richmond, Virginia 23219

In addition, a completed Fee Form for Simplified Inundation Mapping Requests (DCR199-215) and the required fee must be mailed under separate cover to: Virginia Department of Conservation and Recreation, Division of Finance, Accounts Payable, 600 E. Main St., 24th Floor, Richmond, Virginia 23219.

(DCR199-214) (11/12)

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FEE FORM FOR SIMPLIFIED INUNDATION MAPPING REQUESTS

INSTRUCTIONS:
The fee required for the Department of Conservation and Recreation to initiate a dam owner's request for Simplified Inundation Mapping is $2000 for each Impounding Structure, regardless of current Hazard Potential Classification. In addition to this form, the dam owner shall also submit the Simplified Inundation Mapping Request Form (DCR199-214) to the Department.

Fees accompanying this form (DCR199-215) may be paid by check, draft, or postal money order payable to the Treasurer of Virginia, and must be in U.S. currency, except that agencies and institutions of the Commonwealth of Virginia may submit Interagency Transfers for the amount of the fee. This form and the accompanying fees shall be sent to the following address:

Virginia Department of Conservation and Recreation
Division of Finance
Accounts Payable
600 E. Main St., 24th Floor
Richmond, Virginia 23219

PLEASE PRINT

Applicant Name: ____

Address: ____

____

Daytime Phone: (_______)______________________

Name of the Dam:____

DCR Dam Safety Dam Inventory Number (5 digit no.): ______________________________

Location of the dam (Name of County or City): ______________________________

The amount of fee submitted: ______________

NOTE:

- **Fees for all Simplified Inundation Mapping Requests must be received before the analysis will be performed. Mapping will be performed in the order the requests are received. No permit fees remitted to the Department shall be subject to refund.**

Reference: Impounding Structure Regulations, 4VAC 50-20-40, 4VAC50-20-395

Guidance Documents TAB

VIRGINIA DAM OWNER'S HANDBOOK, 2ND EDITION

TABLE OF CONTENTS

<u>GUIDANCE DOCUMENTS</u>

Dam Safety and Floodplain Management
Richmond, VA 23219
Telephone: 804-371-6095
www.dcr.virginia.gov

Fact Sheet for Dam Ownership: Vegetation and Erosion Control on Earthfill Dams

Introduction-With proper care, earthfill embankment dams have proven to be very effective for many years. Most embankment dams are composed of non-organic material and do not deteriorate appreciably with time. An embankment may even continue to undergo additional consolidation and strengthen with age, once the critical points of initial settlement and initial reservoir fill have passed. Nevertheless, the continuing safety of any embankment dam depends on the integrity of its earthen fill to withstand pressure from the volume of water in the reservoir.

Dams and roads can suffer without proper maintenance and vegetation control.

The biggest enemy of any earthfill dam is erosion, either external (water overflow creating ruts or rills on the surface of the fill) or internal (sometimes called '"piping"). External, or surface, erosion is generally obvious if one takes the time and effort to look over the dam carefully. Internal erosion is not readily visible and may not be detected until it is too late for corrective action. This can result in an emergency situation and even lead to a catastrophic failure.

Need for proper vegetation control-A dense cover of low-growing grassy vegetation is recommended because it will provide protection from surface erosion, but its root structure does not penetrate the embankment so deeply as to create a potential path for internal erosion.

Grass growing on clams requires regular mowing.

The type of grass and its fertilization should be appropriate for local conditions. The proper vegetation should be established and maintained over the entire embankment, outlet, plunge pool and spillway area. Coverage should extend at least 25 feet beyond the abutment contacts and toe of the fill. Regular mowing throughout the year is essential so that the surface can be readily traversed by foot. Potential dam safety problems, such as misalignment, cracks, animal burrows, surface erosion, seepage, sloughing, etc., can be spotted early enough to take corrective action. Therefore, mowing should precede each dam inspection.

The problem with trees-Although woody vegetation such as trees and brush may protect against surface erosion, such growth can cause other, serious problems. These problems develop over years and may go undetected until it's too late. In addition, trees or brush can hide an embankment surface, making inspection difficult.

When trees die, it causes the roots to decay, leaving a cavity within the dam. Water leaking through such a cavity can produce a piping failure. In addition, a tree can be blown over during a severe storm, leaving a large hole in the dam in place of the uprooted root ball.

Because tree root problems occur over a long time, even decades, they often go undetected. Many times, dam failure is described as a sudden event when in fact conditions leading to the failure went undetected or ignored for years.

Control of trees on dams-Trees should *never* be allowed to grow on the embankment fill, at the outlet, plunge pool or spillway area, or within 25 feet beyond the abutment contacts and toe of fill. Any tree on a dam should be removed, its roots grubbed out and dense grass cover established in its place. Deviation from this standard must be based on a critical assessment by a professional engineer who specializes in dams. Follow the general guidance below:

Condition	Action needed
Existing dam with trees	Remove all trees. Grub out all roots larger than one inch in diameter. Grade to adjacent contour and establish cover as described below.
New dam or existing dam without trees	Establish and maintain dense grass covers. Maintain a height of four to eight inches with regular mowing to discourage growth of woody vegetation and to facilitate visual inspection for seepage, sloughs or other signs of stress. No new dams should have trees on them.

Removal of trees from existing embankments - A question dam owners often ask is, "Why can't I just cut down the trees at the surface, and then keep the vegetation properly controlled in the future?" This may be acceptable for Low Hazard and Low Hazard-Special Criteria dams, and only if accompanied by a commitment to very carefully monitor the dam and to be prepared for immediate emergency action. Eventually, however, it will be necessary to deal with the decaying roots. In other words, a decision to just '"cut and watch" simply postpones dealing with the underlying problem and may result in an emergency situation or even failure of the dam.

Removal of trees and roots on High and Significant Hazard Potential dams must be done under the direction of a professional engineer. After cutting and removing all trees and brush, all roots should be grubbed out to assure that no roots larger than one inch in diameter remain. Generally, the reservoir needs to be lowered prior to grubbing the roots. The rate of decrease in the reservoir level should not exceed six inches per day unless otherwise directed by a professional engineer. Holes resulting from the grubbing operation should be backfilled with well compacted soil. Upstream slopes should be backfilled with impervious soil, while more pervious soil may be used on the downstream slope. The backfill should then be graded to blend with the surrounding contour, and appropriate grasses should be established on all disturbed areas.

Trees on dams are a serious safety hazard. There is no single ""cookbook" solution on the proper way to remove them --- each case is unique. The advice of professional engineer needs to be sought and followed.

For more information on Dam Safety, contact the Virginia Department of Conservation and Recreation at (804) 371-6095.

DAM SAFETY, FLOODPLAIN MANAGEMENT
Dam Classification

What does it mean? Why does it change?

Virginia impounding structure regulations specify that each dam be classified based on potential loss of human life or property damage if it were to fail. Classification is based on a determination of the effects that a dam failure would likely have on people and property in the downstream inundation zone. *Hazard potential classifications* descend in order from *high* to *low*, *high* having the greatest potential for adverse downstream impacts in event of failure. This classification is unrelated to the physical condition of the dam or the probability of its failure. The hazard potential classifications are:

- *High* - dams that upon failure would cause probable loss of life or serious economic damage
- *Significant* - dams that upon failure might cause loss of life or appreciable economic damage
- *Low* - dams that upon failure would lead to no expected loss of life or significant economic damage. Special criteria: This classification includes dams that upon failure would cause damage only to property of the dam owner.

Safety standards become increasingly more stringent as the potential for adverse impact increases. For example, a *high hazard* dam -- that is, one whose failure would cause probable loss of human life -- is required to meet higher standards than a dam whose failure would not be as likely to result in such severe adverse consequences. Classification, however, is not static. Downstream conditions, including land use, can and often do change. Although a dam itself may remain relatively stable, it is subject to reclassification if a change occurs in the *downstream* inundation zone. For example, if new homes are built in the downstream inundation zone of a Significant, Low or Low-Special Criteria Hazard Potential dam, the dam could be reclassified to High Hazard Potential.

A change in hazard classification can create a dilemma because if a dam is reclassified, it usually does not meet the higher standards of the new hazard classification. To meet the required higher standards, the owner of the dam is often required to make expensive modifications. Any dam that does not meet the most extreme standards of a *high hazard* dam could become deficient in the future if land use in the downstream inundation zone changes.

To avoid the need for some of these expensive modifications, all affected parties -- dam owner, engineer, downstream land owners, and local governments -- need to work together. People should be aware of the impacts development downstream can have on the required standards of a dam. It is better and cheaper to address this potential problem beforehand rather than wait and deal with modifications later.

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VIRGINIA SOIL AND WATER CONSERVATION BOARD GUIDANCE DOCUMENT ON IMPOUNDING STRUCTURE OWNERSHIP

(Approved September 25, 2008)

Summary:
This guidance document serves to clarify who may be considered the "owner" of an "impounding structure" that is responsible for the operation and maintenance of such impounding structure.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at: http://townhall.virginia.gov/L/GDocs.cfm. An electronic copy is also available on the Virginia Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management website at: http://www.dcr.virginia.gov/dam_safety_and_floodplains/index.shtml.

Contact Information:
The Virginia Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management may be contacted with any questions regarding the application of this guidance at dam@dcr.virgina.gov or by calling 804-371-6095.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board (Board) and the Department of Conservation and Recreation that administers the Dam Safety Program on behalf of the Board. This guidance provides a general interpretation of the applicable Code sections and Board regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Impounding Structure (Dam) Ownership

I. Background:

Section 10.1-604 of Virginia Dam Safety Act states that an "owner" means "the owner of the land on which a dam [impounding structure] is situated, the holder of an easement permitting the construction of a dam [impounding structure] and any person or entity agreeing to maintain a dam [impounding structure]". The Impounding Structure Regulations further define "owner" in 4VAC50-20-30 to include the Commonwealth or any of its political subdivisions, including but not limited to sanitation district commissions and authorities, any public or private institutions, corporations, associations, firms or companies organized or existing under the laws of this Commonwealth or any other state or country, as well as any person or group of persons acting individually or as a group. As explained above, the purpose of this guidance is to set forth the

Board's standard operating procedures and general interpretation of the applicable Code sections and Regulations concerning impounding structure ownership.

II. Definitions (pursuant to §10.1-604 and 4VAC50-20-30):

"Impounding structure" or "dam" means a man-made structure, whether a dam across a watercourse or structure outside a watercourse, used or to be used to retain or store waters or other materials. The term includes: (i) all dams that are 25 feet or greater in height and that create an impoundment capacity of 15 acre-feet or greater, and (ii) all dams that are six feet or greater in height and that create an impoundment capacity of 50 acre-feet or greater. The term "impounding structure" shall not include: (a) dams licensed by the State Corporation Commission that are subject to a safety inspection program; (b) dams owned or licensed by the United States government; (c) dams operated primarily for agricultural purposes which are less than 25 feet in height or which create a maximum impoundment capacity smaller than 100 acre-feet; (d) water or silt retaining dams approved pursuant to §45.1-222 or §45.1-225.1 of the Code of Virginia; or (e) obstructions in a canal used to raise or lower water.

"Owner" means the owner of the land on which an impounding structure is situated, the holder of an easement permitting the construction of an impounding structure and any person or entity agreeing to maintain an impounding structure. The term "owner" may include the Commonwealth or any of its political subdivisions, including but not limited to sanitation district commissions and authorities, any public or private institutions, corporations, associations, firms or companies organized or existing under the laws of this Commonwealth or any other state or country, as well as any person or group of persons acting individually or as a group.

III. Authority:

The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

> **§ 10.1-605. Promulgation of regulations by the Board.**
> The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.
>
> **§ 10.1-605.1 Delegation of powers and duties.**
> The Board may delegate to the Director or his designee any of the powers and duties vested in the Board by this article, except the adoption and promulgation of regulations or the issuance of certificates. Delegation shall not remove from the Board authority to enforce the provisions of this article.
>
> **§ 10.1-613.4 Liability of owner or operator.**
> Nothing in this article, and no order, notice, approval, or advice of the Director or Board shall relieve any owner or operator of such a structure from any legal duties, obligations, and liabilities resulting from such ownership or operation. The owner shall be responsible for liability for damage to the property of others or injury to persons, including, but not limited to, loss of life resulting from the operation or failure of a dam.

Compliance with this article does not guarantee the safety of a dam or relieve the owner of liability in case of a dam failure.

The Impounding Structure Regulations contain the following authorities applicable to this guidance (pertinent part included):

4VAC50-20-105. Regular Operation and Maintenance Certificates.

A. A Regular Operation and Maintenance Certificate is required for an impounding structure. Such six-year certificates shall include the following based on hazard classification:

1. High Hazard Potential Regular Operation and Maintenance Certificate;
2. Significant Hazard Potential Regular Operation and Maintenance Certificate; or
3. Low Hazard Potential Regular Operation and Maintenance Certificate.

B. The owner of an impounding structure shall apply for the renewal of the six-year Regular Operation and Maintenance Certificate 90 days prior to its expiration. If a Regular Operation and Maintenance Certificate is not renewed as required, the board shall take appropriate enforcement action.

IV. Discussion and Interpretation:

Under the first part of the definition of "owner" set forth in § 10.1-604 of the Code of Virginia, the individual(s) or entities owning the land on which a dam is situated is/are the fee simple owner(s) of the property underlying the dam. The fee simple ownership is determined from the deed(s) recorded in the local city and/or county courthouse/land records office. Before the Board can issue the dam owner(s) certificates and permits to operate the dam in compliance with state law, the dam owner(s) must complete and sign the appropriate Dam Safety Program documents. These documents may include an Operation and Maintenance Application, a Transfer Form, an Emergency Action Plan or Emergency Preparedness Plan, any necessary Design, Record, or Inspection Reports, and any other such documents as may be prescribed by the Board's regulations.

Under the second part of the definition, in order for the holder of an easement developed for the purpose of permitting the construction of a dam to be considered the "owner" of the dam, the easement must be set forth in a deed between the identified fee simple dam owner(s) as grantor(s) and an identified grantee (which can be an individual or a legal entity). An acceptable deed must bear the appropriate signatures for all parties and be recorded in the local city and/or county courthouse/land records office.

Under the third part of the definition, an individual or entity may agree in writing to maintain and be responsible for a dam and therefore be considered by the Board to be the "owner" of the dam for purposes of the Dam Safety Act. Such a finding requires a clear, enforceable agreement between the individual or entity and the fee simple owner(s) of the dam. While a recorded agreement is not required for an ownership finding to be made under this part, a recorded agreement and easement allowing access to the dam location are considered strong indications of an enforceable agreement between the individual or entity and the fee simple owner(s) of the dam.

The term “entity”, as it is used in this document, includes both public entities (such as state agencies, local governments, soil and water conservation districts, and other such public bodies) and private entities. A private entity (e. g. homeowners’ association, property owners’ association, corporation, limited liability company, etc.) wishing to be considered an owner of a dam should be a legal entity registered with the State Corporation Commission. The entity should have recorded written covenants at the appropriate courthouse which state: 1) that all owners of record in the subdivision are uniting to create restrictions on the use of their land, and such covenants and restrictions are to run with the land; 2) that the property owners agree that the entity is responsible for dam maintenance and repair; and 3) that the entity has the authority to collect assessments from its members for dam maintenance in such amount to allow dam safety standards to be met in a reasonable timeframe.

NOTE: Any property owners wishing to form a homeowners' association, corporation, etc., for the purposes of assuming responsibility for impounding structure maintenance are advised to contact an attorney to draft the necessary documents with the appropriate provisions.

Irrespective of the second and third parts of the definition of “owner”, the Board may elect to seek compliance from the fee simple owners of the land on which a dam is situated if that is the simplest and/or clearest option.

V. Adoption, Amendments, and Repeal:

This document was adopted by the Board on September 25, 2008 and may be amended or repealed as necessary by the Board.

GUIDANCE DOCUMENT ON ROADWAYS ON OR BELOW IMPOUNDING STRUCTURES

(Approved November 30, 2010)

Summary:
This guidance document specifies the decision process to be utilized in determining the hazard potential classification of an impounding structure solely based on the presence of a roadway(s) on or below the impounding structure.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virginia.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Department of Conservation and Recreation in administering the Dam Safety Program on behalf of the Virginia Soil and Water Conservation Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Roadways On or Below Impounding Structures

I. Background:
Section 4VAC50-20-40 of the Impounding Structure Regulations specifies that hazard potential classification of an impounding structure is dependant on the potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. In addition to direct impacts on human life, the classifications are also dependant on impacts to residences, businesses, other occupied structures, or roadways in the dam break inundation zone. In many cases, the existence of roadways and the volume of use of such roadways has an impact on the classification of the impounding structure. This guidance serves to clarify what roadways may trigger a classification of an impounding structure as high, significant, or low hazard potential.

II. Definitions (pursuant to § 10.1-604 and 4VAC50-20-30):
"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

III. Authority:
The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

§ 10.1-605. Promulgation of regulations by the Board.
A. The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.....
C. The Board shall consider the impact of limited-use or private roadways with low traffic volume and low public safety risk that are downstream from or across an impounding structure in the determination of the hazard potential classification of an impounding structure.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

4VAC50-20-40. Hazard potential classifications of impounding structures.
A. Impounding structures shall be classified in one of three hazard classifications as defined in subsection B of this section and Table 1.
B. For the purpose of this chapter, hazards pertain to potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. Hazard potential classifications of impounding structures are as follows:
1. High Hazard Potential is defined where an impounding structure failure will cause probable loss of life or serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways.
2. Significant Hazard Potential is defined where an impounding structure failure may cause the loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways.
3. Low Hazard Potential is defined where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. "No expected loss of life" means no loss of human life is anticipated.
C. The hazard potential classification shall be proposed by the owner and shall be subject to approval by the board. To support the appropriate hazard classification, dam

break analysis shall be conducted by the owner's engineer. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered in determining the classification.

D. Impounding structures shall be subject to reclassification by the board as necessary.

IV. Discussion and Interpretation:

In accordance with Section 4VAC50-20-40 of the Impounding Structure Regulations, the hazard potential classification of an impounding structure is dependant on the potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. Among the downstream factors to be considered in determining the hazard potential classification of an impounding structure are impacts on downstream public and private roadways (including roadways across dams).

Determination of an "impact"

All impacted public and private roadways shall be considered in determining hazard potential classification. For the purposes of the Regulations, the determination as to whether a road will be "impacted" by a dam failure may be evaluated in accordance with any one of the following criteria. The choice as to the criteria to be utilized is within the discretion of the dam owner's professional engineer:

1. First, the approach to roadways outlined in Section IV, Part D of the United States Department of the Interior, Bureau of Reclamation's ACER Technical Memorandum No. 11 (available from Dam Safety) may be generally utilized. An impact shall be deemed to occur where there are one or more "lives-in-jeopardy" as a result of a dam failure; or
2. Second, an approach to determining impacts to roadways found in any document that is an acceptable reference pursuant to 4VAC50-20-320 may be utilized. The owner's engineer must reference any methodology utilized; or
3. Third, any roadway that would be overtopped (at any depth) by a dam failure under any flood condition (probable maximum flood, spillway design flood, or sunny day) may be considered to be impacted.

Classification based upon roadway type and/or traffic volume

Once it is determined that a roadway is impacted, classification of an impounding structure based solely upon potential impacts to roadways depends upon roadway type and/or traffic volume. Considerations for roadway type and/or traffic volume are as follows.

For purposes of determining traffic volumes, the average annual daily traffic (AADT) volumes available in the most recent published Daily Traffic Volume Estimates from the Virginia Department of Transportation for the road segment nearest the impounding structure shall be utilized. This information is available from VDOT at http://www.virginiadot.org/info/ct-TrafficCounts.asp. Data developed by a local government may be utilized where the locality conducts its own traffic counts. Where AADT volumes are not available from VDOT or a locality, an Average Daily Traffic trip rate that meets the standards set forth in the most recent Institute for Traffic Engineers (ITE) ITE Trip Generation information report (available for ordering online at http://www.ite.org/tripgen/trippubs.asp) may be utilized if practicable. In all cases, average daily traffic volumes may also be established by a traffic count that meets VDOT standards and is conducted or overseen by the owner's engineer or otherwise approved by the Regional Engineer.

High hazard impounding structures are those that may impact "major roadways". "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways generally in accordance with VDOT designations. "Interstates" and "primary highways" include those roadways given these designations by VDOT, except that any so designated roadway having an AADT volume of 400 vehicles or less is not required to be considered an "interstate" or "primary highway". The terms "high-volume urban streets" and "other high-volume roadways" are to be defined in the sound judgment of the owner's engineer.

Significant hazard impounding structures are those that may impact "secondary roadways". "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways generally in accordance with VDOT designations. These roadways include those designated by VDOT as secondary roadways and other public and private roadways that are not "interstates", "primary highways", high volume urban streets", or "other high-volume roadways", but do not include those roadways that qualify as "limited use roadways" (ie those having an AADT volume of 400 vehicles or less) as defined below.

Low hazard potential is defined as where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. In certain cases, an impounding structure may qualify for low hazard potential classification in spite of a potential impact to a downstream public or private roadway, provided that other factors (such as downstream residences, businesses, or other concerns as set forth in the Regulations) that would raise the hazard potential classification do not exist. Where it can be demonstrated that a public or private roadway has a limited usage, the roadway may be considered to be "limited use" and the impounding structure may be considered a low hazard potential impounding structure despite the presence of the roadway. Such roadways, located either across or below an impounding structure, include those that result in an AADT volume of 400 vehicles or less. Although a roadway may be considered to have a "limited use", the Emergency Preparedness Plan for the low hazard impounding structure shall also clearly outline a reliable and timely approach for notification of the proper local emergency services by the dam owner regarding the hazards of continued use of the road during an emergency condition. Finally, in situations where multiple limited use roadways would be impacted by an impounding structure failure, the traffic volumes of those limited use roadways shall be combined for the purposes of determining the impounding structure's hazard potential classification unless it can be demonstrated that the traffic using each of the roadways is composed of substantially the same vehicle trips, such that the combined number of individual vehicle trips utilizing all of the roadways would result in an AADT of 400 or less. For example, where two secondary roadways would be impacted by an impounding structure failure and each have an AADT volume of 300 individual vehicle trips, the total AADT volume to be utilized in determining hazard potential classification is 600 vehicles, and the impounding structure would be considered a significant hazard potential. Conversely, where two roadways would be impacted by an impounding structure failure and each have an AADT volume of 150, the total AADT volume to be utilized is 300, and the impounding structure may be considered a low hazard potential so long as other downstream factors would not raise the hazard potential.

Finally, it is of note that the incremental damage analysis permitted in 4VAC50-20-52 remains available for use. While the incremental damage analysis may not be used to reduce hazard potential classification, it may be used to adjust the spillway design flood requirement.

V. Adoption, Amendments, and Repeal:
This document will remain in effect until rescinded or superseded.

11/3/10

David A. Johnson
Director, Department of Conservation and Recreation

Date

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DCR
Virginia Department of Conservation & Recreation
State Parks • Soil & Water Conservation • Natural Heritage
Chesapeake Bay Local Assistance • Land Conservation
Outdoor Recreation Planning • Dam Safety & Floodplains

GUIDANCE DOCUMENT ON AGRICULTURAL EXEMPTION REQUIREMENTS

(Approved November 30, 2010)

Summary:
This guidance document specifies the criteria and processes to be utilized in determining whether an impounding structure is eligible for an agricultural exemption.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virginia.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board and the Department of Conservation and Recreation that administers the program on behalf of the Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Agricultural Exemption

I. Background:
The Virginia Dam Safety Act, §10.1-604 stipulates that the Board shall not regulate as an impounding structure those "dams operated primarily for agricultural purposes which are less than 25 feet in height or which create a maximum impoundment capacity smaller than 100 acre-feet". The Code of Virginia further specifies that agricultural purpose means the production of an agricultural commodity as defined in § 3.2-3900 [as recodified]. Agricultural commodity is defined in § 3.2-3900 as any plant or part thereof, animal, or animal product, produced by a person (including farmers, ranchers, vineyardists, plant propagators, Christmas tree growers, aquaculturists, floriculturists, orchardists, foresters, nurserymen, wood treaters not for hire, or other comparable persons) primarily for sale, consumption, propagation, or other use by man or animals. An owner covered by an agricultural exemption pursuant to § 10.1-604 of the Code of Virginia and 4VAC50-20-30 may validate such exemption by submitting an Agricultural Exemption Report (Agricultural Exemption Report for Impounding Structures, Form DCR199-106) in accordance with 4VAC50-20-165. The regulation also specifies that the Agricultural Exemption Report may be verified by the Department through a site visit.

This guidance document shall provide additional details on how the Board shall make determinations on whether an impounding structure is eligible for an agricultural exemption.

II. Definitions (pursuant to § 10.1-604 and 4VAC50-20-30) (emphasis added by underlining):

"Impounding structure" or "dam" means a man-made structure, whether a dam across a watercourse or structure outside a watercourse, used or to be used to retain or store waters or other materials. The term includes: (i) all dams that are 25 feet or greater in height and that create an impoundment capacity of 15 acre-feet or greater, and (ii) all dams that are six feet or greater in height and that create an impoundment capacity of 50 acre-feet or greater. The term "impounding structure" shall not include: (a) dams licensed by the State Corporation Commission that are subject to a safety inspection program; (b) dams owned or licensed by the United States government; (c) dams operated primarily for agricultural purposes which are less than 25 feet in height or which create a maximum impoundment capacity smaller than 100 acre-feet; (d) water or silt retaining dams approved pursuant to § 45.1-222 or § 45.1-225.1 of the Code of Virginia; or (e) obstructions in a canal used to raise or lower water. "Operation and Maintenance Certificate" means a certificate required for the operation and maintenance of all impounding structures.

"Agricultural purpose dams" means impounding structures which are less than 25 feet in height or which create a maximum impoundment smaller than 100 acre-feet, and operated primarily for agricultural purposes.

"Agricultural purpose" means the production of an agricultural commodity as defined in § 3.1-249.27 [recodified as § 3.2-3900] of the Code of Virginia that requires the use of impounded waters.

Other definitions utilized for the purposes of this guidance include:

§ 3.2-3900. Definitions: "Agricultural commodity" means any plant or part thereof, animal, or animal product, produced by a person (including farmers, ranchers, vineyardists, plant propagators, Christmas tree growers, aquaculturists, floriculturists, orchardists, foresters, nurserymen, wood treaters not for hire, or other comparable persons) primarily for sale, consumption, propagation, or other use by man or animals.

III. Authority:

The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

> **§ 10.1-605. Promulgation of regulations by the Board.**
> The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

> **4VAC50-20-165. Agricultural exemption.**

A. Impounding structures operated primarily for agricultural purposes that are less than 25 feet in height or that create a maximum impoundment capacity smaller than 100 acre-feet are exempt from the Impounding Structure Regulations.

B. An owner covered by an agricultural exemption pursuant to § 10.1-604 of the Code of Virginia and 4VAC50-20-30 may validate such exemption by submitting an Agricultural Exemption Report (Agricultural Exemption Report for Impounding Structures). The Agricultural Exemption Report shall include the following information:

1. Project information including the name and inventory number of the structure and name of the reservoir;
2. Location of the impounding structure including the city or county, number of feet or miles upstream or downstream of a highway and the highway number, name of the river or the stream, and the latitude and longitude;
3. Owner's name or representative if corporation, mailing address, residential and business telephone numbers, and other means of communication;
4. The impounding structure height in feet and the maximum impounding capacity in acre-feet;
5. A list of the agricultural functions for which the impoundment supplies water;
6. The date of validation; and
7. The owner's signature validating that the impoundment is operated primarily for agricultural purposes and is exempt from the regulations.

C. The Agricultural Exemption Report may be verified by the department through a site visit.

IV. Discussion and Interpretation:

Impounding structures operated primarily for agricultural purposes that are less than 25 feet in height or that create a maximum impoundment capacity smaller than 100 acre-feet are exempt from the Impounding Structure Regulations.

If a dam owner believes that the impounding structure is eligible for an agricultural exemption pursuant to §10.1-604 of the Code of Virginia and 4VAC50-20-30, the dam owner may fill out an Agricultural Exemption Report for Impounding Structures, Form (DCR 199-106) (09-08) and submit the Form to the appropriate Dam Safety Regional Engineer (Engineer).

Should the dam height or impoundment capacity requirements be met, an exemption is available to dams operated primarily for agricultural purposes. For the use of making an exemption determination, "agricultural purpose" means the use or holding in reserve of impounded waters for the production of an agricultural commodity, which is defined to include any plant or part thereof, animal, or animal product, produced by a person (including farmers, ranchers, vineyardists, plant propagators, Christmas tree growers, aquaculturists, floriculturists, orchardists, foresters, nurserymen, wood treaters not for hire, or other comparable persons) primarily for sale, consumption, propagation, or other use by man or animals. Agricultural purpose does not speak to who is engaged in this activity, and for the purposes of an impounding structure receiving an exemption, the owner(s) is not required to be the user of the impounded waters for the production of an agricultural commodity. However, in this situation, the owner should provide a signed certification from the operator of the agricultural use substantiating the use claim. The certification should also provide permission for the Department to verify the agricultural use through a site visit.

Situations that would meet the agricultural purpose requirement include any of the following:

1. The dam owner demonstrates that the agricultural land consists of a minimum of five contiguous acres upon which the agricultural commodity is produced and the impounded water is used or held in reserve primarily to assist in this production.
2. As part of the dam owner's exemption request, the owner of the agricultural use certifies gross sales in excess of $1,000 annually over the previous three years for the sale of agricultural commodities produced from the lands served by the impounding structure waters.
3. The dam owner demonstrates that the land on which the agricultural commodity is produced is zoned for agricultural use and the impounded water is used or held in reserve primarily to assist in this production.

As an alternative to the above situations, the dam owner may also provide documentation to the Dam Safety Regional Engineer for consideration explaining the agricultural purpose and commodity, size of the operation, the use of the impounded water in the production of the commodity, and the periodicity and duration of use of the waterbody in the production of the agricultural commodity. The dam owner must identify the other uses of the waterbody as well.

Verification for compliance may be made through a site visit by the Dam Safety Regional Engineer. A site visit is followed by a letter from the Dam Safety Regional Engineer to the dam owner(s) stipulating the findings of the visit. If an exemption is verified, the dam owner will be informed that Dam Safety will reevaluate the exemption at least once every six years, and that once the impounding structure is no longer primarily used for agricultural purposes, the impoundment will become eligible for regulation. Although an exempt impounding structure does not have to comply with the Regulations, the Dam Safety Regional Engineer will recommend, that during the time the impoundment is being used for agricultural purposes, that in the interest of public safety, it is a good practice to maintain the dam according to Virginia Code and the Virginia Impounding Structure Regulations. Conversely, should an agricultural exemption not be verified, then the dam owner shall be subject to regulation.

V. Adoption, Amendments, and Repeal:
This document will remain in effect until rescinded or superseded.

David A. Johnson
Director, Department of Conservation and Recreation

11/30/10
Date

GUIDANCE DOCUMENT ON CREDITS AND REFUNDS OF DAM SAFETY CERTIFICATE APPLICATION FEES

(Approved November 30, 2010)

Summary:
This guidance document serves to clarify how a partial fee credit from an unexpired Conditional Operation and Maintenance Certificate is to be applied towards a Regular Operation and Maintenance Certificate fee as well as it outlines the refund policy for Regular Operation and Maintenance Certificate applicants that are instead issued a lower cost Conditional Operation and Maintenance Certificate.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virginia.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board and the Department of Conservation and Recreation that administers the program on behalf of the Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Credits and Refnnds of Dam Safety Certificate Application Fees

I. Background:
The Virginia Dam Safety Act, §10.1-613.5 stipulates that the Board is authorized to establish and collect application fees from any applicant. Such fees are established for six-year Regular Operation and Maintenance Certificates in accordance with 4VAC50-20-380 and for Conditional Operation and Maintenance Certificates in accordance with 4VAC50-20-390. Subsection C of 4VAC50-20-390 further specifies that "[t]he board may allow a partial credit towards the Regular Operation and Maintenance Certificate fee if the owner of the impounding structure has completed, to the director's satisfaction, the conditions of the Conditional Certificate prior to its expiration". The regulations do not provide guidance to the Board regarding how much partial credit may be applied. As such, this guidance document shall outline the crediting approach to be utilized.

Additionally, an applicant may submit an application and the required fee for a Regular Operation and Maintenance Certificate. Based on a review of the application materials and the condition of the dam, the Board may issue a Conditional Operation and Maintenance Certificate instead. In this case, this guidance document instructs the Department to refund to the dam owner the difference between the two fees (note that there may be other situations requiring refunds of fees as well).

II. Definitions (pursuant to 4VAC50-20-30):
"Conditional Operation and Maintenance Certificate" means a certificate required for impounding structures with deficiencies.

"Operation and Maintenance Certificate" means a certificate required for the operation and maintenance of all impounding structures.

III. Authority:
The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

§ 10.1-605. Promulgation of regulations by the Board.
The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.

§ 10.1-613.5. Program administration fees.
The Board is authorized to establish and collect application fees from any applicant to be deposited into the Flood Prevention and Protection Assistance Fund established pursuant to § 10.1-603.17 for the administration of the dam safety program, administrative review, certifications, and the repair and maintenance of dams.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

4VAC50-20-105. Regular Operation and Maintenance Certificates.
A. A Regular Operation and Maintenance Certificate is required for an impounding structure. Such six-year certificates shall include the following based on hazard classification:

1. High Hazard Potential Regular Operation and Maintenance Certificate;
2. Significant Hazard Potential Regular Operation and Maintenance Certificate; or
3. Low Hazard Potential Regular Operation and Maintenance Certificate.

B……

4VAC50-20-150. Conditional operation and maintenance certificate.
A. During the review of any Operation and Maintenance Certificate Application (Operation and Maintenance Certificate Application for Virginia Regulated Impounding Structures) completed in accordance with 4VAC50-20-105 should the director determine that the impounding structure has nonimminent deficiencies, the director may recommend that the board issue a Conditional Operation and Maintenance Certificate.

B. The Conditional Operation and Maintenance Certificate for High, Significant, and Low Hazard Potential impounding structures shall be for a maximum term of two years. This certificate will allow the owner to continue normal operation and maintenance of the impounding structure, and shall require that the owner correct the deficiencies on a schedule approved by the board.

C.....

D. Once the deficiencies are corrected, the board shall issue a Regular Operation and Maintenance Certificate based upon the impounding structure's meeting the requirements of 4VAC50-20-105.

4VAC50-20-340. Authority to establish fees.

Under § 10.1-613.5 of the Code of Virginia, the board is authorized to establish and collect application fees for the administration of the dam safety program, administrative review, certifications, and the repair and maintenance of impounding structures. The fees will be deposited into the Dam Safety, Flood Prevention and Protection Assistance Fund.

4VAC50-20-380. Regular Operation and Maintenance Certificate application fees.

A. Any application for a six-year Regular Operation and Maintenance Certificate after September 26, 2008, except as otherwise exempted, shall be accompanied by a payment as determined in subsection B of this section.

B. Fees for High, Significant, or Low Hazard Potential impounding structures shall be as follows:

1. $600 for High Hazard Potential.
2. $600 for Significant Hazard Potential.
3. $300 for Low Hazard Potential.

C. Fees for extension of Regular Operation and Maintenance Certificates shall be $250 per year or portion thereof.

4VAC50-20-390. Conditional Operation and Maintenance Certificate application fee.

A. Fees for issuance of a Conditional Operation and Maintenance Certificate shall be as follows:

1. For a certificate for more than one year but no more than two years: $300.
2. For a certificate for one year or less: $150.

B. The fee for an extension of a Conditional Operation and Maintenance Certificate shall be $250 per year or portion thereof.

<u>C. The board may allow a partial credit towards the Regular Operation and Maintenance Certificate fee if the owner of the impounding structure has completed, to the director's satisfaction, the conditions of the Conditional Certificate prior to its expiration.</u>

IV. Discussion and Interpretation:

Section 4VAC50-20-390 C. of the Virginia Impounding Structure Regulations states that the Virginia Soil and Water Conservation Board (Board) may allow a partial credit towards the Regular Operation and Maintenance Certificate fee if the dam owner of the impounding structure has completed, to the director's satisfaction, the conditions of the Conditional Operation and Maintenance Certificate prior to its expiration.

In addition, in order for a dam owner to receive partial credit of a fee paid for a Conditional Operation and Maintenance Certificate, it is required that the dam owner submit the required recertification documents and appropriate full fee for a Regular Operation and Maintenance Certificate. Upon approval of the Regular Operation and Maintenance Certificate by the Board, the Department shall determine the appropriate credit and issue a refund to the dam owner.

Partial credits shall be determined in accordance with Table 1 and are based on the term of the conditional permit issued (one or two-year) as well as the number of months lapsed since issuance of the conditional permit and the approval of Regular Operation and Maintenance Certificate by the Board.

Table1: Proportion of Conditional Operation and Maintenance Certificate Application Fee Applicable for Partial Credit Towards a Regular Operation and Maintenance Certificate

One-Year Cert.: # of Months Lapsed Between Conditional and Regular Certificate Issuance	Cond. Cert. Amt. Applied To Reg. Cert.		Two- Year Cert.: No. Months Lapsed Between Conditional and Regular Certificate Issuance	Cond. Cert Amt. Applied To Reg. Cert.
(original fee)	150		(original fee)	300
2	125		2	275
4	100		4	250
6	75		6	225
8	50		8	200
10	25		10	175
			12	150
			14	125
			16	100
			18	75
			20	50
			22	25

NOTE: For any month of the Conditional Operation and Maintenance Certificate cycle not listed, the next higher number of months will be used to determine the amount to be applied (for example, if nine months of a one-year certificate have lapsed, the amount applied would be $25).

Additionally, should an applicant submit an application and the required fee for a Regular Operation and Maintenance Certificate to the Department for review, and based on the review of the application materials and the condition of the dam the Board determines that a Conditional Operation and Maintenance Certificate should be issued instead, the Department shall refund to the dam owner the difference between the two fees.

V. Adoption, Amendments, and Repeal:
This document will remain in effect until rescinded or superseded.

David A. Johnson
Director, Department of Conservation and Recreation

11/30/10
Date

VIRGINIA SOIL AND WATER CONSERVATION BOARD GUIDANCE DOCUMENT ON DAM BREAK INUNDATION ZONE AND INCREMENTAL DAMAGE ANALYSIS AND MAPPING PROCEDURES

(Approved XXXXX, 2010)
Working Draft Version January 14, 2010

Summary:
This guidance document specifies the procedures to be utilized by the Virginia Soil and Water Conservation Board in determining the adequacy of a dam break inundation zone analysis and map prepared in accordance with 4VAC50-20-54 and the adequacy of an incremental damage analysis conducted in accordance with 4VAC50-20-52.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virgina.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board and the Department of Conservation and Recreation that administers the program on behalf of the Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Dam Break Inundation Zone and Incremental Damage Analysis and Mapping Procedures

I. Background:

The Impounding Structure Regulations require an owner of a regulated dam to conduct a dam break analysis to support the appropriate hazard classification of the impounding structure in accordance with 4VAC50-20-40 (Hazard Potential Classification of Impounding Structures). Additionally, in accordance with Section 4VAC50-20-54 of the Impounding Structure Regulations, a dam break inundation zone map shall be developed that meets the requirements of the Dam Safety Act and the Impounding Structure Regulations for regulated dams with a High, Significant or Low Hazard Potential. The spillway design flood requirement of dams may also be reduced if it can be demonstrated through an incremental damage analysis in accordance with

4VAC50-20-52 that such a determination will not reduce the protection of public safety that would be afforded by using the spillway design flood that would otherwise by specified by Table 1. This guidance outlines the procedures that dam owners and their engineers should utilize to conduct dam break and incremental damage assessment analyses as well as to produce the associated maps.

II. Definitions (pursuant to § 10.1-604 and 4VAC50-20-30):
"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

III. Authority:
The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

> **§ 10.1-605. Promulgation of regulations by the Board.**
> The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

> **4VAC50-20-54. Dam break inundation zone mapping.**
>
> A. Dam break inundation zone maps shall be provided to the department to meet the requirements set out in Hazard Potential Classifications of Impounding Structures (4VAC50-20-40), Emergency Action Plan for High and Significant Potential Hazard Impounding Structures (4VAC50-20-175), and Emergency Preparedness for Low Hazard Potential Impounding Structures (4VAC50-20-177), as applicable.
>
> B. The location of the end of the inundation mapping should be indicated where the water surface elevation of the dam break inundation zone and the water surface elevation of the spillway design flood during an impounding structure nonfailure event converge to within one foot of each other. The inundation maps shall be supplemented with water surface profiles showing the peak water surface elevation prior to failure and the peak water surface elevation after failure.
>
> C. All inundation zone map(s), except those utilized in meeting the requirements of Emergency Preparedness for Low Hazard Potential Impounding Structures (4VAC50-20-177), shall be signed and sealed by a licensed professional engineer.
>
> D. For determining the hazard potential classification, a minimum of the following shall be provided to the department:
>
> 1. A sunny day dam break analysis utilizing the volume retained at the normal or typical water surface elevation of the impounding structure;
> 2. A dam break analysis utilizing the spillway design flood with a dam failure;
> 3. An analysis utilizing the spillway design flood without a dam failure; and
> 4. For the purposes of future growth planning, a dam break analysis utilizing the probable maximum flood with a dam failure.
>
> E. To meet the requirements of Emergency Preparedness set out in 4VAC50-20-177, all Low Hazard Potential impounding structures shall provide a simple map, acceptable to the department, demonstrating the general inundation that would result

from a dam failure. Such maps do not require preparation by a professional licensed engineer, however, it is preferred that the maps be prepared by a licensed professional engineer.

F. To meet the Emergency Action Plan requirements set out in 4VAC50-20-175, all owners of High and Significant Hazard Potential impounding structures shall provide dam break inundation map(s) representing the impacts that would occur with both a sunny day dam failure and a spillway design flood dam failure.

1. The map(s) shall be developed at a scale sufficient to graphically display downstream inhabited areas and structures, roads, public utilities that may be affected, and other pertinent structures within the identified inundation area. In coordination with the local organization for emergency management, a list of downstream inundation zone property owners and occupants, including telephone numbers may be plotted on the map or may be provided with the map for reference during an emergency.

2. Each map shall include the following statement: "The information contained in this map is prepared for use in notification of downstream property owners by emergency management personnel."

4VAC50-20-40. Hazard potential classifications of impounding structures.

A. Impounding structures shall be classified in one of three hazard classifications as defined in subsection B of this section and Table 1.

B. For the purpose of this chapter, hazards pertain to potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. Hazard potential classifications of impounding structures are as follows:

1. High Hazard Potential is defined where an impounding structure failure will cause probable loss of life or serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways.

2. Significant Hazard Potential is defined where an impounding structure failure may cause the loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways.

3. Low Hazard Potential is defined where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. "No expected loss of life" means no loss of human life is anticipated.

C. The hazard potential classification shall be proposed by the owner and shall be subject to approval by the board. To support the appropriate hazard classification, dam break analysis shall be conducted by the owner's engineer. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered in determining the classification.

D. Impounding structures shall be subject to reclassification by the board as necessary.

4VAC50-20-52. Incremental damage analysis.

A. When appropriate, the spillway design flood requirement may be reduced by the board in accordance with this section.

B. The owner's engineer may proceed with an incremental damage an alysis. Once the owner's engineer has determined the required spillway design flood through application of Table 1, further analysis may be performed to evaluate the limiting flood condition for incremental damages Site-specific conditions should be recognized and considered. This analysis may be used to lower the spillway design flood. In no situation shall the allowable reduced level be less than the level at which the incremental increase in water surface elevation downstream due to failure of an impounding structure is no longer considered to present an additional downstream threat. This engineering analysis will need to present water surface elevations at each structure that may be impacted downstream of the dam. An additional downstream threat to persons or property is presumed to exist when water depths exceed two feet or when the product of water depth (in feet) and flow velocity (in feet per second) is greater than seven.

C. The spillway design flood shall not be reduced below the minimum threshold values as determined by Table 1.

D. The required spillway design flood shall be subject to reclassification by the board as necessary to reflect changed conditions at the impounding structure and in the dam break inundation zone.

IV. Discussion and Interpretation:

Dam Break Analysis and Inundation Zone Mapping

The Impounding Structure Regulations require an owner of a regulated dam to conduct a dam break analysis to support the appropriate hazard classification of the impounding structure in accordance with 4VAC50-20-40 (Hazard Potential Classification of Impounding Structures). Additionally, in accordance with Section 4VAC50-20-54 of the Impounding Structure Regulations, a dam break inundation zone map shall be developed that meets the requirements of the Dam Safety Act and the Impounding Structure Regulations for regulated dams with a High, Significant or Low Hazard Potential. This section requires that dam break inundation zone maps shall be provided to the department to meet the requirements set out in Hazard Potential Classifications of Impounding Structures (4VAC50-20-40), Emergency Action Plan for High and Significant Potential Hazard Impounding Structures (4VAC50-20-175), and Emergency Preparedness for Low Hazard Potential Impounding Structures (4VAC50-20-177), as applicable. All dam break inundation zone maps shall be signed and sealed by a professional engineer licensed in the Commonwealth of Virginia (unless solely developed to satisfy the requirements of 4VAC50-20-177 which allows the owner to develop a simple dam break inundation map acceptable to the director, demonstrating the general inundation that would result from an impounding structure failure. Such maps required pursuant to this section do not require preparation by a professional licensed engineer; however, maps prepared by a licensed professional engineer are preferred and are additionally required to satisfy §§ 4VAC50-20-40 and 4VAC50-20-54.)

A dam break analysis using an approved hydrologic/hydraulic computer model shall be conducted by the dam owner's professional engineer. The modeling effort must conform to the intended use of the chosen computer model. Mixing the criteria of one procedure, listed in 4VAC50-20-320 (Acceptable design procedures and references) with criteria from another procedure, unless otherwise mentioned, is prohibited. Compute modeling must generate appropriate inflow hydrographs which are routed through the dam and downstream of the dam. Some computer models that are acceptable include HEC-1, HEC-HMS, HEC-RAS and the NRCS computer models TR-60 with TR-66. Other computer models may be used if approved by the DCR Regional Engineer prior to submitting the results to the Division of Dam Safety and Floodplain Management. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered when conducting the dam break analysis.

For the validation of the hazard potential of a dam and the development of an Emergency Action Plan, at a minimum, the following shall be reflected on each map using an approved hydrologic/hydraulic computer model and shown on one map (numerous sheets are allowed to accommodate scale):

1. Sunny day dam break with the starting water surface elevation at the normal or typical water surface elevation of the impounding structure. If the impounding structure was designed and built for flood control, the starting water surface elevation shall be at the crest of the auxiliary or emergency spillway.
2. Dam failure during the required spillway design flood. An overtopping failure shall be modeled if the emergency spillway is unable to pass the spillway design flood without overtopping the crest of the dam. A piping failure shall be modeled if the emergency spillway has enough capacity to pass the required spillway design flood without overtopping the crest of the dam.
3. Routing the spillway design flood through the dam without any failure.
4. Dam failure during the Probable Maximum Flood.

Topographic information, including TINS, that show at a minimum ten-foot contour elevations shall be used to develop the hydrologic/hydraulic computer model downstream of the dam, including cross sections at potential damage locations (homes, businesses, roads, utilities, etc.) downstream of the dam. The dam owner's engineer must develop reliable cross sections to input into the computer model. If adequate topographic information is not available, the dam owner must provide an alternative method for identifying potential damage locations that must be approved by the DCR Regional Engineer, prior to initiating the evaluation. Topography may be a component of the submitted inundation map; however, map clutter must be avoided. If the topography is not submitted on the inundation map, a copy of the topographical information or

TINS used shall be submitted with the engineering analysis. Paper copies of all hydrologic and hydraulic computer model runs shall be provided to the Regional Engineer.

The owner's engineer shall use sanctioned engineering criteria and sound professional judgment for the worst case storm conditions in the selection of:

a. Dam failure parameters
b. Rainfall distributions
c. Flood routing procedures and coefficients
d. Use of available topography and supporting field surveys
e. Development of SCS Curve Numbers
f. Development of spillway rating curves and area-capacity curves
g. Determination of the Time of Concentration and/or lag time
h. Other steps used during the modeling and analysis of flood conditions in the watershed and downstream of the impounding structure.

The judgments and the engineering criteria used by the dam owner's engineer shall be reviewed and approved by the DCR Regional Engineer for appropriateness. The DCR Regional Engineer will provide specific guidance via written correspondence to the dam owner should the judgments or the use of the engineering criteria be determined to be inappropriate. If the map is acceptable, a statement of confirmation that the map appears to be in conformance with the regulations will also be provided to the owner.

The computer model shall be extended to a point downstream of the impounding structure where the water surface elevations of the spillway design flood with and without dam failure converge to within one foot of each other or to the last impacted structure caused by a sunny-day dam failure, whichever is farthest downstream.

The following shall be clearly marked at each potential damage location on each map:

a. Cross Section number and distance downstream from the dam to the nearest tenth of a mile
b. Relative time of travel, in minutes, of the first flood waters associated with a dam failure to reach the impact location
c. Relative time of travel, in minutes, of the peak flood level associated with a dam failure to reach the impact location
d. Maximum depth of water with a dam failure at each impact location in feet (depth of water on the structure)

The map lines delineating the inundation areas shall be drawn in such thickness (solid, dashed or dotted lines in black) to identify the inundation limits as the main feature of the map. The lines shall not obliterate the location of structures, or features which are shown as being inundated. The map shall also identify the scale and show the north arrow on each map sheet.

Inundation maps may have color in the background and shall be at a scale where impacted structures downstream may be clearly seen. The maps should not utilize color-coding of the inundation lines since the maps will often be copied on black and white reproduction equipment. If the inundation area is too large to be shown on one map, an index map shall be included which shows the full extent of the inundation area and the outline of the detailed maps with an identifier for each map sheet. Impacted structures (homes, businesses, roads, utilities, etc) shall be clearly shown and if cross-hatching is used it must not obscure the structures. The physical addresses and contact persons may be located on a separate attachment to avoid clutter. This information will be used to aid emergency responders in quickly locating impacted structures and conducting evacuations. Inundation maps shall not be produced in a size larger than 11'' by 17" and the final size must be folded to a size of 8 1/2" by 11". The inundation maps shall be submitted to the DCR Regional Engineer electronically in a Windows compatible image format and as a set of paper maps. Acceptable digital image formats consist of JPEG, TIF, BMP, GIF, PNG, or EMF files. Adobe software constructed PDFs are also acceptable. Image resolution should be sufficient to view and read the necessary information noted above.

A narrative describing the accuracy and limitation of the information supplied on the inundation maps, including reference to the datum used, shall be provided to the DCR Regional Engineer. Since local officials are likely to use the maps for evacuation purposes, the following note shall be attached to each map: "Mapping of flooded areas and flood wave travel times are approximate. Timing and extent of actual inundation may differ from the information presented on this map."

The hazard potential classification shall be proposed by the dam owner and shall be subject to reclassification by the Virginia Soil and Water Conservation Board, upon review of the information submitted by the dam owner and the owner's engineer and any pertinent information regarding potential impacts downstream of the dam caused by a failure of the dam.

Incremental Damage Assessment

Once a dam owner has had the consulting engineer complete the Dam Break Inundation Zone Analysis and Map (Map) and concluded a determination of the hazard classification and, once the hazard classification has been reviewed and accepted by the appropriate Regional Engineer; the Spillway Design Flood (SDF) would then be identified in Table 1 of the Impounding Structure Regulations (4VAC50-20-50). Should the dam owner wish to consider lowering the SDF through an Incremental Damage Analysis (IDA), the consulting engineer must then perform the following procedures. However, as noted in Table 1 of the Impounding Structure Regulations an SDF less than the Minimum Threshold will not be accepted.

1. Identify the Required SDF
Once the hazard classification is determined, Table 1 will identify the required SDF. If the dam owner decides to have the consulting engineer perform an incremental damage analysis, the computer models previously used to determine the inundation and subsequent hazard classification must be used to identify the flood event at which no significant increase in damage will occur due to a dam failure. This process may start with the required SDF or with the Minimum Threshold for IDA (Minimum Threshold), see Table 1.

2. Have Models Showing all Requirements with Backup Calculations
The consulting engineer must have at a minimum, hydrologic computer models for the Sunny-Day Dam Failure, Spillway Design Flood With a Dam Failure, Spillway Design Flood Without a

Dam Failure and the Probable Maximum Flood With a Dam Failure. These models must be routed downstream of the dam to a point in which the maximum water surface elevations during the SDF with a Dam Failure and the SDF without a Dam Failure converge to within one foot of each other or to the last impacted structure cause by a sunny-day dam failure, whichever is farthest downstream.

3. Prepare the Map
The results of the models are plotted onto the Map to demonstrate inundation expected by each event. All homes, buildings, roads and other impacted facilities shall be shown on the map.

4. Use IDA to Determine if the SDF can be Reduced
If it can be shown that the aforementioned list of potentially impacted facilities would, at some lesser flood compared to the SDF, be severely damaged due to floods associated storm flows without a dam failure then the owner can have the consulting engineer adjust the input storm in the computer models in an attempt to identify at what storm event that a dam failure would not significantly add to damaged facilities or threats to life downstream.

When structures, such as homes, businesses, and utilities buildings are identified in the inundation zone, the consulting engineer can determine significant impact to that structure if, during a dam failure, the water depth will equal or exceed two feet above the ground/building connection. If the product of the depth of water on a structure in feet and the velocity of water flowing at that location in feet per second equals seven (7) or more, then the structure is considered significantly impacted and projects the probable loss of life. If the depth of water is less than two feet on the structure and the product of the total water depth and the velocity of water at the structure is less than seven (7) during any dam failure, the structure would not be considered threatened nor would result in probable loss of life.

5. Determination of the Adjusted SDF
An IDA should always result in the same answer no matter whether you start at the SDF or at the Minimum Threshold working toward the Adjusted SDF. The Adjusted SDF should represent the maximum flood at which the dam will provide maximum flood protection downstream and no further damages would be expected with larger flood events with a dam failure.

The dam owner may choose to have the engineer design the emergency spillway to the Adjusted SDF or some flood event larger than the adjusted SDF that would consider potential increases in hazard classification due to future development downstream of the dam.

The dam owner's consulting engineer will need to provide one set of paper copies of the computer model results and an electronic copy on diskette. Profiles, calculations and other supporting information used to determine an adjusted SDF shall be submitted to the Dam Safety Regional Engineer for review and acceptance.

Dam Safety's acceptance of an adjusted SDF does not guarantee that any future development will not place new increased spillway capacity requirements on the dam owner.

For a Secondary roadway (secondary highway, low-volume urban street, service road and other low-volume roadway) located below a dam the hazard classification may be significant requiring a SDF of ½ PMF (see roadways guidance for additional information on how roadways may impact hazard classification). If the dam owner desires, an IDA may be performed that would identify at what flood event (between the ½ PMF and the 100-Year Flood) the computed water surface elevation for the flood event without a dam failure would result in a water level at or just below the roadway surface edge without a dam failure. With this storm event, if a dam failure would overtop the roadway by four (4) inches or more, it could lead to possible loss of life of persons in vehicles on the roadway or loss of the roadway itself. If the dam failure does not overtop the roadway for the Sunny-Day Failure and storm events up to the PMF with a dam failure, then the dam should be classified as Low Hazard, if there are no other impacted structures or facilities, should the dam fail. If the roadway is a major roadway (interstate, primary highway, high-volume urban street or other high-volume roadway) then the incremental damage analysis would start at PMF and could result in a SDF no less than the ½ PMF.

If there are several roadways below a dam, then the roadway that results in the largest spillway design flood applies.

If a secondary or low volume roadway crosses the dam then the SDF would usually be at a minimum the ½ PMF (see roadways guidance for additional information on how roadways may impact hazard classification) and no IDA would be permitted for a dam with a significant hazard classification. If a major roadway crosses the dam then the SDF would be the PMF and no IDA would be permitted.

In cases where there are other facilities below the dam along with roadways, the impact that creates the highest hazard classification shall dictate. If permitted, the owner may choose to have the consulting engineer perform an IDA in the hopes of lowering the SDF.

V Adoption, Amendments, and Repeal:

This document was adopted by the Board on XXXX, 2010 and may be amended or repealed as necessary by the Board.

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VIRGINIA SOIL AND WATER CONSERVATION BOARD GUIDANCE DOCUMENT ON IMPOUNDING STRUCTURE HAZARD POTENTIAL CLASSIFICATIONS

(Approved XXXXX, 2010)
Working Draft Version January 14, 2010

Summary:
This guidance document outlines the decision process to be utilized by the Virginia Soil and Water Conservation Board and an owner and his engineer in determining hazard potential classification of an impounding structure in accordance with the Virginia Impounding Structure Regulations.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virginia.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board and the Department of Conservation and Recreation that administers the program on behalf of the Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Impounding Structure Hazard Potential Classifications

I. Background:
Section 4VAC50-20-40 of the Impounding Structure Regulations stipulates that impounding structures shall be classified in one of three hazard classifications. This guidance document shall explain the process by which a determination is made regarding the proper hazard classification of an owner's dam.

II. Definitions (pursuant to § 10.1-604 and 4VAC50-20-30):
"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

"Normal or typical water surface elevation" means the water surface elevation at the crest of the lowest ungated outlet from the impoundment or the elevation of the normal pool of the impoundment if different than the water surface elevation at the crest of the lowest ungated outlet. For calculating sunny day failures for flood control impounding structures, stormwater detention impounding structures, and related facilities designed to hold back volumes of water for slow release, the normal or typical water surface elevation shall be measured at the crest of the auxiliary or emergency spillway.

"Sunny day dam failure" means the failure of an impounding structure with the initial water level at the normal reservoir level, usually at the lowest ungated principal spillway elevation or the typical operating water level.

III. Authority:
The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

> **§ 10.1-605. Promulgation of regulations by the Board.**
> The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

> **4VAC50-20-40. Hazard potential classifications of impounding structures.**
>
> A. Impounding structures shall be classified in one of three hazard classifications as defined in subsection B of this section and Table 1.
>
> B. For the purpose of this chapter, hazards pertain to potential loss of human life or damage to the property of others downstream from the impounding structure in event of failure or faulty operation of the impounding structure or appurtenant facilities. Hazard potential classifications of impounding structures are as follows:
>
> 1. High Hazard Potential is defined where an impounding structure failure will cause probable loss of life or serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways.
>
> 2. Significant Hazard Potential is defined where an impounding structure failure may cause the loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and

agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways.

3. Low Hazard Potential is defined where an impounding structure failure would result in no expected loss of life and would cause no more than minimal economic damage. "No expected loss of life" means no loss of human life is anticipated.

C. The hazard potential classification shall be proposed by the owner and shall be subject to approval by the board. To support the appropriate hazard classification, dam break analysis shall be conducted by the owner's engineer. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered in determining the classification.

D. Impounding structures shall be subject to reclassification by the board as necessary.

4VAC50-20-50. Performance standards required for impounding structures.

A…..Impounding structures of regulated size and not exempted shall be constructed, operated and maintained such that they perform in accordance with their design and purpose throughout the life of the project. For impounding structures, the spillway(s) capacity shall perform at a minimum to safely pass the appropriate spillway design flood as determined in Table 1. For the purposes of utilizing Table 1, Hazard Potential Classification shall be determined in accordance with 4VAC50-20-40.

TABLE 1

Impounding Structure Regulations

Applicable to all impounding structures that are 25 feet or greater in height and that create a maximum impounding capacity of 15 acre-feet or greater, and to all impounding structures that are six feet or greater in height and that create a maximum impounding capacity of 50 acre-feet or greater and is not otherwise exempt from regulation by the Code of Virginia.

Hazard Potential Class of Dam	Spillway Design Flood (SDF)[B]	Minimum Threshold for Incremental Damage Analysis
High	PMF[C]	.50 PMF
Significant	.50 PMF	100-YR[D]
Low	100-YR[D]	50-YR[E]

B. The spillway design flood (SDF) represents the largest flood that need be considered in the evaluation of the performance for a given project. The impounding structure shall perform so as to safely pass the appropriate SDF. Reductions in the established SDF may be evaluated through the use of incremental damage analysis pursuant to 4VAC50-20-52. The SDF established for an impounding structure shall not be less than those standards established elsewhere by state law or regulations, including but not limited to the Virginia Stormwater Management Program (VSMP) Permit Regulations (4VAC50-60). Due to potential for future development in the dam break inundation zone that would necessitate higher spillway design flood standards or other considerations, owners may find it advisable to consider a higher spillway design flood standard than is required.

C. PMF: Probable Maximum Flood is the flood that might be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The PMF is derived from the current probable maximum precipitation (PMP) available from the National Weather Service, NOAA. In some cases, a modified PMF may be calculated utilizing local topography, meteorological conditions, hydrological conditions, or PMP values supplied by NOAA. Any deviation in the application of established developmental procedures must be explained and justified by the owner's engineer. The owner's engineer must develop PMF hydrographs for 6-, 12-, and 24-hour durations. The hydrograph that creates the largest peak outflow is to be used to determine capacity for nonfailure and failure analysis. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

D. 100-Yr: 100-year flood represents the flood magnitude expected to be equaled or exceeded on the average of once in 100 years. It may also be expressed as an exceedence probability with a 1.0% chance of being equaled or exceeded in any given year. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

E..50-Yr: 50-year flood represents the flood magnitude expected to be equaled or exceeded on the average of once in 50 years. It may also be expressed as an exceedence probability with a 2.0% chance of being equaled or exceeded in any given year. Present and planned land-use conditions shall be considered in determining the runoff characteristics of the drainage area.

4VAC50-20-54. Dam break inundation zone mapping.

A. Dam break inundation zone maps shall be provided to the department to meet the requirements set out in Hazard Potential Classifications of Impounding Structures (4VAC50-20-40), Emergency Action Plan for High and Significant Potential Hazard Impounding Structures (4VAC50-20-175), and Emergency Preparedness for Low Hazard Potential Impounding Structures (4VAC50-20-177), as applicable.

B…..

C.….

D. For determining the hazard potential classification, a minimum of the following shall be provided to the department:

1. A sunny day dam break analysis utilizing the volume retained at the normal or typical water surface elevation of the impounding structure;

2. A dam break analysis utilizing the spillway design flood with a dam failure;

3. An analysis utilizing the spillway design flood without a dam failure; and

4. For the purposes of future growth planning, a dam break analysis utilizing the probable maximum flood with a dam failure.

E…..

4VAC50-20-52. Incremental damage analysis.

A. When appropriate, the spillway design flood requirement may be reduced by the board in accordance with this section.

B. The owner's engineer may proceed with an incremental damage analysis. Once the owner's engineer has determined the required spillway design flood through application of Table 1, further analysis may be performed to evaluate the limiting flood condition for incremental damages Site-specific conditions should be recognized and considered. This analysis may be used to lower the spillway design flood. In no situation shall the allowable reduced level be less than the level at which the incremental increase in water surface elevation downstream due to failure of an impounding structure is no longer considered to present an additional downstream threat. This engineering analysis will need to present water surface elevations at each structure that may be impacted downstream of the dam. An additional downstream threat to persons or property is presumed to exist when water depths exceed two feet or when the product of water depth (in feet) and flow velocity (in feet per second) is greater than seven.

C. The spillway design flood shall not be reduced below the minimum threshold values as determined by Table 1.

D. The required spillway design flood shall be subject to reclassification by the board as necessary to reflect changed conditions at the impounding structure and in the dam break inundation zone.

IV. Discussion and Interpretation:

In accordance with 4VAC50-20-40, three hazard potential classifications exist for regulated impounding structures: Low, Significant and High. As the classification increases, likewise the potential hazard to human life and/or economic damage increases.

This Hazard Class determination process is a simplified procedure to determine the potential impacts downstream of a regulated impounding structure, through conducting a dam break inundation zone analysis and developing the required dam break inundation zone map(s). This procedure does not allow the use of the *rule of seven* (impacts occur when the depth of water times the velocity of the flow at any given point in the inundation zone exceeds 7 ft^2/sec.) or the use of water depths (impacts occur when total water depths exceed two feet) in the determination of the hazard classification. The procedure uses a simple mapping principle that determines the Hazard Class by evaluating whether a person or structure containing people is located within the dam break inundation zone. The *rule of seven* and the two foot depth at impact areas can be used in the Incremental Damage Analysis procedure to possibly reduce the size the required Spillway Design Flood (SDF) for the impounding structure once the Hazard Class has been determined.

Computer modeling of flood routings is not an exact science, therefore maintaining a conservative procedure in determining the Hazard Class of an impounding structure is critical in protecting public safety. The purpose of establishing the Hazard Class is to determine required design criteria and establishes the frequency of periodic inspections by the dam owner’s professional engineer.

High Hazard Class dams are impounding structures where failure of the dam will cause probable loss of life or serious economic damage.

"Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways.

A dam break inundation zone map that depicts inundation impacts on any of the items listed above justifies a High Hazard Classification.

Significant Hazard Class dams are impounding structures where failure may cause the loss of life or appreciable economic damage.

"May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways. [NOTE: Low volume roadways are discussed in greater detail in the Board's Roadway Guidance Document.]

A dam break inundation zone map that depicts inundation impacts on any of the items listed above justifies, at a minimum, a Significant Hazard Class.

Low Hazard Class dams are impounding structures where failure would result in no expected loss of life and would cause no more than minimal economic damage.

"No expected loss of life" means no loss of life is anticipated.

A dam break inundation zone map that depicts inundation impacts on properties other than those owned by the dam owner justifies, at a minimum, a Low Hazard Class.

It should be understood that with this Hazard Class determination process, all possible situations with impacted structures/facilities cannot be defined in this procedure. Judgment and common sense should be applied in making any decision on classifications. No allowance for evacuation or other emergency actions for the public can be considered in determining the Hazard Class, because emergency procedures are not a substitute for appropriate design, construction, and maintenance of impounding structures. Consultation with DCR Dam Safety staff by the dam owner and the dam owner's consulting professional engineer is highly recommended in unusual situations that might vary from this procedure.

Engineering analyses performed by the dam owner's engineer to evaluate a sunny-day dam failure and review the complete range of storm event failures (50-year flood to the full PMF) may result in no impacts other than to non-productive lands within the floodplain. Such analyses may be used to justify a Low Hazard classification.

Hazard Procedures Matrix for Determining the Hazard Class of a Dam

Step 1. Run an approved computer model to simulate a sunny day dam break to determine potential inundation downstream of the dam.

Are there any residences, major roadways etc. located within the inundation zone?

Yes: Assign High Hazard Class, proceed to:

- As 4VAC50-20-50 indicates that the established Spillway Design Flood (SDF) is the PMF, the owner's engineer must run approved computer models to simulate the full PMF with a dam break and then without a dam break.
- The owner's engineer must complete a Dam Break Inundation Zone Map that must include inundation lines that represent downstream flooding for a sunny day dam break, a dam break during a full PMF and full PMF without a dam break.

No: Hazard Class unknown, go to Step 2.

Step 2. Run an approved computer model to simulate a dam break during the Probable Maximum Flood to determine potential inundation downstream of the dam.

Are there any impacted residences or major roadways etc. located within the inundation zone?

Yes: Assign High Hazard Class, proceed to:

- As 4VAC50-20-50 indicates that the established SDF is the PMF, the owner's engineer must run an approved computer model to simulate the full PMF without a dam break.
- The owner's engineer must complete a Dam Break Inundation Zone Map that must include inundation lines that represent downstream flooding for a sunny day dam break, a dam break during a full PMF and full PMF without a dam break

No: Hazard Class unknown, proceed to determine:

Are there any secondary roadways, major nonresidential structures or utilities etc. within the inundation zone?

.

Yes: Assign Significant Hazard Class, proceed to:

- As 4VAC50-20-50 indicates that the established SDF is the ½ PMF, the owner's engineer must run an approved computer model to simulate the ½ PMF without a dam break.
- The owner's engineer must complete a Dam Break Inundation Zone Map that must include inundation lines that represent downstream flooding for a sunny day dam break, a dam break during a full PMF, a dam break during a ½ PMF and ½ PMF without a dam break.

No: Assign Low Hazard Class, proceed to:

- The owner's engineer must run approved computer models to simulate the 100-Year Flood with a dam break and the 100-Year Flood without a dam break.

- Complete a Dam Break Inundation Zone Map that must include inundation lines that represent downstream flooding for a sunny day dam break, a dam break during the 100-Year Flood and the 100-Year Flood without a dam break and the full PMF with a dam break.

Note: If the dam owner decides to authorize his consulting professional engineer to perform an Incremental Damage Analysis (IDA) and the IDA results in the reduction in the spillway design flood, the final Dam Break Inundation Zone Map must contain the inundation zones associated with the dam failure during a PMF, a sunny day dam break, the spillway design flood with a dam break and the spillway design flood without a dam break. At no time will a spillway design flood be allowed that would be less than that listed as the Minimum Threshold for Incremental Damage Analysis in Table 1 of the Virginia Impounding Structure Regulations.

V Adoption, Amendments, and Repeal:

This document was adopted by the Board on XXXX, 2010 and may be amended or repealed as necessary by the Board.

VIRGINIA SOIL AND WATER CONSERVATION BOARD GUIDANCE DOCUMENT ON SPECIAL LOW HAZARD IMPOUNDING STRUCTURE REQUIREMENTS

(Approved XXXXX, 2010)
Working Draft Version January 14, 2010

Summary:
This guidance document specifies the decision process to be utilized by the Virginia Soil and Water Conservation Board in determining whether the owner of a an impounding structure needs to perform a dam break analysis in order to certify the dam as a special low hazard classification pursuant to Section 4VAC50-20-51 of the Virginia Impounding Structure Regulations.

Electronic Copy:
An electronic copy of this guidance in PDF format is available on the Regulatory TownHall under the Virginia Soil and Water Conservation Board at http://townhall.virginia.gov/L/GDocs.cfm.

Contact Information:
Please contact the Department of Conservation and Recreation's Division of Dam Safety and Floodplain Management at dam@dcr.virginia.gov or by calling 804-371-6095 with any questions regarding the application of this guidance.

Disclaimer:
This document is provided as guidance and, as such, sets forth standard operating procedures for the Virginia Soil and Water Conservation Board and the Department of Conservation and Recreation that administers the program on behalf of the Board. This guidance provides a general interpretation of the applicable Code and Regulations but is not meant to be exhaustive in nature. Each situation may differ and may require additional interpretation of the Dam Safety Act and attendant regulations.

Special Low Hazard Impounding Structure Requirements

I. Background:
Section 4VAC50-20-51 of the Impounding Structure Regulations provides special criteria applicable to an impounding structure should a licensed professional engineer certify that the impounding structure is a low hazard potential impounding structure and eligible to utilize the provisions of this section. This guidance document shall explain the owner's requirements should their professional engineer be unable to make such a certification.

II. Definitions (pursuant to § 10.1-604 and 4VAC50-20-30):
"Dam break inundation zone" means the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

III. Authority:
The Dam Safety Act in the Code of Virginia contains the following authorities applicable to this guidance:

§ 10.1-605. Promulgation of regulations by the Board.
The Board shall promulgate regulations to ensure that impounding structures in the Commonwealth are properly and safely constructed, maintained and operated.

The Impounding Structure Regulations contain the following authorities applicable to this guidance:

4VAC50-20-51. Special criteria for certain low hazard impounding structures.

A. Notwithstanding the requirements of this chapter, should the failure of a low hazard potential impounding structure cause no expected loss of human life and no economic damage to any property except property owned by the impounding structure owner, then the owner may follow the below requirements instead of the requirements specified in this chapter:

1. No map required pursuant to 4VAC50-20-54 shall be required to be developed for the impounding structure should a licensed professional engineer certify that the impounding structure is a low hazard potential impounding structure and eligible to utilize the provisions of this section; **[NOTE: Department staff must concur.]**
2. The spillway design flood for the impounding structure is recommended as a minimum 50-year flood; however, no specific spillway design flood shall be mandatory for an impounding structure found to qualify under the requirements of this section;
3. No emergency preparedness plan prepared pursuant to 4VAC50-20-177 shall be required. However, the impounding structure owner shall notify the local emergency services coordinator in the event of a failure or emergency condition at the impounding structure;
4. An owner shall perform inspections of the impounding structure annually in accordance with the requirements of 4VAC50-20-105. No inspection of the impounding structure by a licensed professional engineer shall be required, however, so long as the owner certifies at the time of operation and maintenance certificate renewal that conditions at the impounding structure and downstream are unchanged since the last inspection conducted by a licensed professional engineer; and
5. No certificate or permit fee established in this chapter shall be applicable to the impounding structure.

B. Any owner of an impounding structure electing to utilize the requirements of subsection A of this section shall otherwise comply with all other requirements of this chapter applicable to low hazard impounding structures.

C. The owner shall notify the department immediately of any change in circumstances that would cause the impounding structure to no longer qualify to utilize the provisions of this section.

4VAC50-20-40. Hazard potential classifications of impounding structures.

A. Impounding structures shall be classified in one of three hazard classifications as defined in subsection B of this section and Table 1.

B…..

C. The hazard potential classification shall be proposed by the owner and shall be subject to approval by the board. To support the appropriate hazard classification, dam break analysis shall be conducted by the owner's engineer. Present and planned land-use for which a development plan has been officially approved by the locality in the dam break inundation zones downstream from the impounding structure shall be considered in determining the classification.

D…..

IV. Discussion and Interpretation:

Per Section 4VAC50-20-51 of the Virginia Impounding Structure Regulations, if the dam owner's professional engineer certifies that the impounding structure is a low hazard potential impounding structure and that said dam is eligible to utilize the provisions of Section 4VAC50-20-51 of the Regulations, then the following are not required for the impounding structure:

1. No dam break inundation zone map (required pursuant to 4VAC50-20-54) shall be required to be developed;
2. The spillway design flood for the impounding structure is recommended as a minimum 50-year flood; however, no specific spillway design flood shall be mandatory;
3. No emergency preparedness plan prepared pursuant to 4VAC50-20-177 shall be required. However, the impounding structure owner shall notify the local emergency services coordinator in the event of a failure or emergency condition at the impounding structure; and
4. No certificate or permit fee established in the Regulations shall be applicable to the impounding structure.

The dam owner’s professional engineer must certify, with concurrence of Department staff, that the impounding structure is a low hazard dam that is eligible to utilize the provisions of Section 4VAC50-20-51. If the dam owner's professional engineer is initially unable to certify that the impounding structure is eligible to utilize the provisions of Section 4VAC50-20-51, then the engineer must perform a dam break analysis and/or an engineering analysis adequate to determine the hazard potential classification. If, based on this analysis, the engineer decides that there is enough information to certify the dam as a special criteria low hazard classification, the work is complete upon Department staff concurrence. However, should the engineer not be able to certify the impounding structure, the dam owner must conform to all requirements of the Impounding Structure Regulations applicable to their dam.

For those dams that are certified as eligible to utilize 4VAC50-20-51, owners are advised that other requirements of the Impounding Structure Regulations which are not specifically exempted by that section remain applicable and must be complied with (for example, a dam owner of a dam that is eligible for 4VAC50-20-51 who wishes to alter their dam must still obtain an Alteration Permit). Owners are also advised that, while no dam break inundation zone map is required for their dam, failure to file a dam break inundation zone map with their locality may result in the owner's inability to receive compensation to upgrade their spillway from a prospective downstream developer that may alter the hazard classification of their dam in accordance with § 10.1-606.3 and § 15.2-2243.1 of the Code of Virginia.

V. Adoption, Amendments, and Repeal:

This document was adopted by the Board on XXXX, 2010 and may be amended or repealed as necessary by the Board.

Emergency Action Plans TAB

VIRGINIA DAM OWNER'S HANDBOOK, 2ND EDITION

TABLE OF CONTENTS

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EMERGENCY ACTION PLANS and EMERGENCY PREPAREDNESS PLANS

Introduction

Although most dam owners are certain their dams will not fail, history has shown that on occasion dams do fail and that often these failures cause extensive property damage—and sometimes death. A dam owner is responsible for keeping these threats to a minimum. A carefully conceived and implemented emergency action plan (EAP) or Emergency Preparedness plan (EPP) is one positive step you, the dam owner, can take to accomplish dam safety objectives, protect your investment, and reduce potential liability.

An Emergency Action Plan or an Emergency Preparedness Plan are not substitutes for proper maintenance or remedial construction, but it facilitates recognition of dam safety problems as they develop and establishes nonstructural means to minimize risk of loss of life and reduce property damage. These guidelines define the requirements of an acceptable EAP/EPP and facilitate their preparation, distribution, annual testing, and updating.

The Emergency Action Plan (EAP) for High and Significant hazard dams and the Emergency Preparedness Plan (EPP) for Low hazard dams are formal documents that:

- Identify potential emergency conditions.
- Identify key personnel to be notified.
- Specify preplanned actions to be followed to minimize property damage and loss of life.
- Contain inundation mapping which identifies critical areas of action in case of emergency, and identifies potential impacted structures with specific contact information, for aid in evacuation.

It is important that the development of the EAP and EPP be coordinated with all entities, jurisdictions, and agencies that would be affected by a dam failure. The final product should be user friendly and adequately describe each group's capabilities and responsibilities.

The Virginia Dam Safety Regulations requires all High and Significant Hazard Dams to have an up to date Emergency Action Plan (EAP) in place and readily accessible for all parties responsible for maintenance and operation of the dam. Low hazard Dams are required to have an Emergency Preparedness Plan (EPP) accessible to all parties of responsibility.

EAP

Prior to September 26, 2008 the EAP was prepared on a Form provided by the State. After September 26, 2008 the EAP must be prepared in report form following specific guidelines outlined in the Regulations. The following format shall be used as necessary to address the requirements of the EAP:

Title Page/Cover Sheet
Table of Contents
I. Certifications
II. Notification Flowchart
III. Statement of Purpose
IV. Project Description
V. Emergency Detection, Evaluation, and Classification
VI. General Responsibilities under the EAP
A. Impounding Structure Owner Responsibilities
B. Responsibility for Notification
C. Responsibility for Evacuation
D. Responsibility for Termination and Follow-Up

E. EAP Coordinator Responsibility
VII. Preparedness
VIII. Inundation Maps
IX. Appendices
A. Investigation and Analyses of Impounding Structure Failure Floods
B. Plans for Training, Exercising, Updating, and Posting the EAP
C. Site-Specific Concerns

EPP

The Emergency Preparedness Plan applies to Low Hazard Class Dams, only. It is a formal document prepared for Low Hazard impounding structures that provides maps and procedures for notifying owners of downstream property that may be impacted by an emergency situation at an impounding structure. It is prepared on DCR Form DCR199-103, which is included in this Handbook and can be downloaded from the DCR Dam Safety and Floodplain Management website: http://www.dcr.virginia.gov/dam_safety_and_floodplains/index.shtml

Inundation maps for the EPP are not required to be signed and sealed by a licensed professional engineer. However, in order to verify the Hazard Class of impounding structures, inundation maps are required to be prepared, signed, and sealed by a licensed professional engineer.

General information for EAPs and EPPs

Notification requirements

The notification chart (EAP) and the completed form (EPP) shall include contact information providing 24-hour telephone coverage for all responsible parties including, but not limited to, the impounding structure operator or manager, state and local emergency management officials, local police or sheriffs' departments, and the owner's engineer. The notification procedures shall also identify the process by which downstream property owners will be notified, and what party or parties will be responsible for making such notifications. This means that the owner must provide 24 hour coverage of the dam operations in order to activate the EAP as needed on a 24 hour basis.

Emergency Detection, Evaluation, and Classification

The EAP document should include a discussion of procedures for timely and reliable detection, evaluation, and classification of an existing or potential emergency condition.

The conditions, events, or measures for detection of an existing or potential emergency should be listed. Data and information collection systems (early warning system hardware, rule curves, or other information related to abnormal reservoir levels, inspection/monitoring plan, inspection procedures, instrumentation plan) should be discussed. The process that will be used to analyze incoming data should also be described.

Procedures, aids, instruction, and provisions for evaluation of information and data to assess the severity and magnitude of any existing or potential emergency should be discussed.

Emergencies are classified according to their severity and urgency. An emergency classification system is one means to classify emergency events according to the different times at which they occur and to their varying levels of severity. The classification system indicates the urgency of the emergency condition. Emergency classifications should use terms agreed to by the dam owner and emergency management officials during the planning process, in order for the system to work and to ensure organizations understand terminology and respond appropriately to the event.

Declaration of an emergency can be a very controversial decision. The issue should not be debated too long. An early decision and declaration are critical to maximize available response time.

Some locations may require only two emergency classifications, while others may require more. For the purpose of these EAP guidelines, two dam failure emergency classifications and one non-failure emergency classification are provided:

- Failure is imminent or has occurred (Stage 3)
- Potential failure situation is developing (Stage 2)
- Non-failure emergency condition (Stage 1)

General Responsibilities

A. Impounding Structure Owner Responsibilities

The duties of the dam owner or owner's designated representatives under the EAP should be clearly described. Specific actions operators are to take after implementing the EAP notification procedures should be described. The chain of command should be described. Officials and alternates of the dam owner who must be notified should be designated and priority of notification determined.

B. Responsibility for Notification

The person(s) authorized to notify state and local officials should be determined and clearly identified in the EAP. If time allows in an emergency situation, onsite personnel should seek advice and assistance. However, under certain circumstances, such as when failure is imminent or has occurred, the responsibility and authority for notification may have to be delegated to the dam operator or a local official. Such situations should be specified in the EAP. Local agencies will usually establish an Emergency Operations Center (EOC), or Incident Command System (ICS), to serve as the main distribution center for warning and evacuation activities. The availability of specific local resources should be determined through discussion and orientation seminars with local agency personnel.

C. Responsibility for Evacuation

Warning and evacuation planning are the responsibilities of local authorities who have the statutory obligation. Under the EAP, the dam owner is responsible for notifying the appropriate emergency management officials when flooding is anticipated, or a failure is imminent or has occurred. It is the emergency management official’s responsibility for evacuation of persons downstream of the dam. Dam owners should not assume, or usurp, the responsibility of government entities for evacuation of people. However, there may be situations in which routine notification and evacuation will not suffice, as in the case of a resident located just downstream of the dam. In this case, the dam owner should arrange to notify that person directly.

D. Responsibility for Termination and Follow-Up

A person should also be responsible for declaring that the emergency at the dam is terminated. The applicable state or local emergency management officials are responsible for termination of the disaster response activities.

A follow-up evaluation after an emergency by all participants should be specified. The results of the evaluation should be documented in a written report.

E. EAP Coordinator Responsibility

A person should be designated for on-site monitoring of the situation at the dam and keeping local authorities informed of developing conditions at the dam from the time that an emergency starts until the emergency has been terminated. Provisions for security measures at the dam during the emergency should be specified.

The dam owner should specify in the EAP the designated EAP coordinator who will be responsible for EAP-related activities, including, but not limited to, preparing revisions to the EAP, establishing training seminars, and coordinating EAP exercises. This person should be the EAP contact if any involved parties have questions about the plan.

Preparedness

The dam owner is responsible for regularly monitoring the condition of the dam and correcting any deficiencies. The plan must include a routine inspection schedule and name the person or position responsible for the inspection; it should emphasize indicators of the onset of problems that might cause failure of the dam:

*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, especially those associated with beavers or nutria
*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

The plan must address what action to take and what resources will be used when one of these indicators is observed and how quickly you or your responsible agent is to report the problem and address corrections.

Table top exercises and drills (High and Significant Hazard Dams, only)

Drills

A drill shall be conducted annually for each high or significant hazard impounding structure. A drill is a type of emergency action plan exercise that tests, develops, or maintains skills in an emergency response procedure. During a drill, participants perform an in-house exercise to verify telephone numbers and other means of communication along with the owner's response. To the extent practicable, the drill should include a face-to-face meeting with the local emergency management agencies responsible for any necessary evacuations to review the

EAP and ensure the local emergency management agencies understand the actions required during an emergency.

Tabletop Exercise

A tabletop exercise is a type of emergency action plan exercise that involves a meeting of the impounding structure owner and the state and local emergency management officials in a conference room environment. The format is usually informal with minimum stress involved. The exercise begins with the description of a simulated event and proceeds with discussions by the participants to evaluate the EAP and response procedures and to resolve concerns regarding coordination and responsibilities. A table-top exercise shall be conducted once every six years, although more frequent table-top exercises are encouraged. Drills and table-top exercises for multiple impounding structures may be performed in combination if the involved parties are the same.

Owners shall certify to the department annually that a drill, a table-top exercise, or both has been completed and provide any revisions or updates to the EAP or a statement that no revisions or updates are needed. It is important to record and document all drills and tabletop exercises.

Emergency supplies

It recommended that dam owners keep essential emergency supplies on site if possible or immediately available to handle dam emergencies as they may occur.

Where applicable, document the following:

*Materials needed for emergency repair and their location, source, and intended use. Materials should be as close as possible to the dam site.

*Equipment to be used, its location, and who will operate it

*How the operator or contractor is to be contacted.

*Any other people who may be needed, e.g., laborers, engineers, and how they are to be contacted.

*Also include any other special instructions.

*Materials may include: sandbags, rip rap, fill materials, etc.

*Equipment may include: siphon piping and priming pump, construction equipment, emergency cones, short range communication equipment.

The EAP should list the supplies, where they are located and indicate how to access them. It is recommended that this list be presented within the Appendix. (If no materials or equipment are to be stockpiled, this should be stated in the EAP/EPP).

Appendices (required for EAP, recommended for EPP)

Following the main body of the EAP (the basic EAP), an appendix section should be included that contains information that supports and supplements the basic EAP.

Listed below are some of the topics that should be covered in the appendix accompanying the EAP.

- Investigation and Analyses of Dambreak Floods

- Plans for Training, Exercising, Updating, and Posting the EAP
- Site-Specific Concerns
- Approval of the EAP

Updating the plans

The EAP/EPP should be updated promptly after each change in involved personnel or their telephone numbers, or after completion of a scheduled exercise. In addition periodic updating should be performed to update names and addresses of residents and property owners within the inundation zones and evacuation zones.

EAP Form: Attached is a suggested form that may be used to complete the EAP and can be used in place of the Formal report.

EPP Form: Please see the Forms Section in this Handbook for the Official EPP Form: "**EMERGENCY PREPAREDNESS PLAN FOR LOW HAZARD VIRGINIA REGULATED IMPOUNDING STRUCTURES"**

EMERGENCY ACTION PLAN

FOR

__________Dam

Inventory Number _________
County/City________________

Date of completion_________

EMERGENCY ACTION PLAN

TABLE OF CONTENTS

Certification by Dam Owner/Operator

I certify that procedures for implementation of this Emergency Action Plan have been coordinated with and a copy given to each local Emergency Services Coordinator serving the areas potentially impacted by the dam. Also, that a copy of this Emergency Action Plan has been filed with the Virginia Department of Emergency Management in Richmond and a copy of the Dam Break Inundation Map has been provided to the local government office with plat and plan approval authority or zoning responsibilities as designated by the locality for each locality in which the dam break inundation zone resides; that this plan shall be adhered to during the life of the project; and that the information contained herein is current and correct to the best of my knowledge.

____

(Signature of Dam Owner/Operator)

This _______________day of ____________________, 20____

Printed Name

____

Certification by Preparer

I certify that the information provided in this report has been examined by me and found to be true and correct in my professional judgment.

____

(Signature of Preparer)

This ________________day of __________________, 20____

Printed Name _____________________________

Title___________________________

Address _________________________________ Phone

____

____

EMERGENCY ACTION PLAN FOR HIGH AND SIGNIFICANT HAZARD IMPOUNDING STRUCTURES

Reference: Impounding Structure Regulations, 4VAC 50-20-10 et seq., including 4VAC 50-20-175, Virginia Soil and Water Conservation Board

I. BASIC INFORMATION

A. Name of Impounding Structure: ______________________________
Inventory Number:______Other Name (if any): ______________________

B. Hazard Potential Classification, Virginia Dam Safety Regulations:

Low Significant High (Circle One)

C. Name of Owner:
Address: ______________________________
Telephone: (Business)(_)________________
(Residential) (_) ________ (Cell) (_) ______________

D. Name of Dam Operator: ______________________________
Address: ______________________________
Telephone: (Business)(_)________________
(Residential) (_) ________ (Cell) (_) ______________

Name of Alternate Dam Operator: ______________________________
Telephone: (Business)(_)______________
(Residential)(_) _________ (Cell) (_) ________________
_____

E. Name of Rain/Staff Gage Observer:
Address: ______________________________
Telephone: (Business)(_)________________
(Residential)(_)_________ (Cell) (_) ________________

Name of Alternate Rain/Staff Gage Observer: ______________________

Address:
____
Telephone: (Business)(_)_______________
(Residential)(_) __________ (Cell) (_) ________________

F. Name of 24-Hour Dispatch Center:
____
Address: ______________________________
Telephone: (Business)(_)______________or local emergency #
____

G. Name of Local Government Emergency Services Coordinator: ____________________________Address: _____________________________ _____________________

Telephone: (Business)(__)_____________ (Cell)(__) _____________

Provide additional information if other communities may be impacted _________ ____ _

II. EMERGENCY ACTION PLAN OVERVIEW

The Dam Owner, Dam Operator or Designee may use the following Table to assess weather conditions and operational conditions at the dam to determine the appropriate actions for notifying emergency personnel during potential and actual emergencies.

Step 1: Emergency Condition Detection	Event Detection: See Section VI		
Step 2: Emergency Level	Assess Situation: Determine Emergency Level Using Section VI		
	Emergency Stage 1 Non-Emergency Incident Slowly developing situation See Definition Below	**Emergency Stage 2** Potential dam failure situation Quickly developing situation See Definition Below	**Emergency Stage 3** Urgent Dam failure is imminent or in progress See Definition Below
Step 3: Notification & Communication	**Stage 1** Notification List See Section A	**Stage 2** Notification List See Section B	**Stage 3** Notification List See Section C
Step 4: Expected Action	Inspect Dam Every 6 hrs: Monitor & Listen to Weather Forecasts	Inspect Dam Every 2 hrs, Notify Emergency Responders	Constant inspection of Dam, Continuous contact with Emergency Responders
Step 5: Termination and Follow Up	Termination of Monitoring Conditions at the Dam and Proceed to evaluate damages and plan for repairs		

Surveillance monitoring and observing instrument readings at the dam will be the normal methods of detecting potential emergency situations. For conditions beyond the normal range of operations contact the Emergency Services Coordinator (ESC) for assistance with evaluation of the conditions. Each event or situation will fall into one of the following Stages:

Emergency Definitions

1. Stage 1 – Non-emergency, failure unlikely, storm development or operational malfunctions are slow in escalation to a potential emergency. This Stage

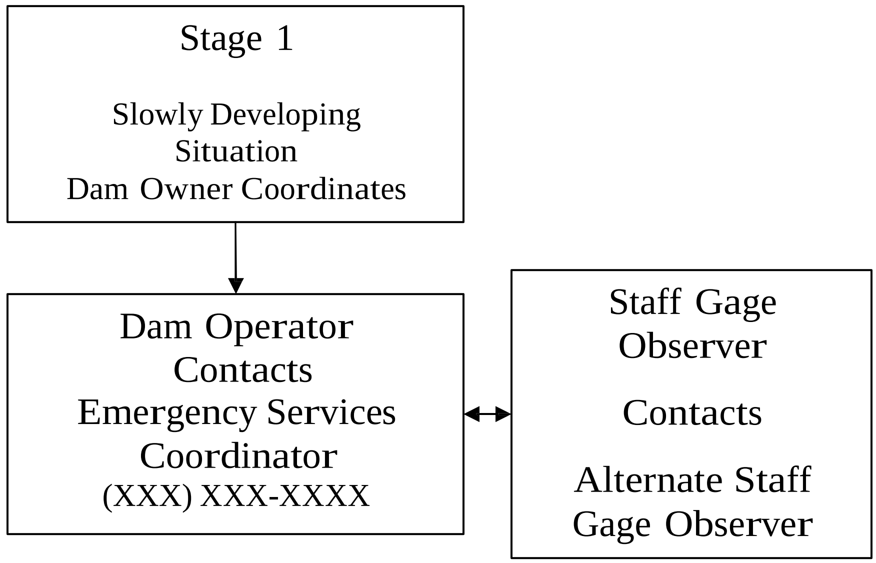
indicates a situation is developing such that the dam is not in danger of failing, but if it continues failure may be possible.

2. Stage 2 – Potential Failure, storm development or operational malfunction are quickly accelerating that could result in failure of the dam. This Stage indicates that a situation is developing that could result in a dam failure.

3. Stage 3 – Imminent Failure, storm or operational malfunction has reached a point that the failure of the dam has started or is imminent. This Stage indicates dam failure is expected or occurring and may result in flooding that will threaten life and/or property downstream of the dam.

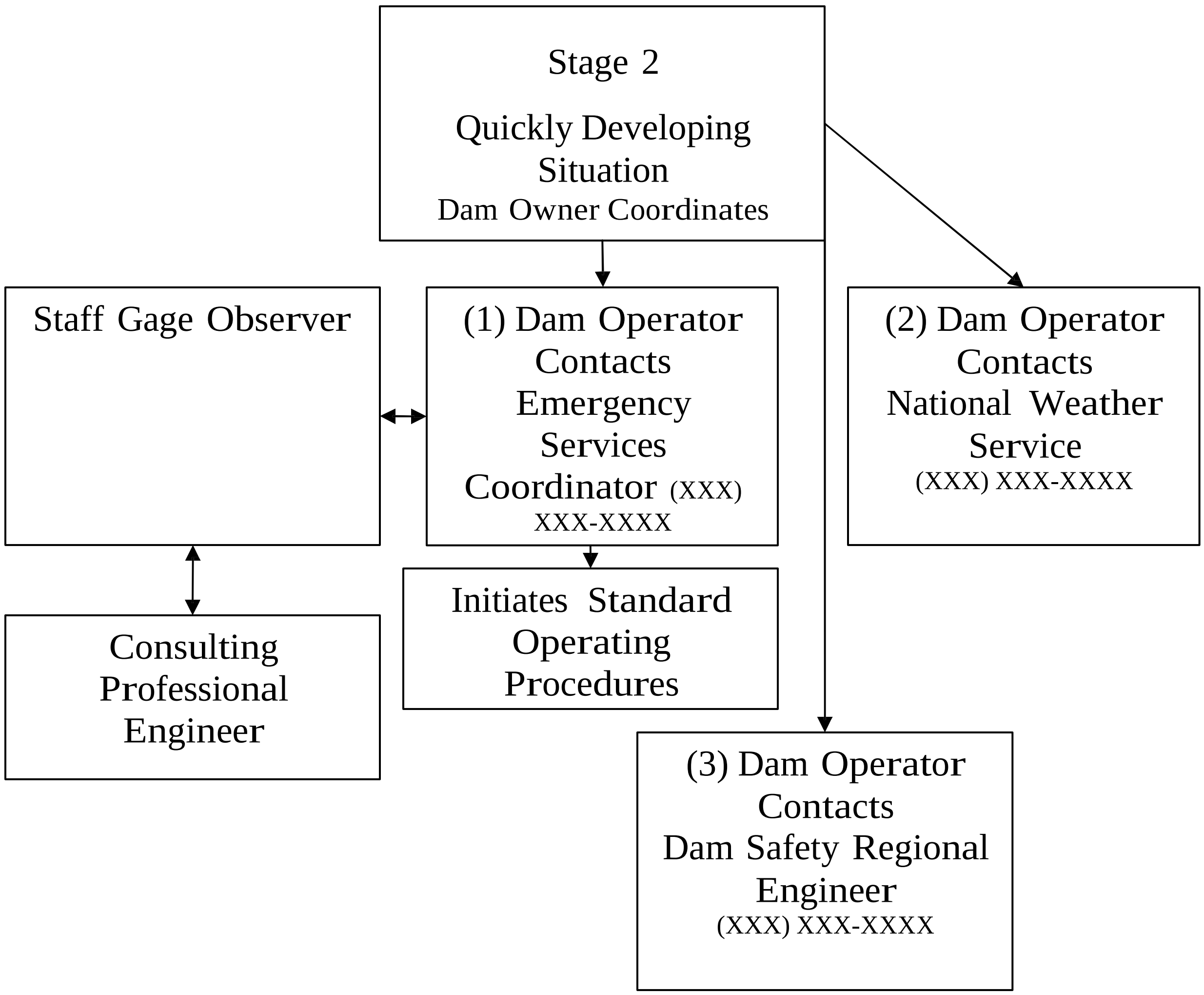
III. NOTIFICATION FLOW CHARTS

A. <u>STAGE 1 NOTIFICATION</u>



Message from dam operator to ESC: I am at **Insert Dam Name** evaluating the general conditions at the dam and coordinating with the staff gage observer as recommended in the emergency action plan. If the impending storm occurs, we may move to stage II and perform more frequent evaluations, otherwise we will visit and make observations every six hours.

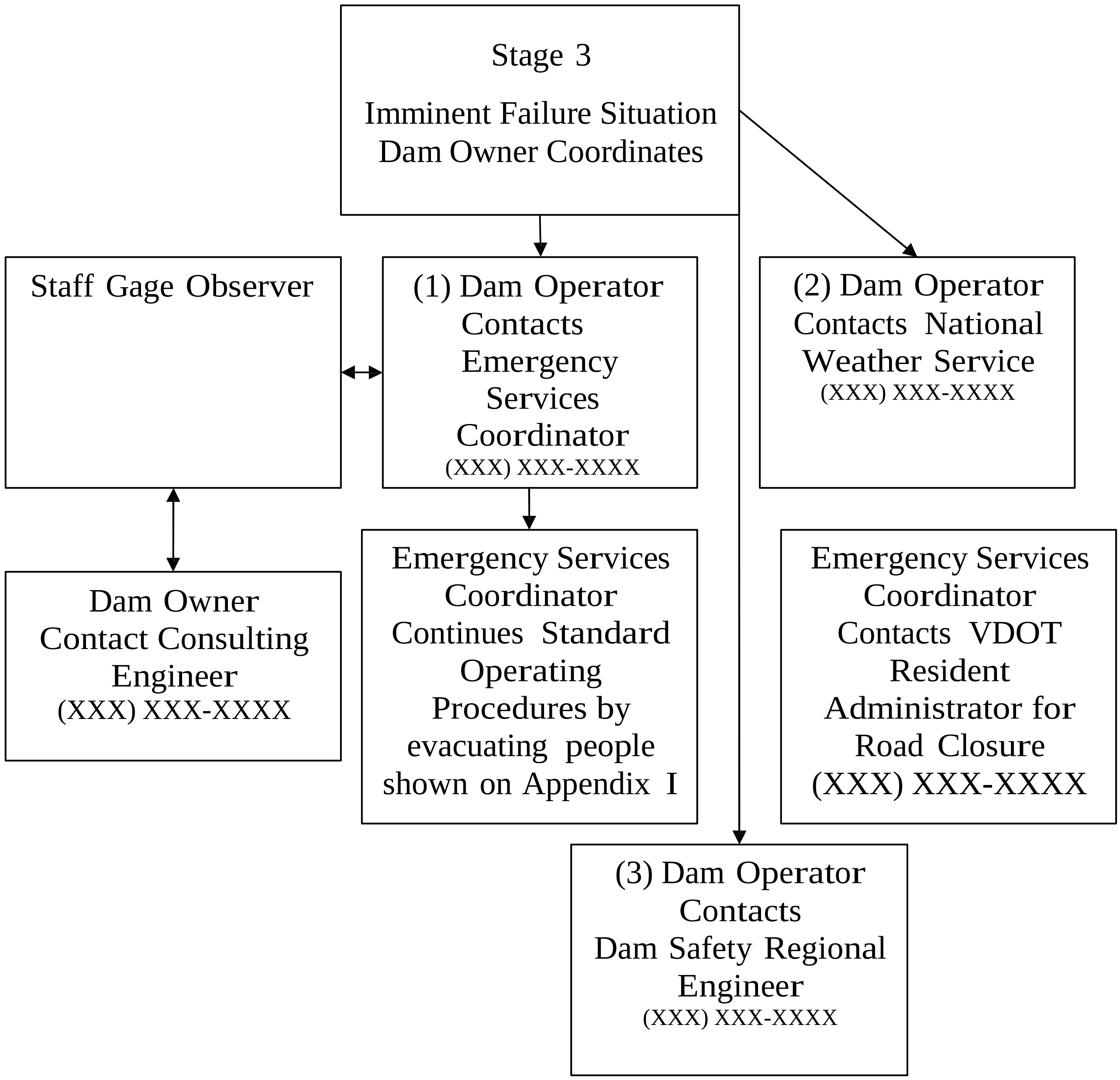
B. STAGE 2 NOTIFICATION



Message from dam operator to ESC: I am at **Insert Dam Name** (or have been to the dam) and the water level has risen into the emergency spillway to the threshold established in the emergency action plan to move to the Stage 2 Emergency Level. Please prepare your personnel in case an evacuation is necessary and continue to initiate your standard operating procedures (SOP). I will be observing the emergency spillway every 2 hours.

Note: Standard Operating Procedures shall include notification of the evacuation team, contacting the National Weather Service for rainfall projections and contacting the state Department of Emergency Management.

C. STAGE 3 NOTIFICATION



Message from dam operator to ESC: I am at **Insert Dam Name** and the water level has risen in the emergency spillway to the threshold established in the emergency action plan to move to the Stage 3 Emergency level. Please proceed with the Standard Operating Procedures. I will remain at the dam to monitor continuously until the dam breaks or the water level recedes to safe levels and the ESC directs me to terminate my responsibility.

IV. STATEMENT OF PURPOSE

"The purpose of this emergency action plan is to safeguard the lives and reduce damage to the property of citizens of **Insert municipality name here** living and/or working along **Insert water course names here,** in the event of failure of **insert dam name, inventory number .**

Impounded water upstream of a dam when released uncontrollably may threaten lives in the flow path downstream or cause damage to homes, roads, bridges and any other infrastructure(s) in its way. This uncontrolled release occurs when the dam or a part of the dam breaks and stored water is released."

V. PROJECT DESCRIPTION

Insert dam name **Insert County or City.** The dam is _____miles upstream from State Route _ on **name of watercourse** used for **state the purpose(s)**. **Describe the general characteristics of the dam and surrounding area, with specific details of potential impacted areas downstream of the dam in the case of a dam failure. Provide the normal and flood operations of this dam.**
.

VI. EMERGENCY DETECTION, EVALUATION, & CLASSIFICATION

The dam owner is responsible for operation and maintenance of this dam. The dam operator and the staff gage observer are responsible for monitoring conditions at the dam and notifying the ESC when emergency stage conditions are activated.

Generally speaking, the dam owner may initiate this emergency action plan based on the issuance of a flood watch or flood warning in the area or when conditions at the dam indicate that the reservoir will continue to rise which will result in flows through the emergency spillway. Embankment erosion or appurtenant malfunction may dictate initiation of the emergency action plan. Public safety is the primary reason that it is incumbent on all responsible parties having roles in the activation of the emergency action plan to work together as a team. While it is the dam owner's responsibility to initiate this process, the Local Government Emergency Services Coordinator may contact the dam owner to inform the team that a flood watch has been issued locally by the National Weather Service and team members would initiate their duties as required in this EAP.

In this section, the specific milestones that trigger the progression from Stage I (slowly developing condition, dam not in danger of failure but downstream flooding possible), to Stage II (quickly developing conditions that could cause the dam to fail if conditions continue to escalate) to Stage III (impending failure/evacuation) are provided. Depth of flow through the emergency spillway is the best indication of flood conditions and should be used as an indicator of the potential impacts downstream. In the absence of actual flow depth data through the emergency spillway, measured rainfall depths in inches monitored in the contributing watershed may be used to determine the emergency level. Visual observations should be made by a team member so that accurate and up to date information can be provided to the ESC.

A. The amount of flow in emergency spillway that will initiate a:

Stage II Condition ______feet

This depth of flow in the emergency spillway should give the ESC enough time/warning to prepare for increased flooding downstream of the dam.

Stage III Condition ______feet

This depth of flow in the emergency spillway should identify when failure is likely to occur or that overtopping of the dam's embankment commences

B. Amount of rainfall that will initiate a:

Stage II Emergency ____inches per 6 hrs.
____inches per 12 hrs.
____inches per 24 hrs.

Stage III Emergency ___inches per 6 hrs.
___inches per 12 hrs.
___inches per 24 hrs.

C. Frequency of observations by rainfall/staff gauge observer during:

Stage I 6 hours; Stage II 2 hour; Stage III Continuous. The actual times should be determined by the consulting engineer

The Gage Observer should use access routes to the dam bearing in mind that roads crossing small streams may be flooded.

D. Public Roads Downstream from this Dam:

If state roads are located downstream of this dam, this EAP and coordination with the ESC and the local transportation office responsible for the road/bridge(s) should determine flood levels in which the roads will be closed to all traffic. These roads are shown below.

The resident administrator, Virginia Department of Transportation/County Office of Transportation, responsible for opening and closing these roads are listed with area of coverage responsibility and telephone numbers is shown below.

Name of Transportation Administrator: ______________
____
Telephone: (Business)(__)_____; (Residential) (__) _________
Route # _____, _____Miles; Route # _____, ____Miles;
Route # _____, _____Miles; Route # _____, ____Miles.

Name of Transportation Administrator: ______________
____
Telephone: (Business)(__)_____; (Residential) (__) _________
Route # _____, _____Miles; Route # _____, ____Miles;

Use the Table below for guidance in determining the proper emergency stage for various situations.

Event	Situation	Emergency Level
Emergency Spillway Flow	Spillway flowing with active gully erosion	2
	Spillway flowing with advancing head cut that is threatening the control section	3
Embankment Overtopping	Any overtopping flow or within 2 feet of the top of the dam, water level rising	3
Seepage	New seepage areas on or near the dam	1
	New seepage areas with cloudy discharge or increasing flow rate	3
	Rapid flow rate increase with cloudy discharge from existing seepage area(s)	3
Sinkholes	Observation of new sinkhole on embankment	1
	Rapidly enlarging sinkhole	3
Embankment Cracking	New cracks in the embankment greater than 1/4 inch wide without seepage	1
	Cracks in embankment with seepage	1
	Cracks in embankment with rapidly increasing seepage	3
Embankment Movement	Visual movement of the embankment slope	1
	Sudden or rapidly progressing slides of the slopes	3
Vortex in Pond	Whirl pool with discharge downstream	3
Earthquake	Measurable earthquake felt or reported on or within 50 miles of the dam	1
	Earthquake resulting in visible damage to the dam	1
	Earthquake resulting in potential uncontrolled release of water from the dam	3
Security Threat, Sabotage & Vandalism	Verified bomb threat that, if carried out, could result in damage to the dam	1
	Detonated bomb that has resulted in damage to the dam or it appurtenances	1
	Damage to the dam or appurtenances with no impacts to the functioning of the dam	1
	Damage to the dam or appurtenances that has resulted in seepage flow	1

	Damage to the dam or appurtenances that has resulted in a potential uncontrolled water release	3

VII. GENERAL RESPONSIBILITIES UNDER THE EAP

A. Impounding Structure Owner Responsibilities

1. The dam owner/operator **IS RESPONSIBLE** for notifying local ESC of any problem or potential problem at the dam site.

2. The dam owner/operator **WILL INITIATE** dam surveillance under Stage I conditions, **when a flood watch is issued by the National Weather Service.**

3. The dam owner/operator **WILL DETERMINE** when Stage II conditions are met at the dam.

4. The dam owner/operator **WILL DETERMINE** when Stage III conditions are met at the dam.

5. The dam owner/operator **WILL BE RESPONSIBLE** for operating such devices as spillway gates and low level outlets such as to cause the dam to function effectively.

B. Responsibility for Notification

1. The dam owner/operator **WILL NOTIFY** the 24-hour dispatch center and local ESC before beginning dam surveillance under Stage I conditions.

2. The dam owner/operator **WILL NOTIFY** the 24-hour dispatch center and the local ESC when Stage II conditions are met in order to alert them to review actions that may be required for the safety and protection of people and property and to mobilize their evacuation team.

3. The dam owner/operator **WILL NOTIFY** the 24-hour dispatch center and the local ESC to initiate warning/ evacuation of residents when Stage III conditions or imminent dam failure are probable.

C. Responsibility for Evacuation

1. The local ESC **WILL NOTIFY** the people, business owners and land owners, attached to the Dam Break Inundation Zone Map, to notify residents of the potential emergency or evacuation prior to or in the event Stage III conditions are met.

2. The local ESC and 24-hour dispatch center should utilize their Standard Operating Procedures (SOPs) to implement in the event that dam failure is possible or occurring. These SOPs should include evacuation plans.

3. The local ESC **WILL CONTACT** the Virginia Department of Transportation (VDOT) or other authorized personnel to set up barricades to close roads where flood waters will cross on the roads across the dam or within the inundation zone downstream of the dam.

D. Responsibility for Termination & Follow-UP

1. Once the Stage III condition has been met the staff gauge observer will continue to provide the ESC with information concerning water level rise, erosion in the emergency spillway and/or dam overtopping. It is particularly important for the ESC to know when the breach is occurring to evacuate their rescue personnel. The staff gauge observer will remain at the dam until the dam breaks and is released from duty by the ESC.

2. Regional flooding may occur prior to an incident at this dam and could continue for long periods of time. The staff gauge observer needs to have plans for staying or returning to the dam as conditions worsen. The termination responsibility should be handled by the ESC.

3. Post flood event discussions should be used to determine strengths and weaknesses in the emergency action plan while the experience is fresh in the minds of those living through it.

E. EAP Coordinator Responsibility

The dam owner should specify in this EAP the designated EAP coordinator who will be responsible for EAP-related activities, including (but not limited to) preparing revisions to the EAP, establishing training seminars, and coordinating EAP exercises. This person should be the EAP contact if any involved parties have questions about the plan.

G. Methods for Notification and Warning:

Check appropriate method(s) to be used during an emergency:

_____ Telephone/Reverse 911 automated warning systems
_____ Police/fire/sheriff radio dispatch vehicles with loudspeakers, bullhorns, etc.
_____ Personal runners from door-to-door alerting residents
_____ Radio/television broadcasts for area involved
_____ Other methods, as described: ________________

G. Evacuation Procedures:

Once the ESC has been notified of any problem at a dam site, the ESC will take appropriate protective measures in accordance with the local Emergency Operations Plan, and accompanying Emergency Action Plan and Standing Operations Procedures.

1. Monitoring the situation and, if time permits, review of evacuation plans.

2. Begin Alert, Notification, and Warning

3. Evacuating the inundation areas, if conditions warrant.

4. Expanding Direction and Control as well as beginning Emergency Public Information and operating shelters.

5. Provide Situation Reports to the State Emergency Operations Center (804-674-2400 or 800-468-8892)

VIII. PREPAREDNESS

A. Surveillance

This dam is unattended under normal operating conditions.

District management and staff should monitor the status of weather fronts through the National Weather Service (NWS). The NWS maintains a hurricane center that reports on hurricanes, tropical storms & tropical depressions as they travel and affect coastal and inland areas. The web site address is: http://www.nhc.noaa.gov/

The expected response time to the dam from the staff gauge observer's home should be less than one (1) hour from the time they receive the information that a flood watch has been declared. The staff gauge observer should never put themselves in harms way. In the event a hurricane or tropical depression occurs with high winds the staff gauge observer shall use extreme caution monitoring conditions.

Preplanned access routes should be utilized given that small streams crossing under state roads may flood preventing safe access. The gauge observers and district staff should never attempt to cross a road that has flood water crossing it at a depth greater than one (1) foot unless the vehicle is specially designed for that purpose.

Alternative routes should be chosen for access by foot in the event that a car is unsafe for use. Other alternative means of transportation may be considered.

B. Response During Periods of Darkness

The staff gauge should be easily read from the location chosen by the staff gauge observer with a flashlight after dark.

The staff gauge observer should check the emergency spillway for erosion once the spillway starts to flow by crossing the top of the dam, if necessary. The staff gauge observer should monitor the water level and go to higher ground when the level rises to within one (1) foot of overtopping the dam.

C. Access to the Site

Access to the site in all weather conditions has been preplanned by the staff gauge observer and alternate observer to avoid areas of flooding.

D. Response During Weekends & Holidays

Staff gauge observers live locally and will respond as needed on a 24 hours per day and a 7 days per week basis.

E. Response During Adverse Weather

The staff gauge observer should never put themselves in harms way. In the event a hurricane or tropical depression occurs with high winds the staff gauge observer should use extreme caution monitoring flood conditions at the dam.

Each staff gauge observer should have protective clothing adequate to ensure their safety at all times during any response to the dam.

F. Alternative Systems of Communications

Communications during a major rainfall event may be problematic. Telephone land lines may be used as the first means of communication. Cellular telephones can be used to supplement the land lines. Unfortunately, telephone lines like electrical lines are subject to being broken by falling trees so radio communication during these events is normally required.

G. Emergency Supplies

Stockpiling of Materials & Equipment: The location of necessary supplies and material, such as barricades, sand, sandbags, etc should be known and available should the need arise.

Emergency access to supplies and equipment should be planned before any emergency is called. The dam owner should list potential supplies and equipment that may be required during an emergency and note address and telephone numbers of the contract sources.

IX. INUNDATION MAPS

NAME, ADDRESS AND TELEPHONE NUMBER OF RESIDENTS AT RISK, COMMERCIAL BUSINESS AT RISK AND PROPERTIES IN THE DAM BREAK INUNDATION ZONE

Name, address and telephone number of all occupied dwellings, businesses, and other constructed facilities that are shown on the Dam Break Inundation Zone Map that may be impacted in the event of a dam failure.

Name	Address	Telephone Number

Name, address and telephone number of owners and or lease holder of lands that are shown on the Dam Break Inundation Zone Map that may be impacted in the event of a dam failure.

<u>**Name**</u>	<u>**Address**</u>	<u>**Telephone Number**</u>

Additional lines or pages may be added as needed to form comprehensive lists.

APPENDIX A

INVESTIGATION & ANALYSIS OF IMPOUNDING STRUCTURE FAILURE FLOODS

APPENDIX B

PLANS FOR TRAINING, EXERCISING, UPDATING, & POSTING THE EAP

1. Training

Emergency action planning, generally, will be held once a year.

a. Included in this training will be a generic version of a table top exercise that requires the decision to evacuate homes and business in harms way downstream.

b. Time available a second scenario will be presented that does not lead to an evacuation order being given.

2. Exercises

a. Table Top Exercises - Table top exercises will be held, at a minimum, once every 6 years. This exercise will occur in the year that certification is required.

b. Drills - A drills will be conducted each year by the owner except when a table top exercise is required.

3. Updating

This emergency action plan will be checked yearly during the drill exercise to determine if names, addresses and telephone numbers of the people shown in Section II. are accurate. The document will be updated at any time when a major change is determined to have occurred.

4. Posting

This document will be on file with <u>Insert Dam Owner Name</u>, the County Office of the Emergency Services Manager, the DCR Division of Dam Safety, and at the Department of Emergency Management.

APPENDIX C

SITE SPECIFIC CONCERNS

APPENDIX D

ADDITIONAL RESOURCES

DIRECTORY OF ADDITIONAL PERSONNEL WITH DAM SAFETY EXPERTISE

In addition to personnel shown elsewhere in this plan, the following list identifies other individuals with expertise in dam safety, design and construction that may be consulted about taking specific actions at the dam when there is an emergency situation:

Name	Telephone	Responsibility
DCR, Division of Dam Safety		Regional E

SUPPLIES AND RESOURCES

In an emergency situation, equipment, supplies and other resources might be needed on short notice, such as sandbags, rip rap, fill material, and heavy equipment. The table below lists resources that may be helpful and indicates contacts to access them.

Earth Moving Equipment	**Rip rap**	**Sand & Gravel**

Sandbags	**Pumps**	**Pipe**

Lighting Equipment	**Laborers**	**Other**

APPENDIX E

OTHER

Federal Guidelines for Dam Safety

Emergency Action Planning for Dams

FEMA 64 / July 2013

FEMA

(DCR-VSWCB-034) (03/14)

Federal Guidelines for Dam Safety

Emergency Action Planning for Dams

FEMA 64 / July 2013

FEMA

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PREFACE

The Federal Emergency Management Agency (FEMA) is responsible for coordinating the Federal response to disasters and for providing Federal guidance to State, local, Tribal, and Territorial emergency management authorities for all foreseeable emergencies in the United States and U.S. Territories. To improve the Nation's emergency preparedness and response capabilities, FEMA believes that formal guidelines are needed to help dam owners, in coordination with emergency management authorities, effectively develop and exercise Emergency Action Plans (EAPs) for dams. The purpose of the guidance in this document is to meet that need. This document is an update of FEMA 64, *Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners* (2004).

Background

In "Dam Safety Memorandum to the Heads of Certain Federal Agencies," dated April 23, 1977, President Jimmy Carter directed that (1) dam safety reviews of various Federal programs be documented, (2) the chair of the Federal Coordinating Council for Science, Engineering, and Technology convene an ad hoc interagency committee provide "recommendations as to the means of improving the effectiveness of the Government-wide dam safety effort" and prepare and report on "proposed Federal dam safety guidelines for management procedures to ensure dam safety," and (3) the Executive Office of Science and Technology Policy arrange for a panel of recognized experts to review agency regulations, procedures, and practices throughout the Federal Government and to review proposed Federal dam safety guidelines. The panel was to advise the President in a report due October 1, 1978, on whether the regulations, procedures, practices, and guidelines were adequate for ensuring the safety of dams.

Executive Order 12148, Federal Emergency Management, issued on July 20, 1979, transferred or reassigned to FEMA the management of emergency planning and assistance functions that had been vested in the President. At that time, FEMA was a new agency, having been established under the Reorganization Plan No. 3 of 1978. In addition to providing that FEMA "establish Federal policies for, and coordinate, all civil defense and civil emergency planning, management, mitigation, and assistance functions of Executive agencies," Executive Order 12148 made FEMA responsible for coordinating efforts to promote dam safety.

On October 4, 1979, President Carter issued a Presidential memorandum directing certain Federal agencies to implement FEMA 93, *Federal Guidelines for Dam Safety*, and to report their implementation progress to FEMA. Consequently, FEMA established the Interagency Committee on Dam Safety (ICODS) to encourage the establishment and maintenance of effective Federal programs, policies, and guidelines for dam safety. FEMA 93 encourages strict safety standards in the practices and procedures of Federal agencies and dam owners regulated by Federal agencies. The guidelines state that "Those charged with administering the guidelines must recognize that the achievement of dam safety is through a continuous, dynamic process in which guidelines, practices, and procedures are examined periodically and updated."

In 1996, the Water Resources Development Act of 1996 (Public Law 104-303) directed FEMA to establish a National Dam Safety Program, transferred additional dam safety functions to FEMA, and authorized the establishment of ICODS as a permanent advisory body. The Act also directed FEMA to establish a National Dam Safety Review Board whose purpose would be to advise the Director of FEMA (now referred to as the Administrator) on setting national dam safety priorities and to provide assistance in monitoring State dam safety programs.

With the advice of the National Dam Safety Review Board and encouragement of ICODS, FEMA has developed and updated the following Federal guidelines to supplement FEMA 93:

- FEMA 64, *Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners* (renamed with this update FEMA P-64, *Federal Guidelines for Dam Safety: Emergency Action Planning for Dams*)
- FEMA 65, *Federal Guidelines for Dam Safety: Earthquake Analyses and Design of Dams*
- FEMA 94, *Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams*
- FEMA 148, *Federal Guidelines for Dam Safety: Glossary of Terms*
- FEMA 333, *Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams*

In 2010, the National Dam Safety Review Board's Work Group on Emergency Action Planning for Dams established a Task Group to review the 2004 edition of FEMA 64 and to make recommendations for updating the guidelines. This document, the 2013 edition of FEMA 64, is an update of the 2004 edition. The updates include the addition of approaches and practices that are consistent with the National Response Framework and with emergency action planning concepts from a variety of contemporary sources. The updates reflect the consensus of the Task Group and have been approved by the ICODS and the National Dam Safety Review Board.

The goal of the updated guidelines is to encourage (1) the development of comprehensive and consistent emergency action planning to protect lives and reduce property damage and (2) the participation of emergency management authorities and dam owners in emergency action planning.

NATIONAL DAM SAFETY REVIEW BOARD

Task Group on Updating FEMA 64, Federal Guidelines for Emergency Action Planning for Dam Owners

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Figures

Tables

Acronyms and Abbreviations

AAR	After Action Report
DHS	Department of Homeland Security
EAP	Emergency Action Plan
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
HSEEP	Homeland Security Exercise and Evaluation Program
ICODS	Interagency Committee on Dam Safety
ICS	Incident Command System
IDF	Inflow Design Flood
NID	National Inventory of Dams
NIMS	National Incident Management System
NWS	National Weather Service
PIO	Public Information Officer
PMF	Probable Maximum Flood
WFO	Weather Forecast Office

I. BASIC CONSIDERATIONS FOR PREPARING AN EMERGENCY ACTION PLAN

A. Purpose

1. General

Residents of areas that could be affected by a dam failure or operational incident have a risk of loss of life, injuries, and damage to property from a failure or operational incident. The purpose of this document is to provide guidelines for the preparation of an Emergency Action Plan (EAP) to facilitate the development of plans that are comprehensive and consistent. The purpose of an EAP is to protect lives and reduce property damage.

Flooding caused by the failure of Teton Dam in eastern Idaho as it was filling for the first time (1976); 14 people died (waterarchives.org)

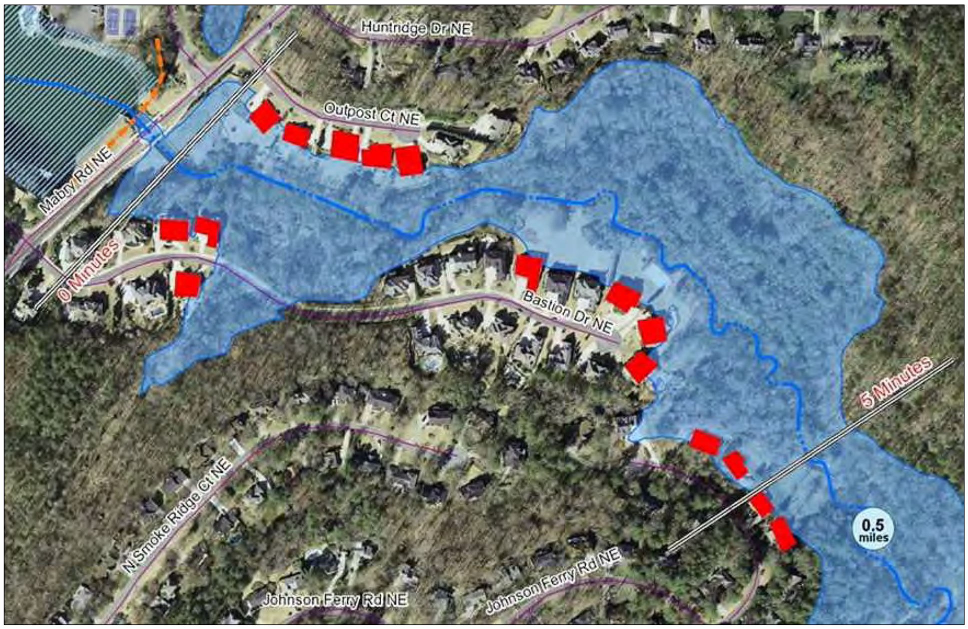
The intended readers of this document are dam owners and emergency management authorities who work together in the response to dam safety emergencies.

An EAP is a formal document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize loss of life and property damage. The EAP includes:

- Actions the dam owner will take to moderate or alleviate a problem at the dam
- Actions the dam owner will take, and in coordination with emergency management authorities, to respond to incidents or emergencies related to the dam
- Procedures dam owners will follow to issue early warning and notification messages to responsible downstream emergency management authorities
- Inundation maps to help dam owners and emergency management authorities identify critical infrastructure and population-at-risk sites that may require protective measures, warning, and evacuation planning
- Delineation of the responsibilities of all those involved in managing an incident or emergency and how the responsibilities should be coordinated

2. Dam Safety Incidents and Emergencies

A dam safety incident is an impending or actual sudden uncontrolled release or excessive controlled release of water from an impounding structure. The release may be caused by damage to or failure of the structure, flood conditions unrelated to failure, or any condition that may affect the safe operation of the dam. The release of water may or may not endanger human life, downstream property, or the operation of the structure.



Projected flooding from a breach in a dam in a residential area

When people live in an area that could be affected by the operation or failure of a dam, there is the potential for an emergency related to a dam safety incident. The National Incident Management System (NIMS) defines an emergency as "any incident, whether natural or manmade, that requires responsive action to protect life or property." The Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988, as amended (42 U.S.C. §§ 5121–5206), defines an emergency in terms of the Federal response ("any occasion or instance for which, in the determination of the President, Federal assistance is needed to supplement state and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen or avert the threat of a catastrophe in any part of the United States").

3. Uniformity of Emergency Action Plans

EAP effectiveness can be enhanced by a uniform format that ensures that all critical aspects of emergency planning are covered in each plan. Uniform EAPs and advance coordination with emergency management authorities should facilitate a timely response to a developing or actual emergency. Organizations and individuals who own or are responsible for the operation and maintenance of dams are encouraged to use these guidelines to develop, update, revise, and exercise their EAPs.

4. National Incident Management System

NIMS provides a systematic, proactive approach to guide all levels of governmental, nongovernmental, and private-sector organizations to work seamlessly to respond to incidents. The NIMS approach is effective for any situation that involves coordination among multiple agencies or partners. The goal is to coordinate activities to reduce consequences (loss of life, property damage, and harm to the environment).

The Incident Command System (ICS) is a fundamental element of NIMS and consists of a standardized, on-scene, all-hazards incident management approach that:

- Allows for the integration of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure
- Enables a coordinated response among various jurisdictions and functional agencies, both public and private
- Establishes common processes for planning and managing resources

As a system, ICS is extremely useful. The ICS provides an organizational structure for incident management and guides the process for planning, building, and adapting that structure. Using ICS for every incident or planned event helps hone and maintain skills needed for larger scale incidents. It is recommended that dam owners coordinate with appropriate emergency management authorities in an effort to incorporate ICS and NIMS concepts and structures into the EAP.

A critical tool for promoting the nationwide implementation of NIMS is a well-developed training program. For further information on NIMS training courses, dam owners and emergency management authorities should contact the appropriate State and/or local response agencies and refer to FEMA's website at www.fema.gov.

B. Scope

The EAP guidelines in this document are focused on developing or revising EAPs for dams that would likely cause loss of life or significant property damage as a result of a failure or other life-threatening incident. The areas downstream of each dam are unique. Therefore, the extent and degree of potential impacts of each dam vary.

Flooding in Cedar Rapids, Iowa, including this hospital from overtopping of the spillway at Coralville Dam as a result of heavy rains (2008)

The level of detail in the EAP should be commensurate with the potential impact of a dam failure or operational incident. A dam with low or no potential impact should not require an extensive evaluation or be subject to an extensive planning process while high- and significant-hazard dams may require a larger emergency planning effort. In addition, high- and significant-hazard dams tend to involve more entities that must coordinate responsibilities and efforts to effectively respond to an incident than low-hazard dams. Every EAP must be tailored to the site conditions.

EAPs generally contain six elements:

- Notification flowcharts and contact information
- Response process
- Responsibilities
- Preparedness activities
- Inundation maps
- Additional information in appendices

The elements of an EAP are described in Chapter II of these guidelines. All elements should be included in a complete EAP. Although the dam owner is responsible for developing and maintaining the EAP, the plan will not be effective unless it is developed and implemented in close coordination with all applicable emergency management authorities. Emergency management authorities will use the information in the dam owner's EAP to facilitate the implementation of their responsibilities. In general, State and local emergency management authorities will have some coordinating plans in place to address local emergency operations and/or warnings and evacuations.

C. Coordination

It is vital that the development of the EAP be coordinated with all entities, jurisdictions, and agencies that would be affected by an incident at the dam or that have statutory responsibilities for warning, evacuation, and post-incident actions. The EAP should contain clearly defined roles and responsibilities for each entity.

Coordination with emergency management authorities responsible for warning and evacuating the public is essential for ensuring agreement on individual and group responsibilities. Participation in the development of the EAP will enhance confidence in the EAP and its accuracy. Coordination will provide opportunities to discuss critical emergency planning concerns such as the order of public official notification, use of backup personnel, alternate means of communication, and special procedures for nighttime, holidays, and weekends.

To ensure a timely and accurate information exchange, coordination between the dam owner, local emergency management authorities, and the appropriate National Weather Service (NWS) Weather Forecast Office (WFO) is highly recommended. The NWS has a congressional mandate to issue official public warnings for all weather-related events, including dam breaches and flooding. The planning process should include a decision about who will contact the NWS. The local emergency authority is recommended unless it is otherwise agreed to by the emergency authority and dam owner. Local NWS websites (www.weather.gov) provide links to local WFOs, a description of NWS services, and a list of NWS products.

Coordination with upstream and downstream dam owners is important to determine operational procedures for mitigating the effects of floods and dam safety emergencies. Dams that provide critical resources to a community should have a recovery plan that was developed in coordination with local emergency management authorities. The loss of a dam that provides a key resource such as power or drinking water could significantly affect the recovery of a community or region. Recovery and continuity of operations of critical infrastructure for these types of dams are discussed in *Dams Sector Crisis Management Handbook: A Guide for Owners and Operators* (DHS, 2008), available at www.dhs.gov/dams_sector_crisis_handbook.pdf.

D. Evacuation

Evacuation planning and implementation is typically the responsibility of State or local emergency management authorities. Although an EAP does not need to include an evacuation plan, it should indicate who is responsible for evacuation and whose plan will be followed.

Voluntary evacuation because of flooding (North Dakota, 2009)

Inundation maps developed by the dam owner must be shared with emergency management authorities and included in the EAP (see Figure 1 on page II-19 for an example of an inundation map). These maps may help in the development of warning and evacuation plans. It is important for dam owners to coordinate with the appropriate emergency management authorities and provide information from dam inundation studies that can assist with evacuation planning.

Dam owners should also include procedures in the EAP for ensuring that emergency management authorities are provided with timely and accurate information on dam conditions during an incident. This information will help agencies make the appropriate decisions on evacuations.

Dam emergency evacuation plans should be developed before an incident occurs. The plans are recommended to be based on a worst-case scenario and to address the following:

Planning session

- Initiation of emergency warning systems
- Pre-incident planning
- Identification of critical facilities and sheltering
- Evacuation procedures, including flood wave travel time considerations (e.g., evacuation of special needs populations, lifting evacuation orders)
- Distance and routes to high ground
- Traffic control measures and traffic routes
- Potential impact of weather or releases on evacuation routes such as flooded portions of the evacuation route before the dam incident occurs
- Vertical evacuation/sheltering in place
- Emergency transportation
- Safety and security measures for the perimeter and affected areas
- Re-entry into affected areas

E. Document Control and Protection of Critical Information

The dam owner should develop an EAP distribution list for all those who would be involved in implementing the EAP. The list must be reviewed and updated as part of updates to the EAP. Each copy of the EAP that is distributed should be controlled by copy number and a notice requesting that other copies of the EAP not be made. When outdated EAPs have been replaced in their entirety with new versions, the dam owner should request that the outdated controlled copies be returned to the owner or otherwise ensure they are securely destroyed to prevent misuse. If EAPs are made available electronically, care should be taken to ensure that document control is maintained, such as through the use of a secure web portal accessible only to the entities on the established distribution list.

To protect critical information, including but not limited to technical data and personal contact information, dam owners should consider maintaining a redacted copy of the EAP. The redacted copy made available to the public upon request should not contain, for example, detailed technical data or contact information of individuals participating in the EAP. Dam owners may also wish to limit the technical information provided to external entities participating in the EAP. Decisions about what to include in the redacted copy should be made by those participating in the EAP.

F. Maintaining an EAP

After the EAP has been developed, approved, and distributed, continual reviews and updates must be performed. Without periodic maintenance, the EAP will become outdated and ineffective.

The EAP should be updated promptly to address changes in personnel and contact information, significant changes to the facility, or emergency procedures. The EAP should be reviewed at least annually for adequacy and updated as needed. Even if no revisions are necessary, the review should be documented.

The review should include an evaluation of any changes in flood inundation areas, downstream developments, or in the reservoir and a determination of whether any revisions, including updates to inundation maps, are necessary. Appendix A contains an EAP review checklist.

The EAP should be updated promptly with the outcome of any exercises, including periodic reviews and verifications of personnel and contact information from Notification Flowcharts and contact lists. Any changes to the dam and/or inundation zone should be reviewed because the changes may affect the inundation maps. Maps should be changed as soon as practicable and noted in the EAP.

Once the EAP has been revised, the updated version (or only the affected pages in minor updates) should be promptly distributed to those on the distribution list. Placing EAPs in loose-leaf binders may simplify the process of removing and replacing outdated pages when updates are made. Including the date of the EAP or the date of the current revision on each page will help to ensure that users have the most current version. It is recommended that the entire EAP be reprinted as necessary and distributed to all plan holders to ensure that all updates have been included in the documents.

II. SUGGESTED EAP OUTLINE AND CONTENTS

A. Suggested EAP Outline

A suggested EAP outline is provided below. Considering all of the items in the outline will ensure that the six EAP elements identified in Chapter I of this document are included, thus providing uniform, comprehensive, and consistent dam emergency action planning. It is also important that the dam owner, emergency management authorities, and regulatory requirements be incorporated into the EAP. The development of the EAP should be coordinated with the appropriate authorities and organized in a format that is most useful to, and consistent with, the organizations involved with its implementation.

Front Matter

- Cover
- Title Page
- Table of Contents
- EAP Signatures

Part I: EAP Information

- I. Summary of EAP Responsibilities
- II. Notification Flowcharts
- III. Statement of Purpose
- IV. Project Description
- V. EAP Response Process
  - Step 1: Incident Detection, Evaluation, and Emergency Level Determination
  - Step 2: Notification and Communication
  - Step 3: Emergency Actions
  - Step 4: Termination and Follow-up
- VI. General Responsibilities
  - Dam Owner Responsibilities
  - Notification and Communication Responsibilities
  - Evacuation Responsibilities
  - Monitoring, Security, Termination, and Follow-up Responsibilities
  - EAP Coordinator Responsibilities
- VII. 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 Adverse Weather
Alternative Sources of Power
Emergency Supplies and Information
Stockpiling Materials and Equipment
Coordination of Information
Training and Exercise
Alternative Systems of Communication
Public Awareness and Communication

VIII. Inundation Maps

Part II: Appendices

The suggested format separates the EAP into two parts: the basic EAP instructions (EAP Information) and supporting information (appendices). The content and depth of detail in the EAP should be appropriate for the risk the dam poses and meet the relevant regulatory requirements.

1. Part I: EAP Information

Sections I through VIII contain information that is likely to be used by all parties (dam owner and emergency management authorities) during an actual incident.

2. Part II: Appendices

The appendices should contain supplementary information. The appendices typically include material that was used to develop the EAP and information that can be used to assist with decision-making during an incident (e.g., detailed operation and maintenance requirements, dam break information and analyses, record of plan reviews and updates, plan distribution list, incident tracking forms).

When developing the appendices, dam owners, in coordination with emergency management authorities, should consider including supporting information that will help them respond rapidly and effectively to an incident.

B. Suggested EAP Contents

The suggested contents of the EAP are described in this section.

1. Front Matter

a. Title Page

The EAP title page identifies it as an Emergency Action Plan and specifies the dam for which it was developed. Both the dam and reservoir names should be included. If the dam has a State, National Inventory of Dams (NID), or other identifying number, it should be included. Other suggested information includes the dam owner's name or organization and, if applicable, a street address or location of the dam site.

b. Table of Contents

The table of contents should list all major sections of the EAP and the figures, tables, and maps.

c. EAP Signatures

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

2. Part I: EAP Information

a. Summary of EAP Responsibilities

Part I, Section I, of the EAP should summarize the critical responsibilities for responding to an incident and implementing the plan. Appendix B, Table B-1, is an example of a table with the general responsibilities of those involved with implementation of an EAP. Appendix B, Table B-2, is an example of a summary of dam owner responsibilities. During an actual incident, these types of summaries can provide quick and easy references to critical activities involved with implementing the EAP.

b. Notification Flowcharts

A Notification Flowchart identifies who is to be notified of a dam safety incident, by whom, and in what order. An example Notification Flowchart is provided in Appendix C. The information on the flowchart is critical for the timely notification of those responsible for taking emergency actions. For ease of use during an incident, the EAP should include Notification Flowcharts that clearly present the information listed below. 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.

- 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, telephone numbers, and radio call numbers. Supplemental contact information may be included in a list or table of emergency contacts. Supplemental contact information may include fax numbers, e-mail addresses, direct connect numbers, and alternate contacts. The Notification Flowchart may also be supplemented by NIMS ICS Forms, such as ICS Forms 205 and 205a, available at www.training.fema.gov/EMIWeb/is/ICSResource/icsforms.htm.

The Notification Flowchart must be tailored to the needs and notification priorities of each dam. It is usually recommended that one person be responsible for contacting no more than three or four other parties. At a minimum, the Notification Flowchart should designate who dam owners will contact and who the local emergency management authorities will contact, as described below.

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 WFO

Mobile command center

If an emergency dispatch center is on the flowchart, a direct contact number for the center should be included because it may be necessary to contact emergency response authorities directly. In addition, it is possible that the caller may be outside the dispatch center's call range. For example, 911 calls made from a dam owner's operations center may not go to the same jurisdiction where the dam is located.

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. An example Notification Flowchart is provided in Appendix C.

If other forms of mass communication or notification are used, these may need to be incorporated into the Notification Flowchart and associated procedures. Examples include warning sirens, loud speakers, conference calling, mass e-mail notifications, and text messaging.

c. 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."

d. Project Description

A description of the dam, its location, and the NID identification number should be provided in this section. If the NID identification number is not available, the State identification number should be used. 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. 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.

e. EAP Response Process

There are generally four steps that should be followed when an unusual or emergency incident is detected at a dam. These steps constitute the EAP response process. 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

During Step 1, an unusual condition or incident is detected and confirmed.

Unusual condition or incidents are unique to each dam and, to the extent possible, should be identified in the EAP. The following information should be considered for inclusion or reference 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 events. 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.

Piping flow through the dam as a result of dam concrete failure

The four dam safety emergency level categories listed below are recommended. However, dam owners, in coordination with emergency management authorities, should determine the number of emergency levels required for each dam on a case-by-case basis.

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

The EAP should describe how each emergency level applies to the particular dam. Information to assist the dam owner in determining the appropriate emergency level should be developed and included in the EAP. An example table describing emergency level for different incidents is included in Appendix D. The four emergency levels are discussed below.

High Flow. The High Flow emergency level indicates that flooding is occurring on the river system, 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 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. An example table is provided in Appendix E.

Earthen dam seepage

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, and (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.

Failure of Teton Dam (Idaho) from seepage (1976)

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. For purposes of evacuation, emergency management authorities may assume the worst-case condition that failure has already occurred.

Step 2: Notification and Communication

After the emergency level at the dam has been determined, notifications are made in accordance with the EAP's Notification Flowchart(s). Details on the use of the Notification Flowchart and any additional contact information should be provided in the EAP.

When developing notification and communication procedures, dam owners should coordinate closely with emergency management authorities. 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.

When performing notification and communication activities, it is important that people speak in clear, nontechnical terms to ensure that those being notified understand what is happening at the dam, what the current emergency level is, and which actions to take. To assist in this step, the EAP may include checklists and/or prescripted messages to help the caller adequately describe the emergency situation to emergency management authorities. Different messages can be developed for each emergency level. Examples of a notification checklist and prescripted messages are included in Appendix F.

After initial notification, the dam owner should make periodic status reports to the affected emergency authorities and other stakeholders in accordance with the Notification Flowcharts and associated procedures. If it appears that the situation is continuing to deteriorate despite actions being taken to moderate or alleviate failure, local authorities may decide to change their course of action. Depending on the location of downstream residents and the estimated time required to warn them, the evacuating agencies may consider early evacuation or continued warnings until the emergency has passed.

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. An example table is provided in Appendix G. Additional information related to response actions may also be provided in the dam operating manuals and instructions.

During an incident, safety and security measures should be implemented to secure the affected operational areas at the dam to protect operations personnel and the public, and permit an effective performance of emergency response actions.

Step 4: Termination and Follow-up

The EAP should explain the expected termination and follow-up procedures for dam safety incidents and emergencies. This step should explain the process to follow and the criteria for determining that the incident at the dam has been resolved. A Dam Emergency Termination Log may be developed and used to document conditions and decisions. An example log form is provided in Appendix I. Generally, the dam owner, or the dam owner's dam safety expert, is responsible for notifying the authorities that the condition of the dam has been stabilized. Government officials are responsible for declaring an end to the public emergency response.

Following the termination of an incident, the dam owner, in coordination with emergency management authorities, should conduct an evaluation that includes all affected participants. At a minimum, the following should be discussed and evaluated in an after-action review:

- Events or conditions leading up to, during, and following the incident
- Significant actions taken by each participant and improvements for future emergencies
- All strengths and deficiencies found in the incident management process, materials, equipment, staffing levels, and leadership
- Corrective actions identified and a planned course of action to implement recommendations

The results of the after-action review should be documented in an After Action Report (AAR) and used as a basis for revising the EAP. The dam owner should participate in the after-action review and the development of the AAR.

f. General Responsibilities

A determination of responsibility for EAP-related tasks must be made during the development of the plan. Dam owners are responsible for developing and maintaining the EAP. Dam owners in coordination with emergency management authorities are responsible for implementing the EAP. Emergency management authorities with statutory obligations are responsible for warning and evacuation within affected areas. All entities involved with EAP implementation should document incident-related events. Appendix I includes an example Emergency Incident Log.

The EAP must clearly specify the responsibilities of all involved entities to ensure that effective and timely action is taken if an emergency at the dam occurs. The EAP must be site-specific because conditions at the dam and upstream and downstream of the dam are unique to every dam. Some responsibilities to be considered are discussed below. An example summary of EAP responsibilities is provided in Appendix B, Table B-1.

Dam Owner Responsibilities

The duties of the dam owner should be clearly described. In general, the dam owner is responsible for detecting and evaluating dam safety incidents, classifying the incident, notifying emergency management authorities, and taking appropriate response actions.

The dam operator's duties should be described in the EAP, and operators should be trained on the importance and use of the plan. Examples of duties may include opening spillway gates per a required sequence and opening or closing water intakes, as appropriate. Instructions for the operation of the project during the anticipated emergency should be provided.

The chain of command in the dam owner's organization should be clearly described. Officials and alternates that must be notified should be identified and priority of notification determined. Notification of supervisory personnel is recommended if time permits. Advice may be needed concerning predetermined remedial action to delay, moderate, or alleviate the severity of the emergency condition. Responsibilities should be coordinated with appropriate levels of management to ensure full awareness of organizational capabilities and responsibilities. An example summary table identifying actions that each member of the dam owner's organization will take during the incident or emergency is provided in Appendix B, Table B-2.

Notification and Communication Responsibilities

The individuals authorized to notify emergency management authorities should be determined and clearly identified in the EAP. If time allows, onsite personnel may be able to seek internal advice and assistance. However, under an Imminent Failure condition, the responsibility and authority for notification may have to be delegated to the dam operator or a local official. When developing the EAP, the dam owner and emergency management authorities should discuss and determine the most efficient notification protocol to follow.

Throughout the United States, the NWS and/or other agencies have the primary responsibility for issuing flood warnings. It is highly recommended that the Notification Flowchart include the agency with this responsibility so that its facilities can enhance warnings being issued.

Emergency Operations Center

Once notified of an incident at the dam, local emergency management authorities may activate an Emergency Operations Center (EOC) to serve as a central coordination center for emergency response, warning, and evacuation activities. A representative of the dam owner should go to the EOC to help agency personnel understand the project-specific information and inundation maps.

Interaction with the media should be implemented through the local or State emergency management authority. These agencies should have a Public Information Officer (PIO) and/or a Joint Information Center for disseminating information and handling inquiries. It is highly recommended that the dam owner and the appropriate incident or emergency management authority work in partnership to accomplish this task.

Proper coordination and communication among onsite technical personnel at the dam, PIOs, and emergency personnel at the EOC are of critical importance to the successful implementation of the EAP. These activities should be thoroughly tested during comprehensive EAP exercises and modified as necessary.

Evacuation Responsibilities

Warning and evacuation planning and implementation are responsibilities of local emergency management authorities with the legal authority to perform these actions. Under the EAP, the dam owner is responsible for notifying the appropriate emergency management authority when an incident is anticipated, is imminent, or has occurred. Warning and evacuation protocols are key elements in an EAP exercise but are not typically included in the EAP. The EAP should, however, clearly describe the notification, warning, and evacuation responsibilities of the dam owner and the local emergency management authority.

Dam owners should not assume or usurp the responsibility of government entities for evacuation of people. However, there may be situations in which routine notification and evacuation will not be sufficient, as in the case of a residence located immediately downstream of a dam or a campground that would be inundated within minutes of a dam failure. In some cases, dam owners may arrange to notify the residence or campground directly. Such procedures should be coordinated with the appropriate authorities before an emergency situation develops.

Monitoring, Security, Termination, and Follow-Up Responsibilities

A person should be designated as an onsite monitor from the beginning of a dam safety incident until the emergency has been terminated. This person should provide status updates to the dam owner so the owner can keep all those involved with the implementation of the EAP informed of developing conditions.

Provisions for security measures during the emergency should be specified in the EAP. For additional information on security measures, see *Dams Sector Security Awareness Guide: A Guide for Owners and Operators* (DHS, 2007), available at www.dhs.gov/xlibrary/assets/ip_dams_sector_securit_awareness_guide.pdf.

Termination of a dam safety emergency is usually twofold. The entity that activates the EAP is usually responsible for determining when the dam safety situation has stabilized. This is typically the dam owner in consultation with engineers and dam safety experts but may include other State and Federal regulatory entities. The applicable emergency management authorities, on the other hand, are responsible for termination of the emergency response activities, including termination of an evacuation. Both the dam owner and the emergency response authorities should coordinate closely while making decisions to terminate both the dam safety event and response efforts.

Recovery activities will continue on different levels for all involved in the dam safety incident after the emergency has been terminated. Although not typically addressed in a dam EAP, recovery activities should be considered by all dam owners and particularly for those dams that can affect a critical public utility such as water supply or electricity.

The dam owner should coordinate a follow-up evaluation after any emergency. All participants should be involved in this evaluation and should keep logs and records during the incident. An example Emergency Incident Log and Emergency Termination Log are presented in Appendix I. The results of the follow-up evaluation should be documented in a written report (After Action Report) and used to improve future response actions.

EAP Coordinator Responsibilities

The dam owner should specify an EAP Coordinator who will be responsible for overall EAP-related activities, including but not limited to preparing revisions to the EAP, establishing training seminars, and coordinating EAP exercises. This person should be the EAP contact for questions about the plan.

g. Preparedness

Preparedness, as it relates to an EAP for a dam, typically consists of activities and actions taken before the development of an incident. Preparedness activities attempt to facilitate response to an incident as well as prevent, moderate, or alleviate the effects of the incident. This section of the EAP should describe preparedness actions already completed, as well as established preplanned actions that can be taken after the development of emergency conditions.

Examples of preparedness actions include conducting regular inspections or surveillance, installing monitoring equipment, installing warning sirens, developing emergency operating instructions, and planning for equipment, labor, and materials to be used in emergency situations.

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

The following sections discuss these categories.

Surveillance and Monitoring

The EAP should contain provisions for surveillance and monitoring at the dam. Prompt detection and evaluation of information from instrumentation and physical monitoring is critical to the effectiveness of the EAP and timely emergency response. Consideration should be given to times when the dam is attended and unattended.

Seepage weir and collection box

When a dam is not continuously attended and an incident could endanger life or cause significant property damage, it is imperative that instrumentation be installed and/or procedures developed to monitor conditions at the facility. To promptly identify and notify emergency management authorities of emergency conditions, a dam owner should be able to detect, confirm, and evaluate developing conditions. Monitoring systems must be able to deliver clear, concise, and reliable information so that emergency authorities with warning and evacuation responsibilities may be promptly alerted. While the EAP is being activated, personnel should visit the site to verify and continue to monitor conditions.

For an unattended dam, remote surveillance systems that include instrumentation for continuous monitoring of headwater and tailwater levels should be considered. If the dam owner has an operations center that is attended 24 hours a day, these systems should include monitoring for water level rate of change and alarms when prescribed limits or levels are exceeded. Monitoring system design must be site-specific and account for changes in headwater and tailwater that may occur during normal dam operations, floods, and maintenance activities.

Tailwater monitoring is generally more sensitive to a dam breach than headwater monitoring. Changes in tailwater will alert operators more quickly to site conditions and help determine whether the EAP should be implemented. If continuous readings of both the headwater and tailwater are available, the operator can obtain concurrent readings at any time and verify alarm conditions.

If automated monitoring systems are used, provisions should be made for indicating power interruptions and loss of communication with the monitoring instrumentation. When a dam operator lives close to a project, consideration may be given to installing an alarm at the operator's home. When power to, or communication with, the site is interrupted, the dam should be manned until conditions return to normal. Operation of the alarms should be checked periodically. Proper functioning of alarms should be confirmed by testing. For instance, annual testing of the EAP may be initiated by artificially tripping one of the alarms.

Reaction time must be minimized when inhabited structures are located immediately downstream of the dam. When these conditions exist, special procedures may need to be included in the EAP to notify the occupants involved. Local emergency management authorities should be fully involved in the development of these special procedures.

Procedures should be described for providing continuous surveillance for periods of actual or forecasted high flows. It may be necessary to send an observer to the dam during these periods and not rely on the instrumentation alone. It is very important that an observer be at the dam when flood conditions or signs of serious structural distress have been identified, provided that it is safe to do so.

If remote surveillance at the dam is not applicable, reasons to support that decision should be provided in this section of the EAP.

Backup systems and procedures should be developed to verify that instrumentation readings are correct. Camera systems that can be accessed from the command center or over the Internet can allow for quick verification of water level alarms and other dam safety conditions.

Evaluation of Detection and Response Timing

Total EAP implementation time from the initiation of an actual incident to determination of an emergency situation and notification of appropriate entities involved with implementation should be evaluated and understood. The impact of the timing should be considered when developing preparedness actions. Timely implementation of the EAP and coordination and communication with emergency management authorities are crucial elements in the effectiveness of the emergency response effort.

Access to the Site

The description of access should focus on primary and secondary routes for reaching the site using various access methods (e.g., foot, boat, helicopter, snowmobile). The expected response time should also be discussed. If the main road to the dam crosses the downstream channel and could be impassable due to flood waters, this situation should be identified and alternate access options described.

Flooded road

Response during Periods of Darkness

Response to potential or actual emergency conditions during periods of darkness should be clearly addressed in the EAP and include any special instructions for the dam operator and/or emergency management authorities. Response times, if different from daylight, should also be included.

Actions to be taken to illuminate the abutments, spillways, operating decks, non-overflow sections, or other areas where failures could occur should be described. Other actions that may facilitate the operation of gates or other emergency equipment should be described if they are different during periods of darkness.

Any special procedures during a power failure should be provided, including manual operation of electrically powered equipment and any additional notification requirements.

Response during Weekends and Holidays

Response during weekends or holidays should be clearly addressed in the EAP and include any special instructions for the dam operator and/or emergency management authorities. Response times, if different from non-holiday or weekdays, should also be included. The availability of the dam operator should be considered, and any special procedures for contacting or notifying personnel addressed.

Response during Adverse Weather

Response under adverse weather conditions should be included and any specific actions to be taken described in detail. Actions should be based on whether the dam is attended or unattended. Methods of access to the site (e.g., foot, boat, snowmobile) should be described. The expected response time should be discussed in detail. Any other special instructions for the dam operators or emergency management authorities should be described.

Alternative Sources of Power

Alternative sources of power for spillway gate operation or other emergency needs should be identified in the EAP. The plan should list the location of each alternate power source, its mode of operation and, if portable, a means of transportation with routes to be followed.

Emergency Supplies and Information

Planning and organizational measures that can help the dam owner and emergency management authorities manage an emergency situation more safely and effectively include stockpiling materials and equipment for emergency use and coordinating information between organizations.

The availability of local resources should be predetermined through discussions with local emergency management authorities and additional resource needs should be identified. The EAP should include the name and contact information (including backups) for suppliers, additional personnel, contractors, consultants, and any other entities who may be needed to assist the dam owner or emergency management authorities in responding to a dam emergency.

Stockpiling Materials and Equipment

Where applicable, the following should be documented:

- Materials needed for emergency repair, including source; materials should be as close as possible to the dam site
- Equipment needed for emergency response or repair, its location, and who will operate it
- Local contractors, vendors, and suppliers for dam-related equipment and supplies, including contact information and maps or directions to their locations
- Justification of decision not to stockpile materials and equipment if stocking is not warranted

Coordination of Information

Where applicable, the following should be described:

- The need for coordination of information on flows based on weather, runoff forecasts, dam failure, and other emergency conditions, including how coordination is achieved and the chain of communication, including names and contact information for responsible parties. Coordination with the NWS or other appropriate agency is recommended to monitor storms, river stages, and flood waves resulting from a dam break. The NWS or other appropriate agency may also be able to supplement the warnings being issued by using its own communication system. If coordination of information on flows is not applicable, this decision should be documented in the EAP.

- Actions to be taken to lower the reservoir water surface elevation, if applicable, including when and how this action should be taken. If not applicable, this should be documented in the EAP.
- Actions to be taken to reduce inflow to the reservoir from upstream dams or control structures. The EAP should provide instructions for contacting operators of these structures and how these actions should be taken. If such actions do not apply, this should be documented in the EAP.
- Actions to be taken to reduce downstream flows, such as increasing or decreasing outflows from downstream dams or control structures on the waterway on which the dam is located or its tributaries. The EAP should provide instructions for contacting operators of these structures and how these actions should be taken. If such actions do not apply, this should be documented in the EAP.

Training and Exercise

Results of training and exercise programs are critical components in evaluating the effectiveness of an EAP. Training and exercise plans should be designed and developed by those entities with responsibilities identified in the EAP. Since many emergency management authorities follow the FEMA Homeland Security Exercise and Evaluation Program (HSEEP) framework, HSEEP should be considered by the dam owner and other entities involved with the EAP when developing training and exercise activities. More information on the HSEEP can be found at hseep.dhs.gov.

Training. The people involved in the implementation of the EAP should be receive training to ensure that they are thoroughly familiar with all elements of the plan, the available equipment, and their responsibilities and duties under the plan.

Technically qualified personnel should be trained in the incident management process, including detection, evaluation, notification, and appropriate response actions during all emergency level determinations. A sufficient number of people should be trained to ensure adequate coverage at all times. A brief description of the training performed at the dam and how often it is performed should be included in the EAP.

Local emergency management authorities may want to consider developing evacuation and shelter-in-place training materials for people who would be affected by a dam failure in their jurisdiction. This is particularly important when a dam is categorized as unsafe or the population immediately downstream of a dam would be inundated within a short time frame.

Exercise. If the EAP action items and procedures are not exercised periodically, those involved in its implementation may lose familiarity with their roles and responsibilities. A proposed exercise schedule and plans for an EAP exercise program should be included in the EAP. Plans for conducting an evaluation of the exercise and for updating the EAP based on the outcome of the evaluation should be considered. See Appendix H for a discussion of the types of EAP exercises, frequency of exercises, and procedures for evaluation.

Tabletop exercise

Alternative Systems of Communication

The availability of alternative communications systems at the dam site should be identified in the EAP. These may include, but are not limited to, emergency sirens, cellular phones, direct connect, e-mail, intranet, radios, social media, and couriers. Operating procedures and special instructions for the use of these systems should be described. Consideration should be given to the target audience involved and the best means for communicating with them.

Public Awareness and Communication

Dams that are immediately upstream of residences, recreation areas, and campgrounds pose unique challenges. It may be necessary for the dam owner to assist emergency management authorities in developing public awareness measures. These measures typically explain the proximity of the dam, how people will be informed of an emergency, and the actions people should take during an emergency. The EAP should include a brief description of any public awareness measures that are performed. Emergency management authorities may consider the use of social media for both primary and alternate systems of communication with the public.

3. Inundation Maps

The primary purpose of an inundation map is to show the areas that would be flooded and travel times for wave front and flood peaks at critical locations if a dam failure occurs or there are operational releases during flooding conditions. Inundation maps are a necessary component of the EAP and are used both by the dam owner and emergency management authorities to facilitate timely notification and evacuation of areas potentially affected by a dam failure or flood condition. See Figure 1.

Figure 1. Inundation Map

Inundation maps should be developed by the dam owner in coordination with the appropriate emergency management authorities. The purpose of this coordination is to ensure that (1) the authorities understand how to interpret the maps and (2) the maps contain sufficient and current information for the authorities to warn and evacuate people at risk from a dam failure.

a. Determining Downstream Impacts

Several factors have to be evaluated when dam failure inundation zones are being determined. The type of dam and the mechanisms that could lead to failures require careful consideration if a realistic breach scenario is to be developed. Size and shape of the breach, time of breach formation, hydraulic head, and storage in the reservoir are all inputs into the development of a dam failure hydrograph. The best available topographic data should be used for developing accurate volume and routing estimates. There are several methods and computer models available for developing the dam failure hydrograph and routing dam break flows downstream. Models that use unsteady flow and dynamic routing method are preferable.

Different inflow conditions at the time of the dam failure should be considered to ensure that the EAP includes all communities that need to be notified. A “fair weather” or “sunny day” dam failure, in which the reservoir is at normal full pool elevation and normal stream flow is prevailing, is generally considered to have the most potential for loss of human life due to the element of surprise. Failure of a dam during flood flow conditions, however, will result in downstream inundation at higher elevations and will include additional affected populations. A failure at the dam's Inflow Design Flood (IDF) is considered to show the upper limit of inundation.

A sensitivity analysis (i.e., varying the breach parameters such as breach width and time to failure for the various flood inflow conditions) is recommended in order to fully investigate the effect of a failure on downstream areas. A sensitivity analysis allows the reviewer to identify the effect of various failure scenarios in order to select the most appropriate failure mode for developing the EAP.

If the assumed failure of a dam would cause the failure of any downstream dams, the analysis should consider the domino effect in routing the flood wave downstream. For example, if a downstream dam has an earthen embankment that would be significantly overtopped due to the upstream dam failure, then it may be necessary that the inundation zone reflect the additional flooding from failure of the downstream dam. Many factors should be considered for these cases, such as the expected performance of the downstream dams during high flows, the lag time between dams, and possible operation actions at downstream dams (e.g., drawdowns) that could alleviate the flood wave. Coordination of such studies with other downstream dam owners should be undertaken when feasible. The flood wave should be routed to a point where it no longer presents a hazard to downstream life or property.

b. Preparing Inundation Maps

Inundation maps should clearly show inundation zones, cross section information, dams, streets, buildings, railroads, bridges, campgrounds, and any other significant features. At the request of emergency management authorities, additional features, such as highlighted evacuation routes and emergency shelters may be included on the maps. All features should be shown using local names or terms. Printed inundation maps should be at a scale that is sufficient to clearly show the downstream inhabited areas within the inundation zones.

To assist emergency management authorities with potential evacuations, the maps should show areas inundated from a dam failure during "fair weather" and IDF conditions. The maps also typically show normal water levels. If inundated areas for the "fair weather" breach and the IDF breach are essentially the same or too close to be shown separately on the inundation maps, a single inundation area for the two breach conditions may be shown.

The lines delineating the inundated area should be drawn in such thickness or form (solid line, dashed line, dotted line) as to readily identify the inundation limits as the main features of the map but not bold enough to block houses, roads or other features which are inundated by the flood waters. The area between the inundation lines representing the water level may be shaded or colored to distinguish the area of inundation. Care should be taken to select shading or colors that will not block important features on the map. Additionally, critical features or inundated structures can be highlighted to ensure visibility.

When plotting inundation limits between cross sections used for analysis, the lines should reasonably reflect the change in water levels with consideration given to topographic patterns and both natural and manmade features.

When inundation lines enter the area of an existing lake or reservoir, they should be drawn to represent an increase in the water level of the lake or reservoir. If the increased water level overtops a dam, the appropriate inundation lines should continue downstream of the dam to represent the expected flooding.

The maps should include cross section information for selected areas downstream of the dam. The following information should be included for the “fair weather” breach and IDF breach scenarios:

- Distance of cross section downstream from the dam
- Travel times (in hours and minutes) of the leading edge and peak of the dam break flood waves starting from when the dam fails
- Expected peak water surface elevations
- Incremental rises in water levels
- Peak discharges
- Estimated duration of inundation

The dam owner should try to prepare maps using terms understood by all emergency responders. For example, a local responder may prefer that the maps show the expected height of water over a road instead of peak water elevation. However, the NWS may need the incremental rise and water level to issue flood warnings.

c. Additional Information

Care should be taken not to include too much technical information on the inundation maps. Excess information will hamper the first responder’s ability to quickly glean critical information from the map. A “Notes” sheet can be included to provide additional information, and detailed information supporting the development of the maps can be provided in an appendix for reference.

The following information should be included with the inundation maps, as applicable:

- A map index if inundation maps are shown on several sheets
- The antecedent flow conditions the maps are based on and any other pertinent dam breach information
- Water surface profiles showing the elevation prior to failure, the peak water surface elevation after failure, and highlighted locations of critical structures

- Written description of the areas affected by the dam break to clarify unusual conditions and the specific area threatened, including the extent and depth of the expected flooding, relative to known landmarks and historical flood heights
- Justification for providing only one inundation zone on the maps instead of both the “fair weather” and IDF conditions, if applicable
- Accuracy and limitation of the information supplied on the inundation maps and how to use the maps. A note should advise that because of 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 be used only as a guideline for establishing evacuation zones. Areas that are inundated depend on actual failure or flooding conditions and may differ from the areas shown on the maps.

4. Part II. Appendices

Appendices follow the main body of the EAP and contain information that supports and supplements the material used in the development and maintenance of the EAP.

Some of the topics that should, at a minimum, be contained in the appendices are:

- Investigation and analyses of dambreak floods
- Plans for updating and distributing the EAP
- Plans for posting the Notification Flowcharts
- Forms and Log Sheets
- Site-specific concerns

Each topic is discussed below.

a. Investigations and Analyses of Dam Break Floods

Although inundation maps are usually provided in the main body of the EAP, details regarding the development of the maps should be in an appendix. See Chapter II, Section B.3, for a discussion of the development of inundation maps. The following types of detailed information may be included in an appendix:

- Type of dam
- Assumed size, shape, and location of breach
- Assumed time of breach formation
- Assumed water surface elevation at failure
- Storage-reservoir curve
- Method/computer model used to determine downstream impacts

- Source of topographic data used
- Source of the base map
- Inflow hydrographs for fair weather and flood conditions
- Discussion of any sensitivity analyses performed and the reasons for the selected values
- Reason for or against including a domino failure of downstream dams
- Table showing output results at cross sections for pre- and post-failure conditions

b. Plans for Reviewing, Revising, and Distributing the EAP

As described in Chapter I, Section F, once developed, the EAP must be continually reviewed and periodically revised and redistributed. Plans for these activities should be documented in an appendix. In addition to a narrative description of this process, distribution lists and a formal record of reviews and revisions should be included. Example forms for reviewing, revising and distributing the EAP are provided in Appendix I.

c. Notification Flowchart

An up-to-date copy of the Notification Flowchart should be posted in prominent places at the dam site and operations center. Posting at appropriate emergency operations centers is also recommended. Maintaining a list of all posting locations in the EAP will ensure that new flowcharts are posted when updates are performed.

d. Blank Forms and Log Sheets

For easy access and use during an incident, blank forms and log sheets may be placed in an appendix. Forms may include a Record of EAP Reviews and Updates, record of Plan Holders, Emergency Incident Log, and Emergency Termination Log.

e. Site-Specific Concerns

Each dam and upstream and downstream areas are unique. As a result, each EAP is unique. Appendices can provide a discussion of site-specific issues that provide valuable information affecting the EAP and its implementation. References to where appropriate structural drawings and flood data are maintained may be helpful. Quick access to this information may be crucial during an emergency event.

III. GLOSSARY

Breach: An opening through the dam resulting in partial or total failure of the dam.

Consequences: Potential loss of life or property damage downstream of a dam caused by floodwaters released at the dam or by waters released by partial or complete failure of dam. Includes effects of landslides upstream of the dam on property located around the reservoir.

Dam failure: Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water. There are lesser degrees of failure, but any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. Lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amendable to corrective action.

Dam owner: Entity that owns the dam and associated facilities. The dam owner also includes the dam operator and operating organization.

Emergency Action Plan (EAP): 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. The EAP describes actions the dam owner will take to moderate or alleviate a problem at the dam, as well as actions the dam owner, in coordination with emergency management authorities, will take to respond to incidents or emergencies related to the dam.

EAP exercise: Activity designed to promote prevention, preparedness, and response to incidents and emergencies, and may also be extended to include recovery operations. The exercise also demonstrates the EAP's effectiveness in an actual situation and demonstrates the readiness levels of key personnel. Periodic exercises result in an improved EAP because lessons learned are incorporated into the updated EAP document. Exercises consist of testing and performing the duties, tasks, or operations identified and defined within the EAP through a simulated event.

Emergency: Any incident, whether natural or manmade, that requires responsive action to protect life or property.

Emergency alert system: A federally established network of commercial radio stations that voluntarily provide official emergency instructions or directions to the public during an emergency.

Emergency management authority: State, local, Tribal, or Territorial agency responsible for emergency operations, planning, mitigation, preparedness, response, and recovery for all hazards. Names of emergency management authorities vary (e.g., Division of Emergency Management, Comprehensive Emergency Management, Disaster Emergency Services, Emergency and Disaster Services).

Emergency Operations Center: The location or facility where responsible officials gather during an emergency to direct and coordinate emergency operations, to communicate with other jurisdictions and with field emergency forces, and to formulate protective action decisions and recommendations during an emergency.

Flood hydrograph: Graph showing the discharge, height, or other characteristic of a flood with respect to time for a given point on a stream.

Flood routing: Process of determining progressively, over time, the amplitude of a flood wave as it moves past a dam or downstream to successive points along a river or stream.

Hazard potential: Situation that creates the potential for adverse consequences, such as loss of life, property damage, or other adverse impact. Impacts may be for a defined area downstream of a dam from floodwaters released through spillways and outlet works of the dam or waters released by partial or complete failure of the dam. They may also be for an area upstream of the dam from the effects of backwater flooding or the effects of landslides around the reservoir perimeter.

Headwater: Water immediately upstream from a dam. The water surface elevation varies due to fluctuations in inflow and the amount of water passed through the dam.

Incident: An incident in terms of dam operation includes an impending or actual sudden release of water caused by an accident to, or failure of, a dam or other water retaining structure, or the result of an impending flood condition when the dam is not in danger of failure, or any condition that may affect the safe operation of the dam. The release of water may or may not endanger human life, downstream property and structures, or facility operations.

Inflow Design Flood (IDF): Flow used in the design of a dam and its appurtenant works, particularly for sizing the spillway and outlet works, and for determining the maximum height of the dam, freeboard, and temporary storage requirements. The IDF is typically the flow above which the incremental increase in water surface elevation due to failure of a dam is no longer considered to present an unacceptable threat to downstream life or property. The upper limit of an IDF is the Probable Maximum Flood.

Inundation map: Map delineating areas that would be flooded as a result of a dam failure.

Inundation zone: Area downstream of the dam that would be inundated by the released water. This zone is typically demarcated by a boundary reflecting the vertical elevation of the peak flow of water for both a flood failure and "sunny day" failure situation.

Notification: To inform appropriate individuals about an emergency condition so they can take appropriate action.

Probable Maximum Flood (PMF): Flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that is reasonably possible in the drainage basin under study.

Tailwater: Water immediately downstream from a dam. The water surface elevation varies due to fluctuations in the outflow from the structures of a dam. Tailwater monitoring is an important consideration because a failure of a dam will cause a rapid rise in the level of the tailwater.

Appendix A
EAP Review Checklist

General Document Items

- ☐ Is the name of the dam and other relevant identifiers, such as NID, State, and Federal ID numbers, clearly labeled in large letters in the EAP?
- ☐ Is the document a controlled document (i.e., each distributed plan is individually numbered and contains a statement that the plan is not to be copied or distributed by anyone other than the dam owner)?
- ☐ Is there a table of contents?
- ☐ Are the roles and responsibilities of key emergency personnel clearly documented, preferably at the beginning of the document?
- ☐ Is there an up-to-date revision sheet provided near the beginning of the document?
- ☐ Are revision numbers and revision dates provided as footers on each page of the document?

Detection Items

- ☐ Are detection and/or early warning systems at the dam clearly described, including dam operators' observations, instrumentation systems, and observations by the general public?

Decision Making Items

- ☐ Are the emergency levels clearly described?
- ☐ Are there clear guidelines and decision criteria to help the dam owner determine the appropriate level for potential unusual and emergency conditions that could occur at the dam?

Notification and Communication Items

- ☐ Are primary and backup communication systems among the dam owner, local emergency responders, and other key stakeholders described in the document?
- ☐ Are the notification flowcharts complete and logical?
- ☐ Are phone numbers, after-hours phone numbers, and backup personnel listed on the notification flowcharts and emergency contact lists?
- ☐ Do the notification flowcharts include contacts to provide timely engineering support?
- ☐ Do the notification flowcharts include contacts for timely notification of local emergency management organizations for more serious emergency levels?
- ☐ Do the notification flowcharts minimize the number of calls that dam operators are required to make, so that they can focus on implementing preventative actions? (Optimally, one or two calls per entity is best with no more than four calls)

Pre-planned Action Items

- ☐ Are there descriptions of recommended preplanned actions for potential unusual and emergency conditions at the dam?
- ☐ Is there a list of locally available engineering, labor, materials, and equipment resources that can be referenced in an emergency?
- ☐ Has the contact information for the locally available resources been recently updated or verified?

Termination and Follow-up Items

- ☐ Is the person with the authority to terminate emergency operations identified?
- ☐ Are the procedures for terminating emergency operations clearly described?
- ☐ Is there guidance on follow-up responsibilities after the emergency is terminated?

Inundation Mapping

- ☐ Does the inundation map include a north arrow and bar scale?
- ☐ Are the inundation areas clearly delineated and labeled? This is especially important if there are "fair weather" failure and "PMF plus breach" inundation limits shown on the inundation maps.
- ☐ Does the inundation map include a qualification stating that the inundation limits for an actual dam failure may vary in some ways from what is shown on the inundation map?
- ☐ Are local roads, drainages, and other landmarks clearly labeled on the base map?
- ☐ Is the downstream limit of the inundation mapping logical (e.g., at a major reservoir, river, other water course)?
- ☐ Were channel cross sections taken at critical downstream locations, such as at major road crossings, schools, major population centers, etc.?
- ☐ Is the following flood inundation information provided at important downstream cross sections:
  - Peak flood stage
  - Floodwave arrival time
  - Time to peak discharge
  - Maximum water surface elevation
  - Peak discharge

Other Items

- ☐ Are clear procedures for testing and updating the document provided?
- ☐ Is the frequency of testing and updating the document clearly described?
- ☐ Is the person or position responsible for updating the document indicated along with current contact information for that person?
- ☐ Are the processes for training personnel in how to use the document and the frequency and responsibility for this training clearly described?
- ☐ Are key hydrologic/hydraulic data, such as spillway and outlet discharge curves and reservoir area capacity curves, provided?
- ☐ Does the document include a general location map that shows where the dam is located relative to other key local roads, drainages, and population centers?

Appendix B
EAP and Dam Owner Responsibilities

In Table B-1, the dam and downstream areas are in both County X and County Y. Town Anywhere is only in County Y.

Table B-1: Summary of EAP Responsibilities

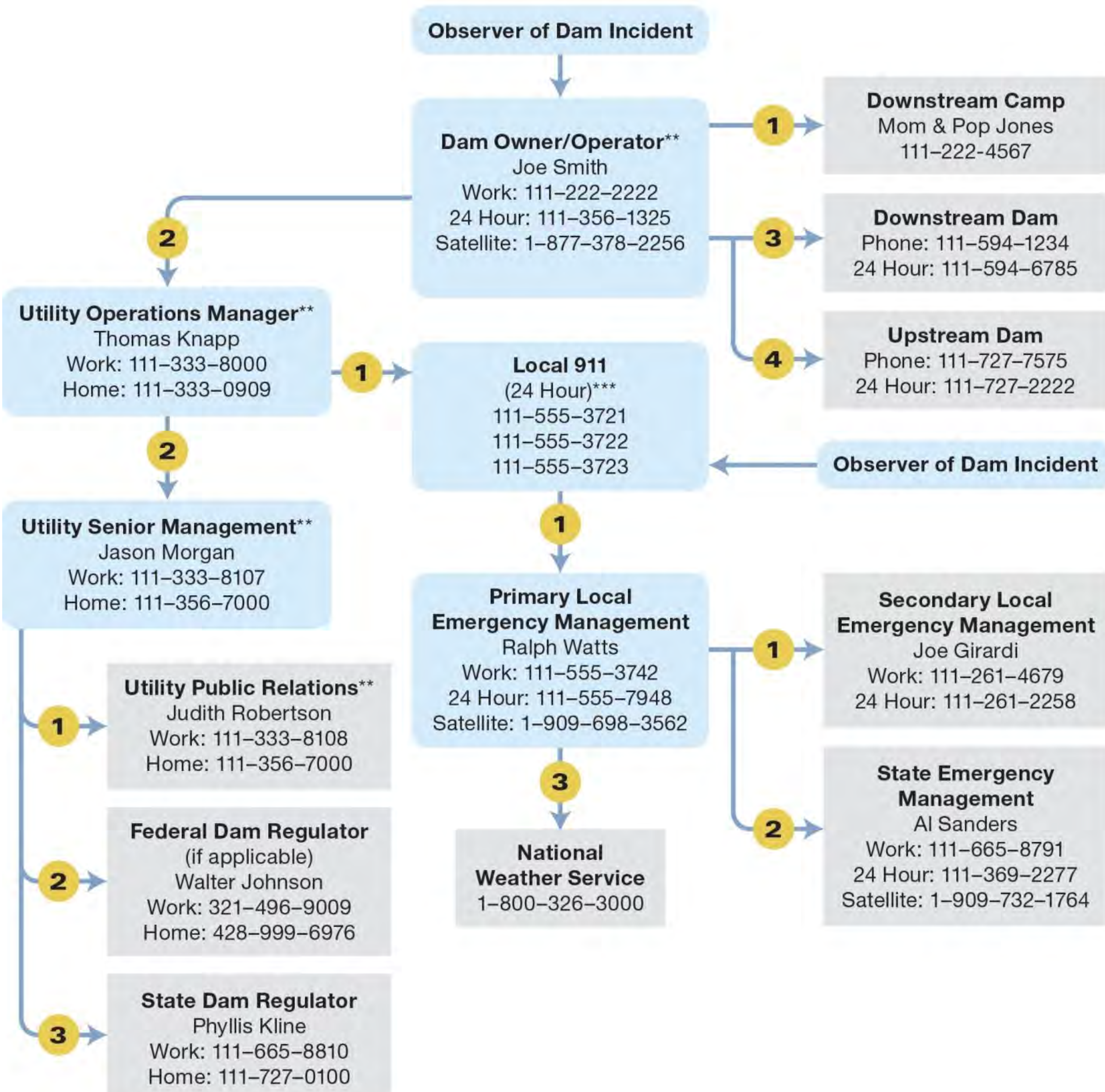
Entity	Responsibilities
Dam Owner / Operator	1. Verify and assess emergency conditions 2. Notify other participating emergency management agencies 3. Take corrective action at facility 4. Declare termination of emergency at facility 5. Update EAP on at least an annual basis 6. Respond to emergencies at the facility 7. Receive condition status reports from the dam operator
Town Anywhere (in County Y) Police, Fire and Rescue	1. Receive condition status reports from dam owner 2. Notify Public within Town Anywhere limits 3. Conduct evacuation from inundation areas within town limits, if required 4. Render assistance to County Y, as necessary 5. Render assistance to dam owner, as necessary
County X Police, Fire and Rescue, and Emergency Services	1. Receive condition status reports from dam owner 2. Notify public within County X 3. Conduct evacuation from inundation areas in County X, if required 4. Provide mutual aid to County Y, if requested and able
County Y Police, Fire and Rescue, and Emergency Services	1. Receive condition status reports from dam owner 2. Notify public within County Y 3. Conduct evacuation from inundation areas in County Y, if appropriate

Table B-2: Summary of the Dam Owner's Responsibilities

Entity	Responsibilities
24/7 Operations Command Center	1. Detect incident from alarms 2. Confirm incident by camera system 3. If no one is onsite, determine emergency level and dispatch operator to the site 4. Make calls on notification flow chart 5. Coordinate with Operator and Engineering on gate operations and emergency procedures 6. Coordinate with upstream and downstream dams on operations 7. Provide regular status reports to senior management
Onsite Dam Operator	1. Detect/confirm incident at dam 2. Determine emergency level 3. Make calls on Notification Flowchart 4. Coordinate with Command Center and Engineering on gate operations and emergency procedures 5. Implement gate operations and other emergency procedures 6. Provide regular status reports to senior management
Engineering Manager	1. Support onsite Operator and Operations Command Center on emergency level 2. Make calls on notification flow chart 3. Determine emergency operation and construction procedures 4. Coordinate with Operator and Command Center on gate operations and emergency procedures 5. Dispatch engineers and construction crews as necessary 6. Dispatch engineer as technical liaison to County Emergency Operations Center 7. Provide regular status reports to senior management
Senior Management	1. Make calls on Notification Flowchart 2. Initiate periodic status report conference calls with dam site, command center, engineering, and public relations 3. Provide regular status reports to County Emergency Operations Center 4. Coordinate with upper management 5. Coordinate with public relations staff at County and technical liaison at County Emergency Operations Center
Public Relations	1. Mobilize to County Offices 2. Participate in periodic status report conference calls with dam site, command center, engineering, and management 3. Provide input to staff on emergency communications 4. Represent utility to media

Appendix C
Example Notification Flowchart

Appendix C
Example Notification Flowchart*



= call sequence

* Use this chart in coordination with Notification Contact Table for additional contact information.

** Utility personnel should refer to EAP for sample warning messages.

*** Call Dam Operator if 911 is notified by non-utility observer.

Figure C-1. Example Notification Flowchart

Appendix D
Sample Guidance Table for Determining Emergency Level

Table D-1 provides only examples.

Table D-1: Sample Guidance for Determining Emergency Level

Event	Situation	Emergency Level
Earth Spillway Flow	Reservoir water surface elevation at auxiliary spillway crest or spillway is flowing with no active erosion	Non-failure
	Spillway flowing with active gully erosion	Potential failure
	Spillway flow that could result in flood of people downstream if the reservoir level continues to rise	Potential failure
	Spillway flowing with an advancing headcut that is threatening the control section	Imminent failure
Embankment Overtopping	Reservoir level is XX feet/inches below the top of the dam	Potential failure
	Water from the reservoir is flowing over the top of the dam	Imminent failure
Seepage	New seepage areas in or near dam	Non-failure
	New seepage areas with cloudy discharge or increasing flow rate	Potential failure
	Seepage with discharge greater than XX gallons per minute	Imminent failure
Sinkholes	Observation of new sinkhole in reservoir area or on embankment	Potential failure
	Rapidly enlarging sinkhole	Imminent failure
Embankment Cracking	New cracks in the embankment greater than XX inches wide without seepage	Non-failure
	Cracks in the embankment with seepage	Potential failure
Embankment Movement	Visual movement/slippage of the embankment slope	Non-failure
	Sudden or rapidly proceeding slides of the embankment slopes	Imminent failure
Instruments	Instrumentation readings beyond predetermined values	Non-failure
Earthquake	Measurable earthquake felt or reported on or within XX miles of the dam	Non-failure
	Earthquake resulted in visible damage to the dam or appurtenances	Potential failure
	Earthquake resulted in uncontrolled release of water from the dam	Imminent failure
Security Threat	Verified bomb threat that, if carried out, could result in damage to the dam	Potential failure
	Detonated bomb that has resulted in damage to the dam or appurtenances	Imminent failure
Sabotage/ Vandalism	Damage that could adversely impact the functioning of the dam	Non-failure
	Damage that has resulted in seepage flow	Potential failure
	Damage that has resulted in uncontrolled water release	Imminent failure

Appendix E
Example High Flow Notification Table

Table E-1 is an example that correlates outflows from a dam, expected impacts, and the organizations that will be notified. Actual organizations and order of notification should be coordinated with all emergency management authorities involved.

Table E-1: Example High Flow Notification Table

Number of Gates Open	Flow (cfs)	Downstream Impacts	Organizations to be Notified
1-4	<10,000	None	None
5	12,500	Minor riverbank flooding	Town Police, National Weather Service, Downstream Dam Owner
6	15,000	Minor flooding of local roads near river	Town Police, National Weather Service, Downstream Dam Owner
7	17,500	Significant flooding of local roads near river	Town Police, National Weather Service, Downstream Dam Owner
8	20,000	State Highway 92 bridge flooded, significant flooding of local roads and houses near river	Local Police, National Weather Service, Downstream Dam Owner, State Emergency Management Authority

cfs = cubic feet per second

Appendix F
Emergency Notification Information and Messages

Table F-1 is an example of the information a dam owner will provide to external organizations during emergencies:

Table F-1: Examples of Notification Information by Emergency Level

Level	Information to External Organizations
High Flow	1. Explain how much flow the dam is currently passing, and the timing and amount of projected flows. 2. If known, describe at what flows downstream areas get flooded. 3. State that the dam is **NOT** in danger of failing. 4. Indicate when you will give the next status report. 5. Indicate who can be called for any follow-up questions.
Non-failure	1. Explain what is happening at the dam. 2. Describe if the event could pose a hazard to downstream areas (e.g., gate failure). 3. State that the dam is **NOT** in danger of failing. 4. Indicate when you will give the next status report. 5. Indicate who can be called for any follow-up questions.
Potential Failure	1. Explain what is happening at the dam. 2. State you are determining this to be a **POTENTIAL FAILURE**. 3. Describe what actions are being taken to prevent the dam failure. 4. Provide an estimate of how long before the dam would be at risk of failing (e.g., during floods that could overtop the dam). 5. Refer to the inundation maps and explain what downstream areas are at risk from a dam failure. 6. Indicate when you will give the next status report. 7. Indicate who can be called for any follow-up questions.
Imminent Failure	1. Explain that the dam is failing, is about to fail, or has failed. 2. State you are determining this to be an **IMMINENT FAILURE**. 3. Refer to the inundation maps and explain what downstream areas are at risk from a dam failure and estimate when flows should reach critical downstream areas. 4. Indicate when you will give the next status report. 5. Indicate who can be called for any follow-up questions.

The source of the following prescripted notification messages is the **sample** Emergency Action Plan (EAP) for Rock Creek Watershed, Dam No. 23, developed by the U.S. Department of Agriculture, Natural Resources Conservation Service. The emergency levels and parts of the messages have been modified to conform to this guidance document.

Potential Failure

This is _______________ [your name and position].

We have an emergency condition at Rock Creek Watershed, Dam No. 23, located 2 miles south of Rock City.

We have activated the Emergency Action Plan for this dam and are determining this to be a **Potential Failure** condition.

We are implementing predetermined actions to respond to a rapidly developing situation that could result in dam failure.

Please prepare to evacuate the area along low-lying portions of Rock Creek.

The dam could potentially fail as early as 11 am today.

Reference the evacuation map in your copy of the Emergency Action Plan.

We will advise you when the situation is resolved or if the situation gets worse.

I can be contacted at the following number: ______________________.

If you cannot reach me, please call the following alternative number: ________________.

Imminent Failure

This is an emergency. This is ____________ [your name and position].

Rock Creek Watershed, Dam No. 23, located 2 miles south of Rock City, is failing.

The downstream area must be evacuated immediately.

Repeat, Rock Creek Watershed, Dam No. 23, is failing; evacuate the area along low-lying portions of Rock Creek.

We have activated the Emergency Action Plan for this dam and are determining this to be an **Imminent Failure** condition.

Reference the evacuation map in your copy of the Emergency Action Plan.

I can be contacted at the following number _____________________.

If you cannot reach me, please call the following alternative number: __________________.

The next status report will be provided in approximately 30 minutes.

The following prescripted message may be used as a guide for emergency management authorities to communicate the status of the emergency with the public:

- Attention: This is an emergency message from the Sheriff. Listen carefully. Your life may depend on immediate action.
- Rock Creek Watershed, Dam No. 23, located 2 miles south of Rock City is failing. Repeat. Rock Creek Watershed, Dam No. 23, located 2 miles south of Rock City is failing.
- If you are in or near this area, proceed immediately to high ground away from the valley. Do not travel on Highway 44 south of Rock City or return to your home to recover your possessions. You cannot outrun or drive away from the flood wave. Proceed immediately to high ground away from the valley.
- Repeat message.

Appendix G

Example Emergency Level – Potential Failure

Table G-1: Example Emergency Level – Potential Failure

Condition	Description of Condition	Action to be Taken
High Water Level / Large Spillway Release	Reservoir level reaches elevation XXX ft. and is rising at a rate of greater than one foot per hour.	1. Check for signs of erosion from spillway channel, particularly near wing walls.
		2. Assess cause of increased reservoir stage, especially during fair weather conditions.
		3. Perform additional tasks as directed by Dam Engineer.
		4. Make notifications if condition worsens such that downstream flooding is imminent.
Seepage	Localized new seepage or boil(s) observed along downstream face / toe of earthen embankment with muddy discharge and increasing but controllable discharge of water.	1. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos if camera is available. Document location on a site plan and in inspection report.
		2. Place a ring of sand bags with a weir at the top towards the natural drainage path to monitor flow rate. If boil becomes too large to sand bag, place a blanket filter over the area using non-woven filter fabric and pea gravel. Attempt to contain flow in such a manner (without performing any excavations) that flow rates can be measured. Stockpile gravel and sand fill for later use, if necessary.
		3. Inspect the dam and collect piezometer, water level and seepage flow data daily unless otherwise instructed by engineer. Record any changes of conditions. Carefully observe dam for signs of depressions, seepage, sinkholes, cracking or movement.
		4. Contact geotechnical engineer and provide all data collected.
		5. Maintain continuous monitoring of feature. Record measured flow rate and any changes of condition, including presence or absence of muddy discharge.
		6. Review information collected by field inspection and provide additional instructions / actions as required. Recommend remedial seepage and stability measures.
		7. Make notifications if condition worsens such that failure is imminent.
Sabotage and Miscellaneous Other Issues	Criminal action with significant damage to embankment or structures where significant repairs are required and the **integrity** of the facility is **compromised – condition appears stable with time**.	1. Contact law enforcement authorities and restrict all access (except emergency responders) to dam. Restrict traffic on dam crest to essential emergency operations only.
		2. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications.

Condition	Description of Condition	Action to be Taken
Sabotage and Miscellaneous Other Issues (cont.)	Criminal action with significant damage (cont.)	3. If necessary to lower reservoir level, open drain valve(s).
		4. Perform additional tasks as directed by the Dam Engineer or designee.
		5. Make notifications if conditions worsen.
Embankment Deformation	**Cracks:** New longitudinal (along the embankment) or transverse (across the embankment) cracks more than 6 inches deep or more than 3 inches wide or increasing with time. New concave cracks on or near the embankment crest associated with slope movement.	1. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos if cameral is available. Document location on a site plan and in inspection report.
		2. Restrict traffic on dam crest to essential emergency operations only.
		3. Contact geotechnical engineer and provide all data collected.
		4. Place buttress fill (min 3 ft. high, 15 ft. wide) against base of slope immediately below surface feature and extending 20 ft. beyond visible feature limits (parallel to the embankment). Stock pile additional fill.
		5. Place sand bags as necessary around crack area to divert any storm water runoff from flowing into crack(s).
		6. Inspect the dam; collect piezometer and water level data twice daily unless otherwise instructed by engineer; and record any changes of condition. Carefully observe dam for signs of depressions, seepage, sinkholes, cracking or movement.
		7. Review information collected by field inspectors and provide additional instructions / actions as required. Consider survey monitoring.
		8. Make notifications if conditions worsen such that failure is imminent.
	Slides / Erosion: Deep slide / erosion (greater than 2 feet deep) on the embankment that may also extend beyond the embankment toe but does not encroach onto the embankment crest and appears stable with time.	1. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos if camera is available. Document location on a site plan and in inspection report.
		2. Restrict traffic on dam crest to essential emergency operations only.
		3. Contact geotechnical engineer and provide all data collected.
		4. Re-establish embankment fill slope. Place 5 ft. high buttress fill against base of slope at the slide location that extends at least 15 ft. beyond the furthest downstream limits (perpendicular to the embankment) and extending 20 ft. beyond visible feature limits at either end (parallel to the embankment).

Condition	Description of Condition	Action to be Taken
Embankment Deformation (cont.)	Slide / Erosion (cont.)	5. Place sand bags as necessary around slide area to divert any storm water runoff from flowing into slide(s).
		6. Inspect the dam; collect piezometer and water level data daily unless otherwise instructed by engineer; and record any changes of condition. Carefully observe dam for signs of depressions, seepage, sinkholes, cracking or movement.
		7. Review information collected by field inspectors and provide additional instructions / actions as required. Consider survey monitoring.
		8. Make notifications if conditions worsen such that failure is imminent.
	Sinkholes: Small depression observed on the embankment or within 50 feet of the embankment toe that is less than 5 feet deep and 30 feet wide or which is increasing with time.	1. Slowly open drain valve(s) to lower reservoir elevation.
		2. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos if camera is available. Document location on a site plan and in inspection report.
		3. Restrict traffic on dam crest to essential emergency operations only.
		4. Contact geotechnical engineer and provide all data collected.
		5. Backfill the depression with relatively clean earth fill (free of organic materials) generally even with surrounding grade and slightly mounded (6 to 12 inches higher) in the center in order to shed storm water away from the depression. Stock pile additional fill.
		6. Inspect the dam; collect piezometer and water level data daily unless otherwise instructed by engineer; and record any changes of condition. Carefully observe dam for signs of depressions, seepage, sinkholes, cracking or movement.
		7. Review information collected by field inspectors and provide additional instructions / actions as required. Consider remedial construction such as grouting.
		8. Make notifications if conditions worsen such that failure is imminent.
Gate (Valve) Malfunction or Failure	Dam gates / valves damaged structurally (sabotage, debris, etc.) with uncontrolled release of water at a constant volume. Condition appears stable.	1. Close any other gates, if open.
		2. Install XXX or use other methods to stop or slow down the flow of water.
		3. Consult a structural / mechanical engineer for evaluation and recommendations. Consult dam remediation contractor for evaluation and recommendations.

(DCR-VSWCB-034) (03/14)

Condition	Description of Condition	Action to be Taken
Gate (Valve) Malfunction or Failure (cont.)	Dam gates / valves (cont.)	4. Repair / replace gate / valve as necessary.
		5. Make notifications if conditions worsen such that further structural failure is imminent.
Sabotage and Miscellaneous Other Issues	Criminal action with significant damage to embankment or structures where significant repairs are required and the **integrity** of the facility is **compromised – condition appears stable with time**.	1. Contact law enforcement authorities and restrict all access (except emergency responders) to dam. Restrict traffic on dam crest to essential emergency operations only.
		2. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications.
		3. If necessary to lower reservoir level, open drain valve(s).
		4. Perform additional tasks as directed by the Dam Engineer or designee.
		5. Make notifications if conditions worsen.

Appendix H
Exercising the Emergency Action Plan

Dam owners should exercise the Emergency Action Plan (EAP) in coordination with State, local and tribal emergency management authorities. Exercises promote prevention, preparedness, and response to incidents and emergencies and may also be extended to include recovery operations. Exercising also demonstrates the EAP's effectiveness in an actual situation and demonstrates the readiness levels of key personnel. Periodic exercises result in an improved EAP as lessons learned are incorporated into the updated EAP document.

Dam owners should include State, local and tribal emergency authorities in exercise activities. This includes, but is not limited to, entities listed on the Notification Flowchart. To facilitate the participation of emergency management authorities, dam safety exercises also can be coordinated with, or integrated into, other event exercise scenarios for earthquakes, floods, hurricanes, and other hazards.

Types of Exercises

There are seven types of exercises defined in the Homeland Security Exercise and Evaluation Program (HSEEP). Although it is not required that every exercise program include all seven exercises, the program should be built from the ground up, beginning with simple exercises and advancing to more complex exercises. Sufficient time should be provided between each exercise to learn and improve from the experiences of the previous exercise. More information on the HSEEP is available at hseep.dhs.gov.

Discussion-based Exercises

Discussion-based exercises familiarize participants with current plans, policies, agreements, and procedures, or may be used to develop new plans, policies, agreements, and procedures. The following are types of discussion-based exercises:

- ***Seminar.*** A seminar is an informal discussion designed to orient participants to new or updated plans, policies, or procedures (e.g., a seminar to review a new Evacuation Standard Operating Procedure). Seminars should include internal discussions as well as coordination with emergency management authorities and other organizations with a role in EAP implementation.
- ***Workshop.*** A workshop resembles a seminar but is used to build specific products such as a draft plan or policy. For example, a Training and Exercise Plan Workshop is used to develop a Multi-Year Training and Exercise Plan.
- ***Tabletop Exercise.*** A tabletop exercise involves key personnel discussing simulated scenarios in an informal setting. Tabletop exercises can be used to assess plans, policies, and procedures.
- ***Games.*** A game is a simulation of operations that often involves two or more teams, usually in a competitive environment, using rules, data, and procedures designed to depict an actual or assumed real-life situation.

Operations-based Exercises

Operations-based exercises validate plans, policies, agreements and procedures; clarify roles and responsibilities; and identify resource gaps in an operational environment. Types of operations-based exercises are:

- ***Drill.*** A drill is a coordinated, supervised activity usually employed to test a single operation or function within a single entity, such as testing sirens and warning systems, calling suppliers, checking material on hand, and conducting a call-down drill of those listed on the Notification Flowchart.
- ***Functional Exercise.*** A functional exercise examines and/or validates the coordination, command, and control between various multi-agency coordination centers, such as Emergency Operation Centers (EOCs) and Joint Field Offices. A functional exercise does not involve any "boots on the ground" such as first responders or emergency officials responding to an incident in real time.
- ***Full-Scale Exercises.*** A full-scale exercise is a multi-agency, multi-jurisdictional, multi-discipline exercise involving functional (e.g., Joint Field Office, EOC, "boots on the ground" response to a simulated event, such as activation of the EOC and role-playing to simulate an actual dam failure).

Functional and full-scale exercises are considered comprehensive exercises that provide the necessary verification, training, and practice to improve the EAP and the operational readiness and coordination efforts of all parties responsible for responding to emergencies at a dam. The basic difference between these two exercise types is that a full-scale exercise involves actual field movement and mobilization; in a functional exercise, field activity is simulated.

The primary objectives of a comprehensive exercise (functional and full-scale) are listed below:

- Reveal the strengths and weaknesses of the EAP, including specified internal actions, external notification procedures, and adequacy of other information, such as inundation maps.
- Reveal deficiencies in resources and information available to the dam owner and emergency management authorities.
- Improve coordination efforts between the dam owner and emergency management authorities. Close coordination and cooperation among all responsible parties is vital for a successful response to an actual emergency.
- Clarify the roles and responsibilities of the dam owner and emergency management authorities.
- Improve individual performance of the people who respond to the dam failure or other emergency conditions.
- Gain public recognition of the EAP.

Frequency of Exercises

The seminar, drill, tabletop exercise, and functional exercise should receive the most emphasis in an EAP exercise program. The following are recommended frequencies for these exercise types. Dam owners, in consultation with emergency management authorities, should determine actual frequencies appropriate for their dam.

- Seminars with primary emergency management authorities – annually
- Drills to test the Notification Flowchart and emergency equipment/procedures – annually
- Tabletop exercise – every 3 to 4 years or before functional exercises
- Functional exercise – every 5 years

A full-scale exercise should be considered when there is a need to evaluate actual field movement and deployment. When a full-scale exercise is conducted, safety is a major concern because of the extensive field activity. If a dam owner has the capability to conduct a full-scale exercise, a commitment should be made to schedule and conduct the entire series of exercises listed above before conducting the full-scale exercise. At least one functional exercise should be conducted before conducting a full-scale exercise. Functional and full-scale exercises also should be coordinated with other scheduled exercises, whenever possible, to share emergency management resources and reduce costs.

Evaluation of Exercises

Emergency exercises and equipment tests should be evaluated orally and in writing. Immediately after an exercise or actual emergency, an after-action review should be conducted with all involved parties to identify strengths and deficiencies in the EAP. The after-action review should focus on procedures and other information in the EAP, such as outdated telephone numbers on the Notification Flowchart, inundation maps with inaccurate information, and problems with procedures, priorities, assigned responsibilities, materials, equipment, and staff levels. The after-action review also should address the procedures that worked well and the procedures that did not work so well. Responses from all participants involved in the exercise should be considered. The after-action review should discuss and evaluate the events before, during, and after the exercise or actual emergency; actions taken by each participant; the time required to become aware of an emergency and to implement the EAP; and improvements for future emergencies.

After the after-action review has been completed, the EAP should be revised, as appropriate, and the revisions disseminated to all involved parties.

Appendix I
Example Forms and Logs

Table I-1: Example Dam Emergency Incident Log

NAME:	JOB TITLE:
INCIDENT START DATE:	INCIDENT START TIME:
INCIDENT DESCRIPTION:	
INITIAL INCIDENT LEVEL:	
INCIDENT DETECTION:	
When did you detect or learn about the incident?	
How did you detect or learn about the incident?	

LOG ALL NOTIFICATIONS AND ACTIVITY IN THE TABLE BELOW

DATE	TIME	ACTION/INCIDENT PROGRESSION	ACTION TAKEN BY

Table I-2: Example Record of Plan Holders

Copy Number	Organization	Person Receiving Copy
1	Regional Dam Safety Engineer,	
2	Div. of Dam Safety Director	
3	County 24-hr. Emergency Communications Center	
4	County Coordinator of Emergency Operations	
5	Utility General Managers Office, incident command post	
6	State emergency management agency	
7	Technical Consultants / engineer	
8	DOT, Resident Engineer	

Table I-3: Example Record of Reviews and Revisions

Revision #	Date	Sections Reviewed or Revisions Made	By Whom

Table I-4: Example Dam Emergency Termination Log

DAM NAME:	COUNTY:
DAM LOCATION:	STREAM / RIVER:
DATE / TIME:	
WEATHER CONDITIONS:	
GENERAL DESCRIPTION OF EMERGENCY SITUATION:	
AREA(S) OF DAM AFFECTED:	
EXTENT OF DAMAGE TO DAM & POSSIBLE CAUSES:	
EFFECT ON DAM OPERATION:	
INITIAL RESERVOIR ELEVATION / TIME: MAXIMUM RESERVOIR ELEVATION / TIME: FINAL RESERVOIR ELEVATION / TIME:	
DESCRIPTION OF AREA FLOODED DOWNSTREAM / DAMAGE / LOSS OF LIFE:	
JUSTIFICATION FOR TERMINATION OF DAM SAFETY EMERGENCY:	
OTHER DATA AND COMMENTS:	
REPORT PREPARED BY (PRINTED NAME & SIGNATURE): DATE:	

Additional Resources TAB

VIRGINIA DAM OWNER'S HANDBOOK, 2ND EDITION

TABLE OF CONTENTS

ADDITIONAL RESOURCES

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ACER TECHNICAL MEMORANDUM NO. 11
ASSISTANT COMMISSIONER - ENGINEERING AND RESEARCH
DENVER, COLORADO

DOWNSTREAM HAZARD CLASSIFICATION GUIDELINES

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
1988

ACER TECHNICAL MEMORANDUM NO. 11

Assistant Commissioner - Engineering and Research

Denver, Colorado

DOWNSTREAM HAZARD CLASSIFCIATION GUIDELINES

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

December 1988

PREFACE

The purpose of this document is:

1. To define the Safety Evaluation of Existing Dams (SEED) method for assigning a dam's hazard classification;

2. To provide guidance and present methods, for the purpose of downstream hazard classification, for estimating the downstream area susceptible to flooding due to a dam failure;

3. To provide guidance and criteria for identification of downstream hazards; and

4. To bring objectivity and consistency into downstream hazard classification.

Although these guidelines are intended to be used for all dams, they are especially useful for small dams, and/or dams whose failure flood would affect only a small population. For larger dams, downstream hazard classification is usually obvious.

This ACER Technical Memorandum was written by Douglas J. Trieste of the Dam Safety Inspection Section at the Denver Office. Deep appreciation goes out to all of those who have offered valuable review, information, and suggestions which greatly helped in preparing this document.

This document replaces in entirety the previous hazard classification guidelines, "Dam Safety Hazard Classification Guidelines," United States Department of the Interior, Bureau of Reclamation, Division of Dam Safety, October 1983. Questions or comments regarding the materials presented herein should be directed to the Chief, Dam Safety Office (D-3300) at the Denver Office.

Darrell W. Webber
Assistant Commissioner
Engineering and Research

CONTENTS

APPENDIXES

FIGURES

TABLE

DOWNSTREAM HAZARD CLASSIFICATION GUIDELINES

I. INTRODUCTION

A. Definition of Downstream Hazard

A downstream hazard is defined as the potential loss of life or property damage downstream from a dam and/or associated facility (e.g., dike) due to floodwaters released at the structure or waters released by partial or complete failure of the structure [1].[1]

Downstream hazard classification is not associated with the existing condition of a dam and its appurtenant structures or the anticipated performance or operation of a dam. Rather, hazard classification is a statement of potential adverse impact on human life and downstream developments if a designated dam failed.

The cost of the dam, related facilities (e.g., pump stations, canals, pipelines, etc.), and project losses are not considered in downstream hazard classification. Also, the consequences of a rapid reservoir drawdown; due to a dam failure, on persons upstream from the dam are not considered in downstream hazard classification. Only the direct effects of a dam-break flood on persons, property, or outstanding natural resources at officially designated parks, recreation areas, or preserves downstream from the dam are considered.

B. Purpose of Downstream Hazard Classification

Dams are given a hazard classification for two reasons:

1. The Department of the Interior (DOI) Departmental Manual, Part 753 [2], establishes that a hazard classification is to be assigned to every DOI dam.

2. Hazard classification serves as a management tool for determining which dams are to undergo the full SEED (Safety Evaluation of Existing Dams) process. Dams having a low downstream hazard classification are excluded, whereas those having a significant or high downstream hazard classification are included.

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[1]Numbers in brackets identify references listed in section VI.

For large dams, hazard classification guidelines may seem superfluous; almost all large dams are obvious high-hazard facilities. Although it is with the smaller structures that these guidelines become most useful, all dams are given the same depth of analysis if needed. The hazard classification of small dams is often uncertain and requires detailed technical analysis, good engineering judgment, and a good "feel" for the impacts of dam failure floods (app. A).

For any dam, a situation can always be imagined that would result in loss of life regardless how remote the location of a dam and/or how little the chance of persons being affected by its failure flood. Thus, guidelines can be very useful in these situations to avoid being unduly conservative and to provide consistency to hazard classification as much as possible.

C. Purpose of the Downstream Hazard Classification Guidelines

The purpose of this document is:

1. To define the SEED method for assigning a dam's hazard classification (secs. I and II);

2. To provide guidance and present methods, for the purpose of downstream hazard classification, for estimating the downstream area susceptible to flooding due to a dam failure (sec. III and app. A);

3. To provide guidance and criteria for identification of downstream hazards (sec. IV); and,

4. To bring objectivity and consistency into downstream hazard classification.

Section III on estimating inundated area is included to present state-of-the-art methodology and a systematic approach that can be used by analysts not familiar with dam-break/inundation study techniques. A discussion of other accepted methods is included in appendix A.

Identifying downstream hazards is often controversial and/or nebulous. Due to this, section IV on identification of hazards is presented in order to bring objectivity and consistency, as much as can be reasonably expected, into the identification of downstream hazards. New concepts that equate flood depth and velocity relationships to hazard identification have been developed and are presented in section IV.

It is very important to note that these guidelines are intended for hazard classification purposes, but not for preparation of inundation maps for Emergency Preparedness Plans (EEPs) or hazard assessments.

Dam-break/inundation studies are not an exact science, and guidelines and criteria for performing these studies will vary depending upon the intent. Although studies for hazard classification and EPPs have some similarities, there are still major differences; these differences are explained in subsection III.A.

Dam-break/inundation studies performed for hazard assessments (as opposed to hazard classification) pose still another set of criteria. Such studies focus upon risk analysis which uses expected values. Thus, guidelines and criteria for these studies are based upon the highest probability of what is expected to occur [3].

II. DOWNSTREAM HAZARD CLASSIFICATION SCHEME

The system presented in table 1 is used by the SEED Program for classifying Bureau of Reclamation (Reclamation) and other DOI dams.

Table 1. - Downstream hazard classification system

Classification	Lives-in-jeopardy	Economic loss
Low	0	Minimal (undeveloped agriculture, occasional uninhabited structures, or minimal outstanding natural resources)
Significant	1-6	Appreciable (rural area with notable agriculture, industry, or worksites, or outstanding natural resources)
High	More than 6	Excessive (urban area including extensive community, industry, agriculture, or outstanding natural resources)

A. <u>Lives-in-Jeopardy</u>

Lives-in-jeopardy is defined as all individuals within the inundation boundaries who, if they took no action to evacuate, would be subject to danger commensurate with the criteria in section IV.

Lives-in-jeopardy is limited to <u>direct downstream</u> impacts resulting from the dam failure flood. Thus, lives-in-jeopardy does not consider situations such as persons in the reservoir or vehicle accidents due to a washed out highway crossing (after the flood wave has passed).

Lives-in-jeopardy is divided into permanent and temporary use. Permanent use includes:

- Permanently inhabited dwellings (structures that are currently used for housing people and are permanently connected to utilities, including mobile homes; three residents per dwelling are assumed based on 1980 National Census)

- Worksite areas that contain workers on a daily (workweek) basis. Commonly affected worksites include:

  - Public utilities and vital public facilities (powerplants, water and sewage treatment plants, etc.)

  - Private industrial plants or operations including materials production (sand, gravel, etc.)

  - Farm operations

  - Fish hatcheries

Temporary use includes:

- Primary roads along the channel, on the crest of the dam, or crossing the channel

- Established campgrounds and backpacker campsites

- Other recreational areas

The values in table 1 ("1-6" and "more than 6" for significant and high, respectively) are purely arbitrary. Previous downstream hazard classification criteria used lives-in-jeopardy of "few" and "more than few" for the significant- and high-hazard categories, respectively. The values in the table are presented for the intent of quantifying "few" and "more than few." It seemed reasonable to consider all occupants of two average households as "few." According to the 1980 census, the average U.S. household has three occupants; thus, "few" was quantified as six persons, and "more than few" was considered "more than 6." The lives-in-jeopardy for low-hazard classification, which had been "none expected," was quantified as "zero."

It is important to note that hazard classification deals only with lives in jeopardy, as opposed to "estimated loss of life". Estimated loss of life is the likely number of fatalities that would result from a dam failure flood event and is a forecast based on warning time that the population at risk would receive of dangerous flooding, and also on the use of historical relationships between warning time and loss of life. Details of the "estimated loss of life" are included in ACER Technical Memorandum No. 7 [3].

Determining the estimated loss of life involves many uncertainties and good judgment by the analyst. Analyses may indicate catastrophic flooding of a permanently occupied area, thus, indicating obvious loss of life to any occupants, or indicate as little as only shallow flooding (e.g., 1 to 2 feet (0.3-0.6 m)) with low velocities in areas of temporary use. In the latter case, it is difficult to determine the extent of loss of life, if any, that will occur to occupants affected by the flood. People may be safe if they remain in buildings, automobiles, move to high ground, etc. Flooding may be little more than just wetting of an area such that a person is safe to wade, but it is conceivable that a small child could fall into a ditch or depression or be drowned by locally fast moving water. Persons commuting to work may be unaware of a current dam failure, residents may not receive warning or may ignore warnings, residents may not be able to safely evacuate, etc.

Other factors to consider regarding estimating loss of life are proximity of the hazard and time of day. A community may be susceptible to catastrophic flooding but be located far enough downstream to allow ample warning and evacuation of its occupants. A dam could fail during the most inopportune time of day (11:00 p.m. to 6:00 a.m.), thus, allowing for little or no warning to downstream residents.

Due to these many uncertainties and unknowns with regard to estimated loss of life, a conservative approach of using lives-in-jeopardy (versus estimated loss of life) in the hazard classification system (table 1) is adopted by the SEED Program.

B. Economic Loss

Economic loss is that loss resulting from damage to residences, commercial buildings, industries, croplands, pasturelands, utilities, roads and highways, railroads, etc. Consideration should also be given to economic loss resulting from damage to outstanding natural resources within officially declared parks, preserves, wilderness areas, etc. Also, if a toxic or harmful substance is known to be present in significant quantities in the impoundment, the effect of its dispersion on downstream areas (with respect to economic loss only) should be considered in the downstream hazard classification. Because the dollar value of real property changes over time and varies according to the uses of the property, no attempt is made to assign dollar values as guidelines.

Economic loss does not include the loss of the dam and associated project facilities.

Hazard classification due to economic loss is based on the judgment of the analyst. However, judging economic value is, in most cases, not a problem because it is rarely addressed. The reason for this is that if economic loss is involved, then usually lives-in-jeopardy is a factor and the downstream hazard classification will be based solely on that. Thus, if a dam is classified as low or significant hazard based on lives-in-jeopardy, only then is economic loss evaluated to determine if a higher hazard classification is justified.

C. Multiple Dams

If failure of an upstream dam could contribute to failure of a downstream dam(s), the minimum hazard classification of the upstream dam should be the same as the highest classification of the downstream dam(s).

III. ESTIMATING INUNDATED AREA

A. Introduction

Determining hazard classification based on the downstream hazard classification scheme presented in table 1 is straightforward providing the lives-in-jeopardy and/or economic loss that would result from a dam failure is known. Lives-in-jeopardy and/or economic loss can be determined if the potential inundation downstream from a dam is known.

This section presents methods used to estimate the downstream inundation should a dam fail. These methods include:

- Use of an existing inundation study,
- Engineering judgment, or
- Performing a dam-break/inundation analysis.

The methods presented here are recommended for hazard classification purposes only, as opposed to preparation of inundation maps for publication (e.g., EPPs). Several reasons for this are:

1. Flood routing for a downstream hazard classification study is terminated at the downstream channel location such that the hazard classification can accurately be defined, or the downstream terminal point is reached. Thus, the study may involve only a small channel reach downstream from a dam if a high hazard classification is justified. Studies used for preparation of inundation maps almost always consider the full channel reach to the downstream terminal point.

2. The analytical procedure for hazard classification can vary from simply engineering judgment to the most detailed, state-of-the-art analytical methods. Studies performed for published inundation maps follow more strict procedures.

3. Hazard classification has no relevance to flood wave travel times, whereas EPPs do. Analyses for hazard classification purposes are not concerned with accurate traveltimes. Rather, the focus is on maximum depths and velocities at specific channel cross sections.

B. Existing Inundation Study

Many dams have comprehensive dam-break/inundation studies prepared for the downstream area. If these studies exist, they should be used as the basis for hazard classification. Frequently, these inundation studies have been performed by hydrologists/hydraulic engineers using state-of-the-art analytical techniques, and consequently can be used with confidence for determining hazard classification.

A dam-break/inundation study normally contains a map depicting the predicted extent of flooding downstream from a dam. If a map does not exist, sufficient data and information will likely be included so that an accurate assessment of flooding can be made.

Dam-break/inundation studies may be obtained from (but not limited to) Bureau Regional Offices, the U.S. Army Corps of Engineers, Federal Emergency Management Agency (FEMA), State and local governments, and private engineering and consulting firms.

C. Engineering Judgment

In some situations, the downstream hazard classification may be obvious; thus, the downstream hazard classification is based solely on engineering judgment using information from a field survey and/or current topographic maps. For example,

1. A community located in the flood plain immediately downstream from a dam, or

2. A flood plain completely unoccupied and undeveloped downstream to a point where the failure flood would obviously attenuate and be contained within the main channel banks, or reach a large body of water (e.g., large reservoir or ocean) without threat to human life, or economic loss.

In the first case, the dam would be an obvious high-hazard facility, and in the second case, the dam would be an obvious low-hazard facility. No computational analysis is necessary in either case.

D. Performing a Dam Break/Inundation Study for Downstream Hazard Classification

If a comprehensive dam-break/inundation study does not exist, or the hazard classification is not obvious, then an analysis should be performed to define the inundated area. Many methods with differing levels of sophistication are available for performing such an analysis. A specific method is presented in subsection III.D.3. Also, the subject is discussed in general terms with reference to state-of-the-art methods in appendix A. A bibliography (app. B) referencing other useful literature is included if additional information is desired.

There are three main phases to a dam-break/inundation study:

- Assume a dam failure scenerio,
- Determine downstream terminal point of flood routing, and
- Perform the recommended analytical procedure.

1. Assuming a Dam Failure Scenario. - The results of a dam-break/inundation study would be the most accurate if we knew the failure scenario a priori. However, for dam-break/inundation studies, this is uncertain and can only be assumed.

The failure scenario possibilities are nearly infinite. A dam failure may be earthquake induced, result from piping on a clear day, from a sudden structural breakdown on a clear day, from structural damage due to a large flood, from erosion due to overtopping, etc. Discharges and downstream flooding due to different dam failure scenarios could result in different downstream hazard classifications being assigned to the same dam.

Because the dam failure scenario is not known a priori, and for dam safety conservativeness, a procedure for selecting a dam failure scenario which seeks the highest hazard classification that is reasonable is suggested. This approach could be lengthy and labor intensive. Fortunately, it is rarely used. Usually, if the dam has the potential for a high-hazard classification, an assumed "sunny-day"[2] failure scenario results in sufficient downstream flooding to classify the dam as high hazard, as is the case for most large Bureau dams. But, for smaller dams where the hazard classification may be borderline between categories (table 1), the following procedure should be applied (fig. 1).

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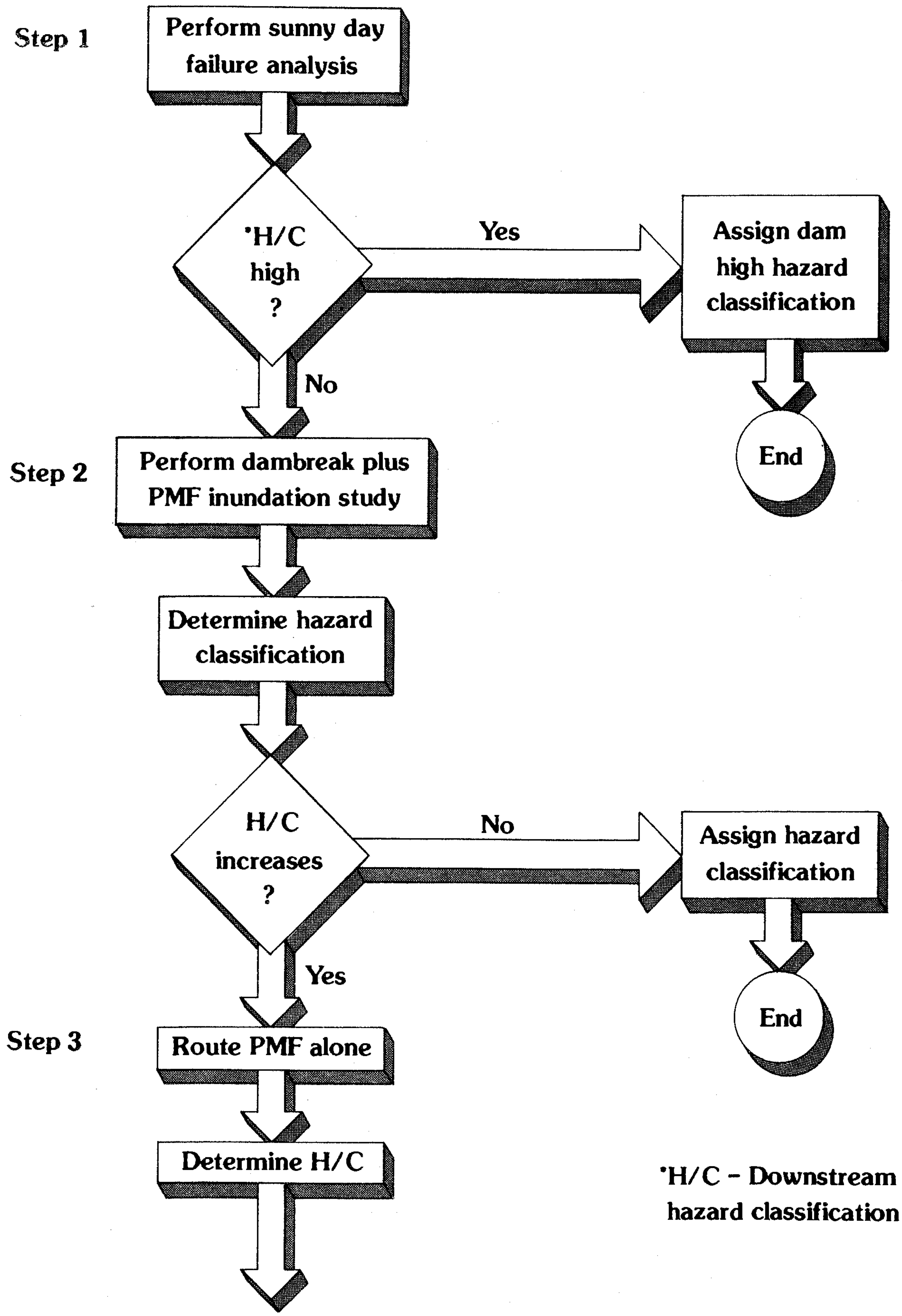
[2]A sunny day failure is a failure other than from a large flood. The reservoir is assumed at NWS and inflows are average. The mode of failure may be earthquake induced, structural weakness, piping, etc.

Figure 1 – Downstream hazard classification procedure flow chart



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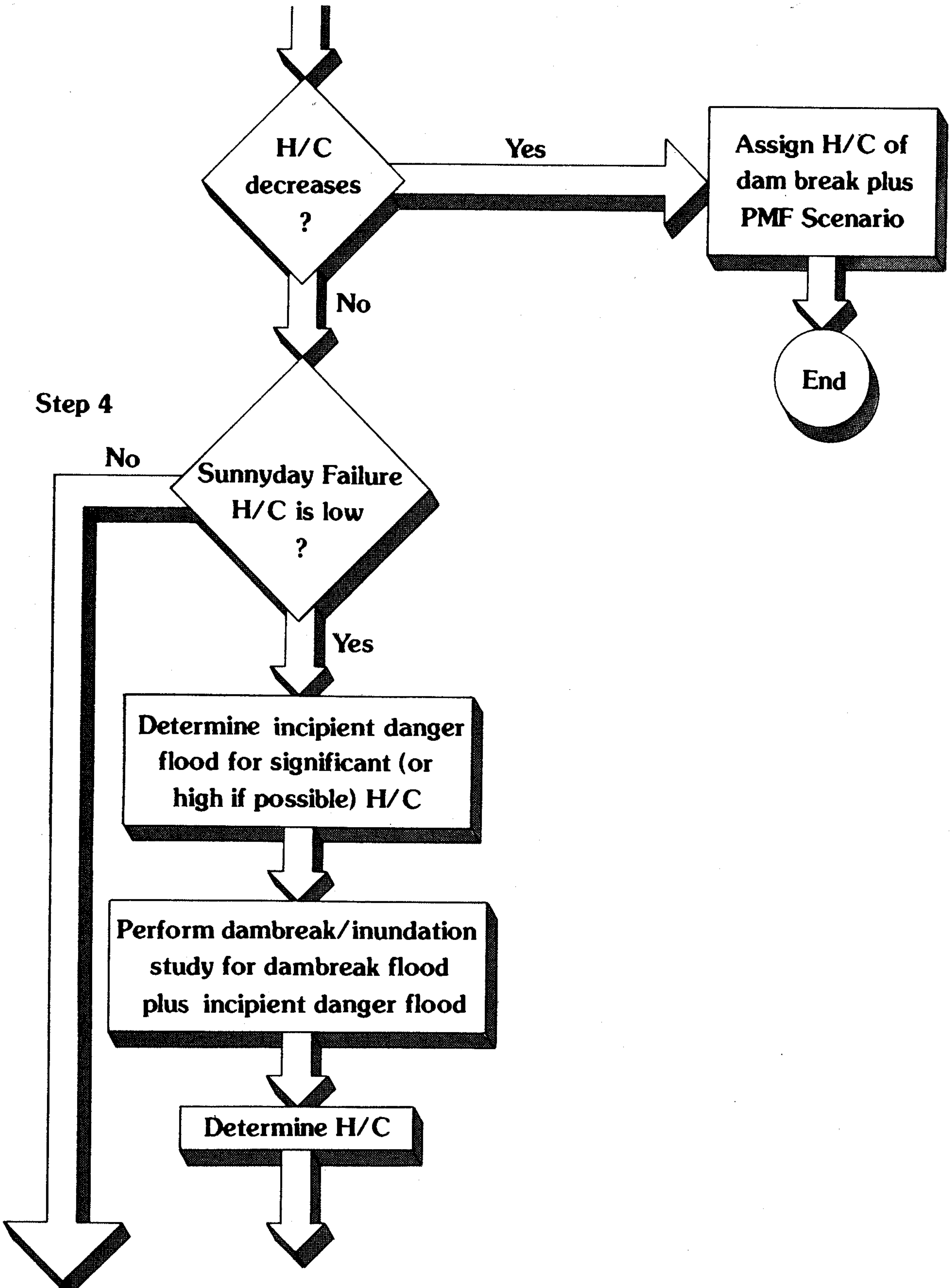

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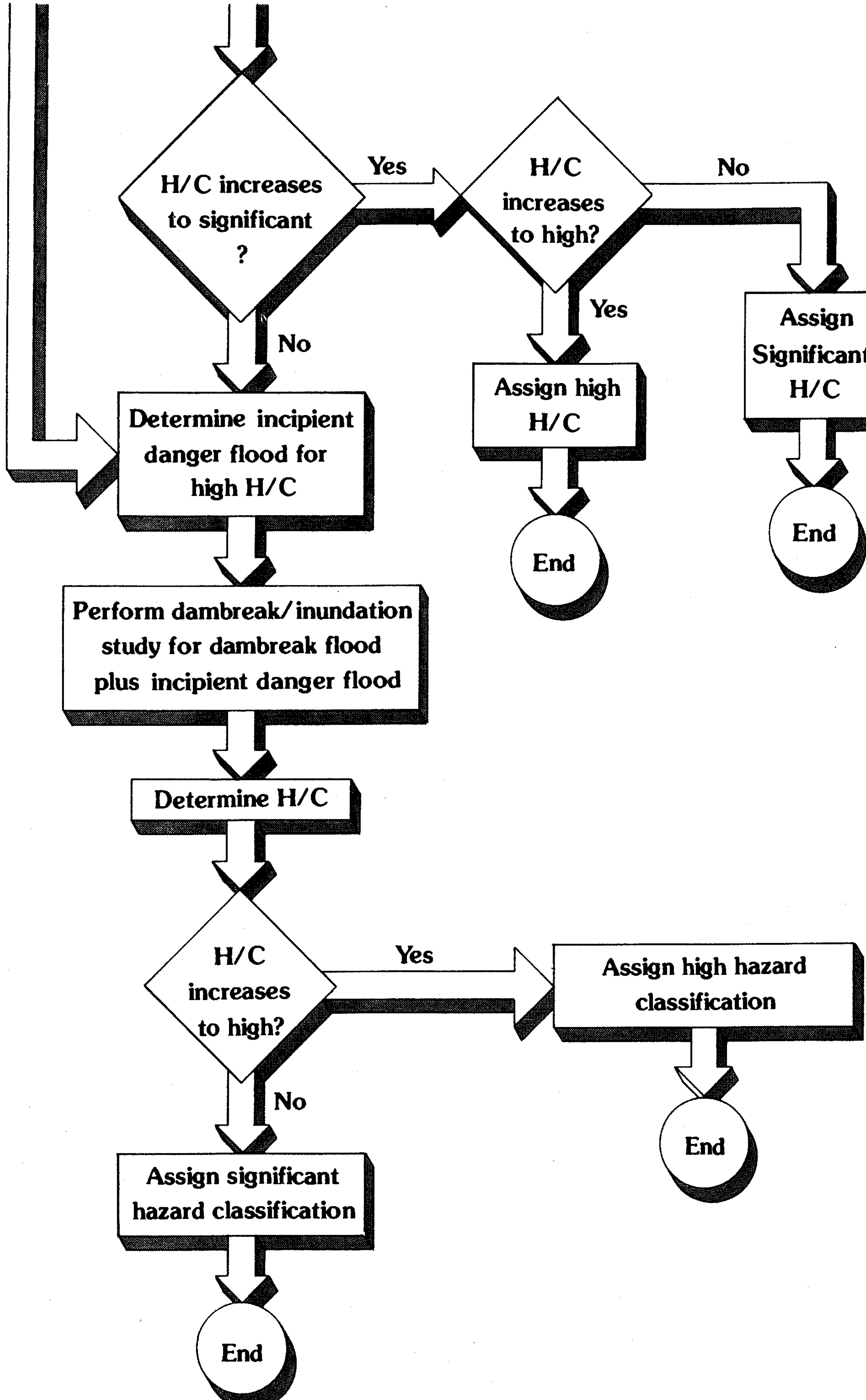
H/C increases to significant ?
Yes
No
H/C increases to high?
No
Yes
Assign Significant H/C
Assign high H/C
End
End
Determine incipient danger flood for high H/C
Perform dambreak/inundation study for dambreak flood plus incipient danger flood
Determine H/C
H/C increases to high?
Yes
No
Assign high hazard classification
End
Assign significant hazard classification
End

Step 1. Assume a "sunny day" failure and perform a dam-break/inundation study (subsec. III.D.3). If a high-hazard classification is valid for this assumption, then this dam failure scenario is sufficient. Increasing the loading conditions (that is, inflow flood) for the dam-break/inundation study would not change the hazard classification.

Step 2. If the hazard classification obtained from the first step is less than high, then it is necessary to increase the loading conditions; that is, determine if a dam-break discharge combined with a large inflow flood would result in an increase in the hazard classification.

The easiest method in making this determination is to create a scenario that combines the dam-break discharge with the probable maximum flood (PMF). The PMF is used, rather than the inflow design flood (IDF) because the IDF may be a less severe flood than the PMF. The intent is to evaluate a worst case scenario which has to account for the PMF. If the hazard classification does not increase under these assumptions, then the hazard classification obtained from the "sunny day" failure scenario does not change with an increase in loading conditions and can be assigned with confidence. But, if the hazard classification is raised, then some specific size inflow flood can occur, such that when combined with the dam-break discharge, it will raise the hazard classification. This inflow flood, referred to as the "threshold inflow flood," is some fraction of the PMF.

Thus, when the dam-break plus PMF flood results in a hazard classification higher than that for a "sunny day" failure assumption, it becomes necessary to determine the incremental effects of a dam-break flood combined with an inflow flood on the downstream flooding. The reason for this is to separate the flooding due to a dam failure from that due to a natural flood. That is, if a natural runoff flood can occur such that a situation is a borderline hazard, then would the additional (incremental) flooding resulting from a dam failure cause the "borderline hazard" to become a hazard?

A dam can actually have a higher hazard classification under a "sunny day" failure assumption than under PMF failure assumptions. For example, a dam is rated as significant hazard due to potential inundation of one dwelling downstream. But, if the hazard classification is evaluated under PMF assumptions (that is, the dam fails during the PMF event and the dam-break discharge is combined with the PMF discharge), the dam is rated low hazard because the incremental impact of flooding is negligible (that is, the dwelling is inundated by the PMF whether or not the dam fails).

Increasing the loading conditions does not always raise the hazard classification. For example, consider a small dam and reservoir located in a channel that drains a basin capable of producing very large floods. The dam is rated low hazard under "sunny day" failure conditions. However, downstream flooding from a runoff flood (not including a dam failure discharge) would result in large loss of life and severe economic loss. The effects of the dam failure combined with such a flood would be negligible and probably imperceptible. Thus, the dam would still be rated low hazard.

Because situations similar to those illustrated in the preceding examples actually exist, an incremental loading condition approach is important.

Step 3. Route the PMF alone (without considering the dam in place) and determine the "hazard classification" in the same manner as if done for a dam. If a hazard classification less than that obtained from the dam failure discharge plus PMF scenario is obtained, then the hazard classification obtained from the dam break plus PMF scenario is assigned to the dam. The reasoning here is that the incremental effects of a dam failure raise the hazard classification above that for a PMF alone; hence, the effects of a dam-break flood on downstream inundation should not be ignored.

Step 4. If, when routing the PMF alone, the hazard classification raises above that obtained from a "sunny day" failure, then the incremental effects of a dam-break flood on the hazard classification are evaluated. To make this evaluation, the "incipient danger flood" is sized. This is accomplished by determining the flood discharge that results in the hazard in question ("possible hazard", see subsec. IV.A.) to experience incipient flooding. For example, the discharge that results in a house having floodwater reaching its foundation; or the discharge that results in a roadway just getting wet. Next, the incipient danger flood is combined with a dam-break flood, and the downstream hazard classification reevaluated. This can be done by modeling the incipient danger flood as "initial conditions" prior to the dam-break; or by determining an inflow flood hydrograph such that when routed to the downstream hazard site, its peak will equal the incipient danger flood peak.

The incremental downstream hazard classification is determined by applying figures 2 through 6, per the criteria in section IV. If the incremental differences in depths and velocities are within the low-danger zone, then the incremental lives-in-jeopardy is zero. If the incremental differences in depths and velocities are above the low-danger zone, then a dangerous situation is possible. More information on the use of figures 2 through 6 is explained in section IV.

If the hazard classification raises, then it is the result of increased flooding from the dam failure combined with a specific-size natural flood. Thus, the flood from a dam failure is capable of inundation significantly greater than that by the runoff flood alone.

The full results of an incremental hazard classification should be discussed when presenting the results.

2. Determining Downstream Terminal Point of Flood Routing. - A dam-break flood routing needs only to be performed for a distance downstream from the dam until the hazard classification can be ascertained, or until "adequate floodwater disposal" is reached. For example, if a community located 1 mile (1.6 km) downstream from a dam would be inundated by a dam failure flood and hence the dam would be assigned a high-hazard classification, then additional downstream analysis is not necessary, because additional analysis would not change the hazard classification from "high."

Adequate flood water disposal is defined as: that point below which potential for loss of life and significant property damage caused by routed floodflows appear limited [4]. This includes such situations as:

- No human occupancy
- No anticipated future development
- Floodflows being contained in a large downstream reservoir

- Floodflows entering a bay, ocean, or large channel
- Floodflows being contained within the channel banks

3. Recommended Analytical Procedure. -

a. General. - The procedure presented in this subsection is a compromise between simplistic and complex analytical methods for performing dam-break/inundation studies. This procedure will result in consistency among analysts, does not require an extensive hydraulics background, and will produce reasonably accurate results.

The procedure is simply application of the National Weather Service Simplified Dam-Break Model (SMPDBK) [5], with guidelines and criteria given for determination of all model input parameters. Tests of SMPDBK versus the National Weather Service DAMBRK model [6], a very sophisticated state-of-the-art dam-break flood forecasting model, have indicated accuracy of SMPDBK in computing peak flood depths and velocities to be less than 20 percent of those computed from using DAMBRK, as long as model assumptions are not violated. This particularly applies to backwater conditions where SMPDBK results are usually in large error.

Model input parameters can vary considerably for a single dam and still be "correct." Due to this, SMPDBK results can also vary considerably while being "correct." These "correct" output values can range from liberal to conservative; that is, depths and velocities ranging from minimum to maximum, respectively.

It is very important to note that the recommended parameter values presented in this section are not intended to predict peak breach discharge. Rather, they are intended to bring consistency among analysts while resulting in reasonable upper-limit peak breach discharges and downstream depths and velocities. Such reasonable maximum values add a margin of safety to flood inundation predictions, and are consistent with the downstream hazard classification philosophy of considering worse-case dam-break scenarios and downstream flooding.

The breach parameters TFM (time for breach to develop) and BW (width of rectangular breach) need special attention. Many different methods are available for "predicting" these values as well as peak breach discharge (app. A). When different methods are applied to a specific dam, a very wide range of values typically results. Also, different TFMs and BWs can result from different analysts using the same method. Thus, the study results, and consequently the downstream hazard classification, can be dependent on the method used for predicting breach parameters and/or peak breach discharge. Because of this, the recommended prediction equations presented in the following section for determining TFM and BW are a combination of policy and the consideration of historical failure data, intended to satisfy one of the overall purposes of these guidelines, that of bringing consistency and objectivity into downstream hazard classification. Also, the parameter equations are very helpful for the inexperienced analyst and/or those without the proper technical background. These equations will yield values that are within the range determined by application of all other methods.

In the majority of downstream hazard classification studies, SMPDBK will yield adequate results. However, sometimes situations may have to be analyzed that violate the assumptions of SMPDBK, and/or may require sophisticated modeling that is beyond the scope of SMPDBK. In such cases, DAMBRK should be used (app. A). To the contrary, simplistic calculations may be adequate, or computer facilities may not be available. Should this be the case, the simpler methods explained in appendix A may be used.

Appendix A is included to provide information on various state-of-the-art methods of performing dam-break/inundation studies. The analyst should become familiar with these methods so that they can be applied when a situation requires their use. However, a method other than the "recommended procedure" should not be used unless it can be justified. Such justification should be explained in the hazard classification report.

b. Guidelines for Determining SMPDBK Input Data Values. - SMPDBK requires user specified values of the following input parameters:

DAMN	- Name of the dam
RIVN	- Name of the river
IDAM	- Code for type of dam
HDE	- Elevation of crest of dam, or elevation of water surface when dam breaches
BME	- Final bottom elevation of breach bottom
VOL	- Volume (acre-ft) of reservoir

SA	- Surface area (acres) of reservoir at HDE
BW	- Width (ft) of rectangular breach
TFM	- Time (min) for breach to develop
QO	- Nonbreach flow (spillway, outlet, overtopping) which occurs with maximum breach flow
NS	- Number of cross sections
NCS	- Number of top widths for each cross section
CMS	- Manning's "n" associated with off-channel storage
D(I)	- Distance (mi) from dam to Ith cross section
FLD(I)	- Depth (ft) in cross section at which flooding and deflooding times will be computed
HS(K,I)	- Elevation (m.s.l.) associated with Kth top width (BS) of Ith cross section; first elevation is the invert elevation
BS(K,I)	- Kth top width (ft) of Ith cross section
BSS(K,I)	- Kth inactive top width (ft) of Ith cross section
CM(K,I)	- Kth Manning's "n" associated with Kth top width of Ith cross section

Criteria for determining input values follow. Should an experienced analyst have sound reason to vary from these criteria, this may be done, but should be documented in the hazard classification report.

DAMN. - Name of dam.

RIVN. - Name of river.

IDAM. - Type of dam.

HDE. - Use a value commensurate with the dam-break scenario. For a sunny day failure where the dam is assumed to fail at normal pool, enter normal pool elevation. For an overtopping failure where dam is assumed to fail when overtopped by 1.0 foot (for example), enter dam crest elevation plus 1.0 foot.

BME. -

Earthen dam: Use the streambed elevation at the downstream toe of the dam.

Concrete and stone-masonry dam: Same as for earthen dam except add 0.20(HDE - BME) to BME.

VOL. - Use the reservoir volume associated with HDE - BME.

SA. - Use the reservoir surface area associated the HDE.

BW. -

Earthen dam: BW = 3 (HDE - BME).

Concrete arch dam: BW = 0.45 (CL + BL).

Concrete gravity dam: BW = 0.375 (CL + BL).

Stone-masonry dam: BW = 0.3 (CL + BL).

Rock-placed dam: BW = 2.5 (HDE - BME).

TFM. -

Earthen dam: TFM = 0.20 BW.

Concrete arch dam: TFM < (HDE - BME)/1,000; i.e., instantaneous failure.

> Note: If TFM < (HDE - BME)/1,000, then the SMPDBK assumption of gradually varied breach flow is violated and SMPDBK defaults to computing peak breach discharge via an instantaneous failure equation. Thus, TFM will not be used in peak breach discharge calculations.

Concrete gravity dam: TFM equals the lesser of:

(1) 1 minute per toppled monolith (if applicable), or
(2) 0.050 BW.

Stone-masonry dam: TFM = 0.075 BW

Rock-placed dam: TFM = 0.125 BW

QO. - Use maximum spillway, outlet, and overtopping (when applicable) discharge commensurate with HDE.

NS. - Use sufficient cross sections to adequately represent the routing reach. Fewer cross sections are needed for uniform channels than for channels that vary significantly in cross section geometry.

NCS. - Use at least 3.

CMS. - Use SMPDBK default of 0.3 if in doubt.

D(I). - Note that the slope used in breach discharge submergence calculations is computed as [D(2) - D(1)] / [Elev(2) - Elev(1)]. Thus, it is important to select these two cross sections so that the true slope immediately downstream from the dam can be calculated as accurately as possible by the model.

FLD(I). - Enter 0. Not needed for hazard classification.

HS(K,I), BS(K,I), and BSS(K,I). - These values can usually be determined from USGS 7-1/2-minute topographic quadrangle maps. However, when contour intervals are large (i.e., 40 ft, or 10 or 15 m), and/or sufficient detail is lacking, a field survey may be necessary.

CM(K,I). - Use values commensurate with large floods rather than typical in-bank flows [7]. When in doubt, select values on the high side of the possible range of values.

4. Peak Flood Depths and Velocities. - Both peak depths and velocities are needed for the criteria specified in section IV. The March 1988 version of SMPDBK outputs peak depths at each cross section, but not peak velocity. To determine peak velocity, compute cross-sectional area of flow at the cross section of interest and divide the peak discharge by this area (V = Q/A).

If many hazard classifications are to be performed using SMPDBK, SMPDBK could be modified to output peak velocity; a few lines of code are all that is necessary.

IV. IDENTIFICATION OF HAZARDS

A. Introduction

A dam-break/inundation study is performed for the purpose of determining the impact of a dam failure flood on "possible hazards." A possible hazard is one that has been identified as having the possibility to constitute a hazard, but field work and/or analysis needs to be performed for confirmation.

Possible hazards are identified from topographic maps, photographs, field surveys, and information from "locals." They include any situation that is suspicious of having potential for lives-in-jeopardy or economic loss due to a dam failure. Some examples are listed in section II.

Sometimes, downstream hazard classification is obvious. That is, an analysis is not necessary because lives would be in jeopardy, and/or property damage would occur, with little doubt, due to a dam failure.

Analysis does not always prove a possible hazard to be a confirmed hazard; many "gray areas" exist in hazard classification. Analysis may indicate that a residence could be flooded by 1 foot (0.3 m) of water, but will this result in loss of life? If a failure flood overtops a highway bridge, will the bridge be destroyed? If not, will a vehicle be carried by floodwater or go out of control due to hydroplaning? Or, will a vehicle crash due to a damaged road or bridge after the flood has passed? Questions and gray areas such as these are the underlying reasons for guidelines regarding identification of downstream hazards. Such guidelines are presented in subsections B. through G.

Subsections B. through E. contain curves of depth versus velocity (figs. 2 through 6) that are indicative of dangerous floodflows for various possible hazards. Figure 2 is a modification by the author of a study performed by Black [8]. The curves in figures 3 through 6 were derived theoretically by the author. Figure 4 is in reasonable agreement with a theoretical analysis performed by Simons, Li and Associates [9]. The lower curve in figure 5 is in reasonable agreement with a theoretical analysis performed by David J. Love and Associates, Inc. [10], and a laboratory flume study performed at Colorado State University by Abt and Wittler using monoliths [11]. Very little research has been done on this topic; however, even if this were the case, there would be discrepancies which cannot be avoided due to the many initial assumptions that have to be made, very large number of variables that have to be considered, and philosophy. This was emphasized by Abt and Wittler [11] who conclude, "Physical tests of human subjects, even in a controlled laboratory environment, indicated that the ability of the subject to adapt to flood flow conditions is difficult to quantify." The relationships presented in figures 2 through 6 are very reasonable for estimating lives-in-jeopardy for downstream hazard classification purposes, and satisfy one of the purposes of these guidelines - to bring consistency and objectivity into downstream hazard classification. In addition, they are logical and easy to use.

The depth-velocity flood danger level relationships are divided into three zones: low danger, judgment, and high danger. An explanation of these zones follows:

Low-danger zone. - If a possible hazard is subject to a depth-velocity combination plotting within this zone, then the number of lives-in-jeopardy associated with possible downstream hazards is assumed to be zero.

High-danger zone. - If a possible hazard is subject to a depth-velocity combination plotting within this zone, then it is assumed that lives are in jeopardy at all possible downstream hazards.

Judgment zone. - The low-danger and high-danger zones represent the two extremes of reasonable certainty regarding the occurrence of no lives-in-jeopardy and some lives-in-jeopardy, respectively. Between these two extremes exists a zone of uncertainty with respect to assessing lives-in-jeopardy. Because every flood situation is unique, it is impossible to account for all of the variables that may result in lives to be in jeopardy if the flood magnitude (depth and velocity) plots in this zone. Thus, in this case, it is left up to the analyst to use engineering judgment for determining lives-in-jeopardy. Whenever possible, several opinions, and a common agreement among analysts should be reached in making this determination. There are many possible factors to consider; examples include:

- A designated campground, attraction, monument, etc. may receive very little visitor use. Such facilities may be visited for a very small total time during a year (e.g., 100 person-hours). Thus, the chance for lives to be in jeopardy due to flood depths and velocity combinations being in the judgment zone of figure 5 or 6, is very small and lives-in-jeopardy can be considered zero.

- The total time that the flood depths and velocities reach magnitudes within the judgment zone. An example is a dam-break flood from a small reservoir that rapidly reaches a peak discharge, then rapidly decreases. If the only possible hazard is a highway receiving little use, then the chance of a vehicle being exposed to a dam-break flood is very small. On the other hand, vehicles on a heavily traveled highway that could receive flooding from a large reservoir having sustained high flows are likely to be "caught" in a flood situation. Although the effect of the flood on loss of life is uncertain in this zone, the fact that there is a large population involved cannot be ignored, and conservative judgment should be used such that loss of life is considered possible.

- A residence subject to a flood depth-velocity in the judgment zone may be a three-story, well-built, brick home. In such a case, the assumption could be made that the occupants are not in serious danger - especially if the flooding is of fairly short duration. However, occupants of a single-story, poorly constructed home subject to floods of a long duration should be assumed to be in danger.

- Multiple-story frame houses may provide safety to occupants above the first floor. However, it has to be assumed that the occupants will be aware of the flood (e.g., not sleeping) and will move to a higher level.

It is very important to understand that the zones (low-danger, judgment, high-danger) represented in figures 2 through 6 are not "cast in stone." Predicting lives-in-jeopardy is far from being an exact science. If the analyst has <u>sound reason</u> to believe that lives are in jeopardy for conditions in the low-danger zone, or no lives are in jeopardy for conditions in the high-danger zone, then such reasoning can override figures 2 through 6. However, the reasons have to be documented in the hazard classification report.

In many hazard classifications, especially where large dams and catastrophic flooding are involved, reference to figures 2 through 6 is superfluous because of the obvious flood danger. But, for situations where the hazard classification of a dam is solely dependent upon an isolated flood situation where occupants of a dwelling or vehicle may be in danger, or a person having no protective environment (e.g. house, vehicle) may be in danger, these figures should be used. In such situations, the analyst will have predicted a reasonable maximum depth and velocity, "with confidence" (refer to the following paragraph), at the possible hazard site and needs to make a decision as to the floods effect on the possible hazard so that lives in jeopardy can be assessed. If depths and velocities cannot be predicted with confidence, then a conservative approach should be used that assumes any possible hazard in the path of a dam-break flood is in danger and is considered a downstream hazard. But, for situations where the analyst is confident about the predicted depths and velocities, figures 2 through 6 can be used for estimating the susceptibility of a possible hazard to impacts from the predicted floodwaters. Then, the analysts can decide if the possible downstream hazard should be confirmed as a downstream hazard, and assess lives-in-jeopardy.

The adequacy of predicted depths and velocities can be ascertained by performing sensitivity analyses on critical breach outflow and channel routing parameters. If predicted depths and velocities at a specific channel site do not change significantly with significant changes in the critical parameters, then the predicted depth and velocity can be used "with confidence." More information regarding sensitivity analysis is contained in appendix A, subsection D.

Extent of economic loss is the decision of the analyst, as previously stated. Thus, depth-velocity-damage relationship curves are not presented in the following sections.

B. Permanent Residences, Commercial and Public Buildings, and Worksite Areas

Permanent residences are considered dwellings attached to foundations, and hooked to utilities. Some mobile homes are not attached to foundations; these are discussed separately in subsection IV.C.

Worksite areas include facilities that contain workers on a daily (work week) basis. This includes farm operations, oil and gas operations, sand and gravel operations, and fish hatcheries.

The lives-in-jeopardy includes all occupants of dwellings located within the inundation boundaries, subject to a combination of flood depth and velocity plotting above the low-danger zone of figure 2. However, but

HIGH DANGER ZONE – Occupants of most houses are in danger from floodwater.

JUDGEMENT ZONE – Danger level is based upon engineering judgement.

LOW DANGER ZONE – Occupants of most houses are not seriously in danger from flood water.

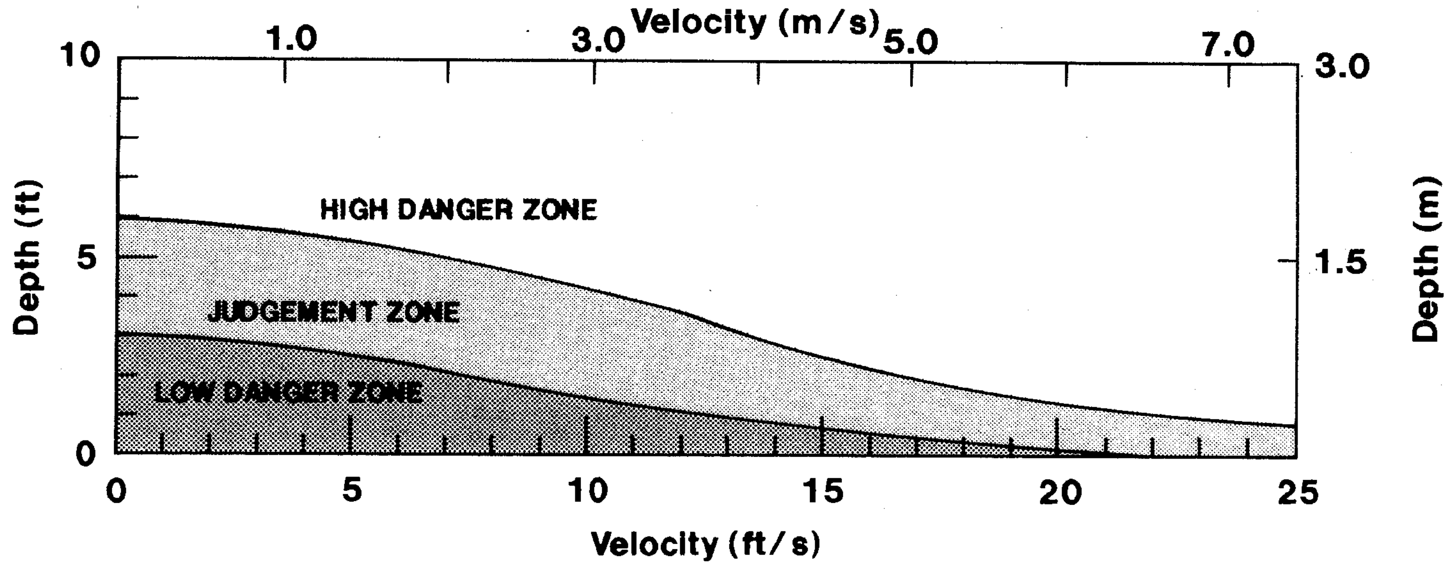

Figure 2. – Depth–velocity flood danger level relationship for houses built on foundations.

only if justifiable, no lives-in-jeopardy has to be associated with occupants of dwellings subject to a flood depth and velocity plotting within the judgment zone. Lives-in-jeopardy is always associated with occupants of dwellings subject to a combination of flood depth and velocity plotting within the high-danger zone except very special cases where the analyst can present strong justification.

If flood depth and velocity cannot be predicted with reasonable confidence, then the lives-in-jeopardy includes all occupants of residences within the inundation boundaries with no reference to depth or velocity, and the downstream hazard classification can be assigned accordingly.

For situations where pedestrians may be a factor in the downstream hazard classification, refer to subsection IV.E.

C. Mobile Homes

Mobile home parks are typically located in flood plains due to zoning requirements in many areas. This creates a very dangerous situation for occupants of mobile homes, as they are very susceptible to movement from relatively small floods. Thus, depth-velocity-flood danger level relationships (fig. 3), other than those for houses on foundations, are used for mobile homes.

The lives-in-jeopardy includes all occupants of mobile homes located within the inundation boundaries, subject to a combination of flood depth and velocity plotting above the low-danger zone of figure 3. However, but only if justifiable, no lives-in-jeopardy has to be associated with occupants of mobile homes subject to a combination of flood depth and velocity plotting within the judgment zone. Lives-in-jeopardy is always associated with occupants of mobile homes subject to a combination of flood depth and velocity plotting within the high-danger zone except very special cases where the analyst can present strong justification.

If flood depth and velocity cannot be predicted with reasonable confidence, then the lives-in-jeopardy includes all persons likely to be in the inundated area with no reference to depth and velocity, and the downstream hazard classification can be assigned accordingly.

HIGH DANGER ZONE – Occupants of almost any size mobile home are in danger from flood water.
JUDGEMENT ZONE – Danger level is based upon engineering judgement.
LOW DANGER ZONE – Occupants of almost any size mobile home are not seriously in danger from flood water.

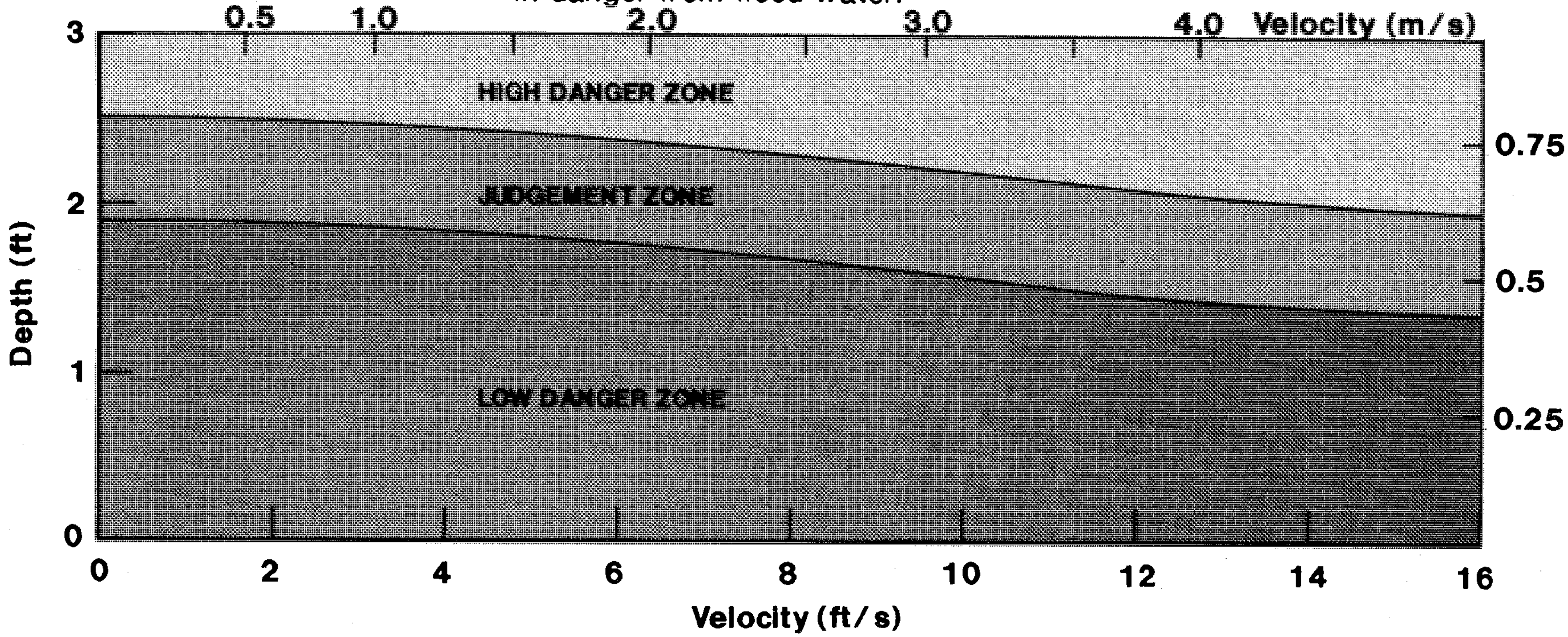

Figure 3. – Depth–velocity flood danger level relationship for mobile homes.

D. Roadways

If a dam-break flood wave inundates a roadway, the possibility for loss of life to motorists and pedestrians (guidance for pedestrians is covered in subsec. IV.E.) should be evaluated. In most cases, a roadway is inundated due to its crossing the channel via a bridge or culvert, or due to its running parallel to the channel such as in a canyon.

Loss of life is possible on a roadway as a result of a dam failure due to several causes. These include:

- A vehicle being carried downstream by floodwater,
- Loss of control and subsequent crash of a vehicle due to its impact with the floodwater, and,
- A vehicle crash resulting from road damage after the flood has passed.

However, because downstream hazard classification is based on the direct impacts from a dam-break flood (subsec. I.A.), situations such as a vehicle crash resulting from road damage after the flood wave has passed are not considered when estimating lives-in-jeopardy. It is assumed that vehicles are already on, or attempting to enter a roadway when it is inundated.

The lives-in-jeopardy includes all occupants of vehicles within the inundation boundaries subject to a combination of depth and velocity plotting above the low-danger zone of figure 4. However, but only if justifiable, no lives-in-jeopardy has to be associated with occupants of vehicles subject to a combination of flood depth and velocity plotting within the judgment zone. Lives-in-jeopardy is always associated with occupants of vehicles subject to a combination of flood depth and velocity plotting within the high-danger zone except very special cases where the analyst can present strong justification.

If flood depth and velocity cannot be predicted with reasonable confidence, then the number of lives-in-jeopardy includes all persons likely to be in the inundated area with no reference to depth and velocity and the downstream hazard classification can be assigned accordingly.

A roadway will be a factor in determining the downstream hazard classification of a dam, only when it is paved. This criteria provides a simplified way of accounting for the amount, frequency, and speed of traffic on that particular roadway.

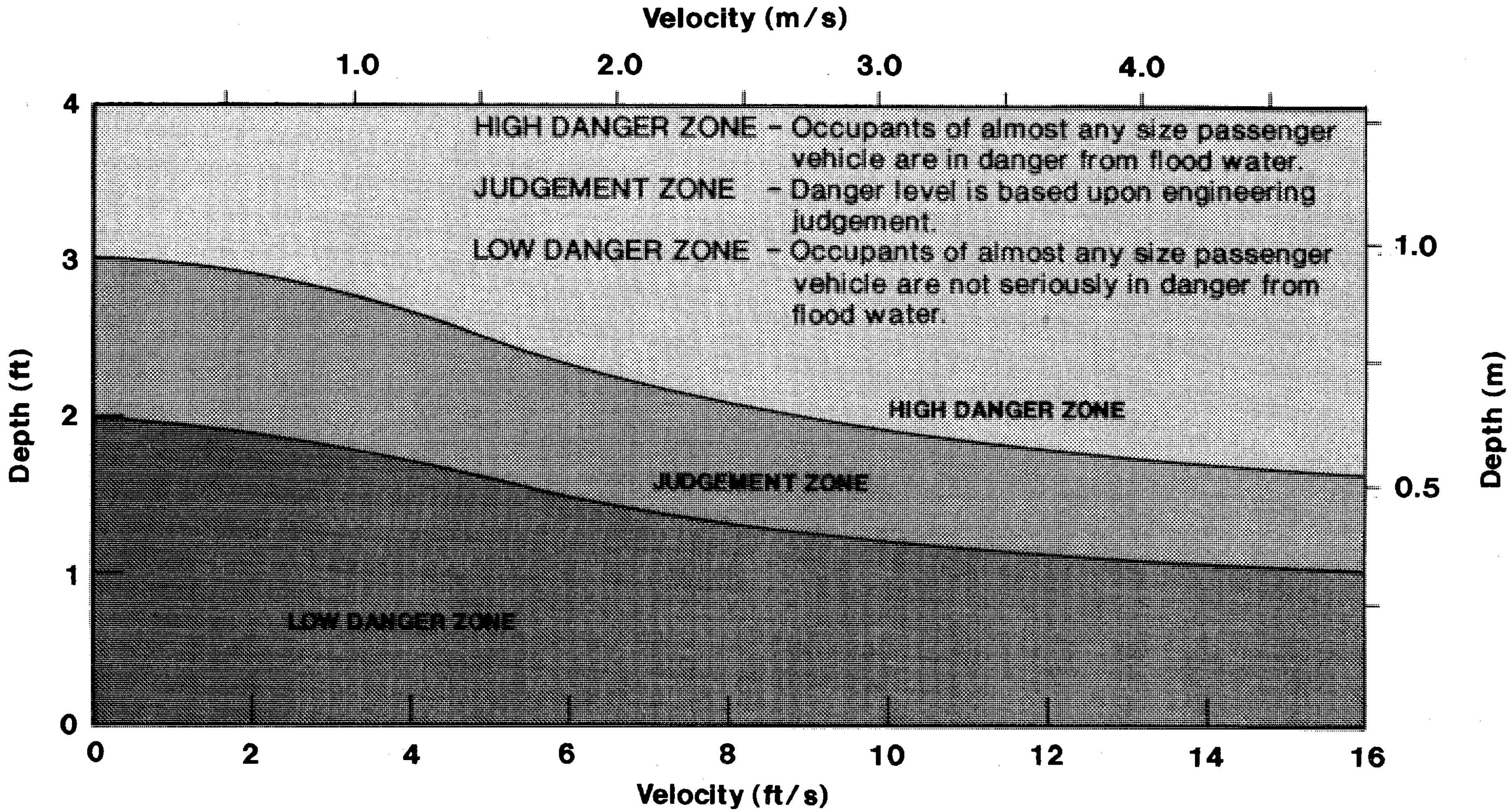

Figure 4. – Depth–velocity flood danger level relationship for passenger vehicles.

The paved road criteria apply unless the analyst can provide reason to the contrary. For example, a paved roadway may be located in a very remote location and rarely traveled. Or a roadway may be closed during the time of year that the dam failure is assumed to occur. Such a case is when a dam failure flood can only endanger a roadway if the failure occurs in combination with a large flood, but, the large flood can only occur in late spring (rain-on-snow flood) when a roadway located in an alpine area is closed.

Conversely, unpaved roads can also present a lives-in-jeopardy situation, thereby resulting in a significant- or high-hazard classification if proper justification can be made. An example is a gravel road in a long narrow canyon with a dam located upstream. This road receives moderate traffic because it is an access to an established recreational area, scenic attraction, residential housing division, etc. However, because the road passes through a long narrow canyon, a dam failure flood could very likely result in loss of life to motorists in the canyon due to the difficulty in escaping the flood.

Economic loss includes replacement costs of the highway and crossings only.

E. Pedestrian Routes

Pedestrian routes include sidewalks, bicycle paths, and walking/hiking trails. For situations where pedestrian routes are isolated, and/or may influence the hazard classification, the lives-in-jeopardy can be estimated using figures 5 and 6. Figures 5 and 6 are depth-velocity-flood danger level relationships for adults and children, respectively. Separate figures for adults and children (versus one figure for all humans) are included so possible hazards that may not include children can be evaluated differently than mixed populations of both adults and children. Examples of "adult only" populations are worksites and adult-only residential areas. An adult is considered (for the use of figures 5 and 6) any human over 5 feet (150 cm) tall and weighing over 120 pounds (54 kg). The choice of using either figure 5 or 6 is the decision of the analyst based on knowledge and understanding of the population. However, when populations are mixed (i.e., adults and children), figure 6 should be used for conservativeness.

Infants are not treated separately; instead, they are assumed to be safely attended by adults.

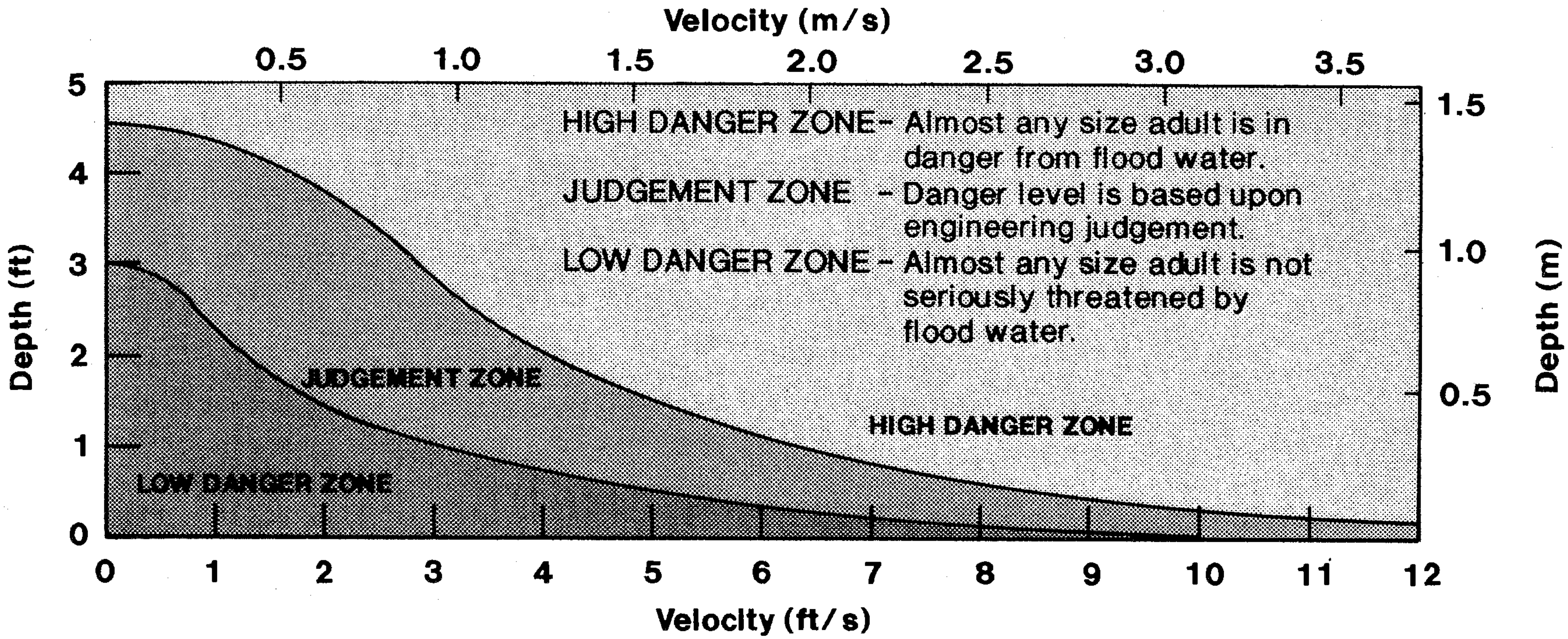

Figure 5. – Depth–velocity flood danger level relationship for adults.

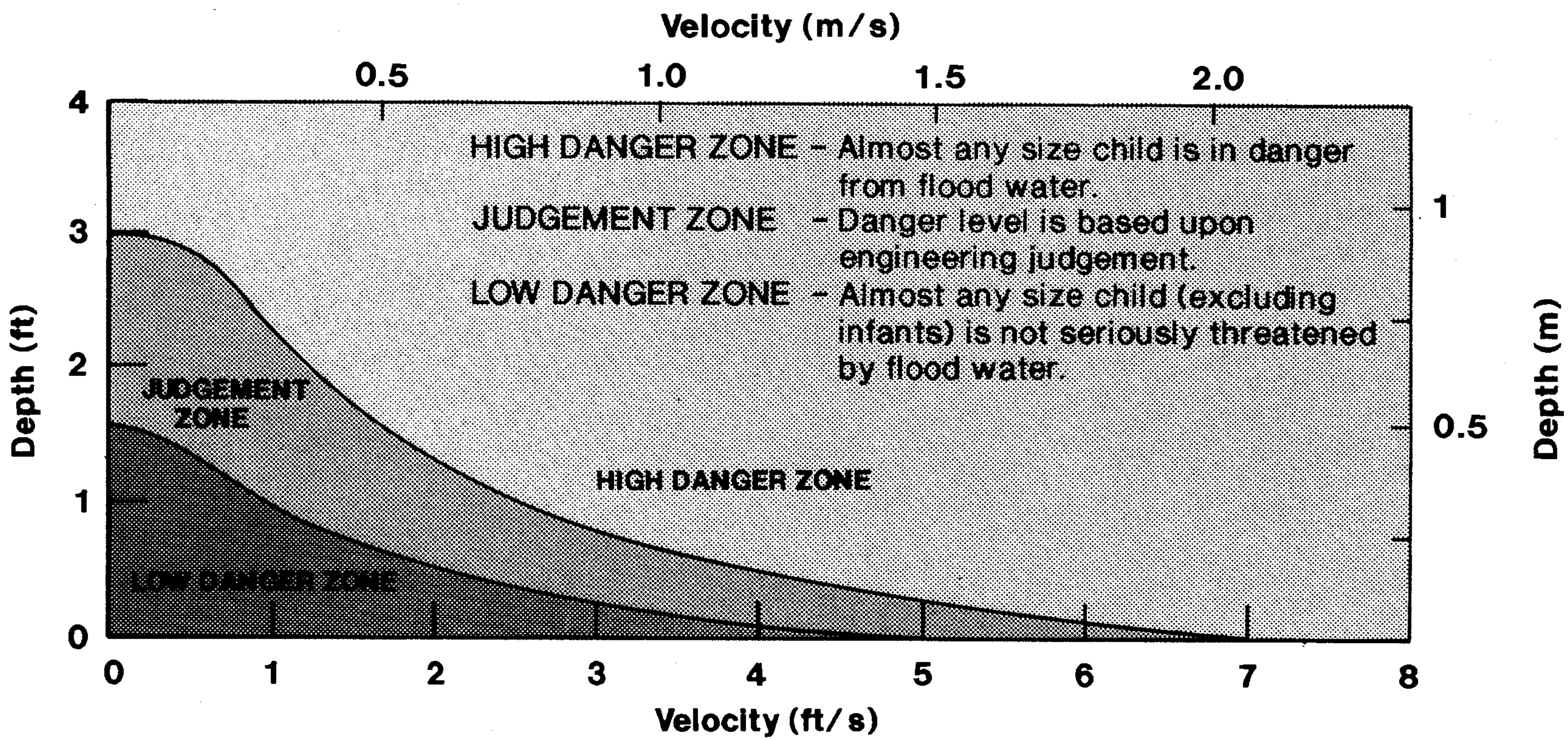

Figure 6. – Depth–velocity flood danger level relationship for children.

The lives-in-jeopardy includes all pedestrians, located within the inundation boundaries, subject to a combination of flood depth and velocity plotting above the low-danger zone of figure 5 or 6. However, but only if justifiable, no lives-in-jeopardy has to be associated with pedestrians subject to depths and velocities plotting within the judgment zone. Lives-in-jeopardy is always associated with pedestrians subject to a combination of flood depth and velocity plotting within the high-danger zone except very special cases where the analyst can present strong justification.

If flood depth and velocity cannot be predicted with reasonable confidence, then the lives-in-jeopardy includes all persons likely to be in the inundated area with no reference to depth and velocity and the downstream hazard classification can be assigned accordingly.

F. Designated Campgrounds and Recreation Areas

A designated campground and/or recreational area downstream from a dam is treated the same as pedestrian routes. Such a facility can be one that is owned, operated, and maintained by a Government agency or by private interests, and is advertised via signs, brochures, maps, etc. Campgrounds may include facilities intended for recreational vehicle hookups, to facilities intended for primitive camping. Recreational areas include scenic attractions, hiking trails, fishing and hunting areas, golf courses, boating areas and launching facilities, etc. For hazard classification purposes, it is assumed that such a facility will be occupied during a dam failure flood (unless the failure scenario takes place out of season) and lives may be in jeopardy. For estimating lives in jeopardy, the number of people likely to use the facility during a heavy use period (e.g., Fourth of July) should be considered.

The failure scenario may be such that persons are in danger only when the dam failure is combined with a large runoff flood occurring during a certain time period (e.g., spring runoff). In such a case, the use of the facility during this time period should be considered in estimating lives-in-jeopardy. For example, if the dam can threaten lives in the facility only for the case when failure occurs during the spring runoff, then anticipated use during the spring should be considered when estimating lives-in-jeopardy.

G. Mixed Possible Hazard Sites

A typical community usually contains all of the possible hazards identified in subsections IV.B. through F. Estimating lives-in-jeopardy for this situation may require the use of all, or some of the criteria in subsections IV.B. through F. For example, if a small community is comprised of permanent residences on foundations, mobile homes, and a small park, then all of the criteria in subsections IV.B. through F. are needed to accurately estimate lives-in-jeopardy.

H. Economic Loss

As stated in subsection II.C., no dollar value is used for determining economic loss. However, hazard classification is rarely based on economic loss alone, so judging economic loss usually is not required. This is because in most situations where economic loss is involved, lives-in-jeopardy is a consideration also. Rarely does a situation exist where the lives-in-jeopardy is zero, but appreciable or excessive economic loss will occur resulting in a significant- or high-hazard classification based on economic loss alone (table 1).

Thus, it is best to assign the dam a hazard classification based on lives-in-jeopardy before economic loss is considered. Then, if the lives-in-jeopardy is greater than 6, resulting in a high-hazard classification, estimation of economic loss is not necessary because it will have no influence on the hazard classification. However, if the hazard classification is less than high, economic loss should be evaluated to determine if the hazard classification could increase.

V. CONCLUDING REMARKS

Downstream hazard classification is important as a management tool because it could be the deciding factor that determines whether or not a formal safety evaluation and possible modification are performed on a dam.

Determining hazard classification could vary simply from a "windshield survey" or glancing at a topographic map to analyses requiring detailed field data, sophisticated analytical models needing a high-speed digital computer, and extensive user training and experience.

While hazard classification may be obvious for many large dams, it often requires detailed analysis combined with good judgment for small dams. However, detailed analysis does not always result in a firm hazard classification. Many unknowns exist with regard to structural damage to buildings, roads, occupancy, behavior of persons threatened by flooding, etc. Due to these unknowns, agency policy is important to give objectivity and consistency in assigning hazard classifications. These guidelines are intended to provide such assistance.

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APPENDIXES

APPENDIX A - METHODS FOR PERFORMING A DAM-BREAK/INUNDATION STUDY

A. Estimating Breach Hydrograph or Peak Discharge
   1. Physically based
   2. Parametric
   3. Empirical
   4. Comparison

B. Routing Breach Discharge Downstream
C. Determining Flood Depths and Inundation Boundaries
D. Errors Associated With Dam-Break Flood Routing Models

APPENDIX B - BIBLIOGRAPHY

APPENDIX A

METHODS FOR PERFORMING A DAM-BREAK/INUNDATION STUDY

Dam-break/inundation studies are both an art and a science. Although many advances in computer models and analytical methods have been made in recent years, much knowledge and judgment by the analyst are still necessary for meaningful results.

The purpose for this appendix is to present an overview of state-of-the-art dam-break/inundation study methods of varying complexities, for persons not familiar with or wanting more information on such methods. From this, an individual can choose a method best suited for his/her specific needs, resources (time, money), and computing facilities (or lack of). As stated in subsection III.D.3., other analytical methods can be used if the analyst has good reason to do so; this appendix presents such "other methods."

A. Estimating Breach Hydrograph or Peak Discharge

If the breach size, slope, and time to develop are known, the breach outflow can be determined using hydraulic principles. However, unless a major structural weakness and obvious failure condition are known, estimating the breach parameters is based on previous experience and engineering judgment.

Many assumptions can be made and scenarios envisioned regarding a dam failure. For example, a dam could fail from overtopping by a large inflow flood or by piping on a clear day. A thin arch dam may burst almost in its entirety, or just a section of it may fail. The complete breaching of an embankment dam may take as little as 30 minutes to form, or 2 hours or longer; it can vary widely in size and shape. The reservoir may be half full or at its maximum capacity. These factors can only be speculated prior to a dam failure.

The type of failure (assumed) and dam should be considered when estimating a peak breach discharge. Two basic categories of failure are possible. The first is an "overtopping failure." This failure of a dam by erosion and/or structural damage is due to the reservoir overtopping the dam. The reservoir storage and discharge capability of the appurtenances are insufficient during the occurrence of a large flood of significant magnitude and duration to prevent overtopping of the dam for a significant time period.

The other failure category is a "sunny day" or "normal pool" failure. Basic assumptions are that the reservoir's water surface elevation is at the normal pool level and the reservoir is receiving average inflow (usually insignificant) when dam failure occurs. Failure mechanisms in this case include seepage, piping, embankment slope instability, structural weakness, reservoir rim landslide induced, and earthquake induced.

The type of dam has a significant effect on breach configuration and peak breach discharge. The dam may be either a well constructed or poorly constructed embankment dam, a concrete gravity, arch or buttress dam, slag pile (mine waste), or other type.

In general, breach discharge increases with dam height, reservoir surface area, and a small time for full breach development. The reverse is true regarding small breach discharges.

A reasonable maximum breach discharge can be estimated based on four principal methods:

- Physically based,
- Parametric,
- Predictor, and
- Comparison.

A discussion of each follows:

1. Physically based. - Physically based methods are those such as BREACH [12] which computes a breach size and shape using principles of hydraulics, sediment transport, soil mechanics, and material properties of the dam.

2. Parametric. - Parametric models use observations of previous dam failures to estimate the size, shape, and time to failure of a breach. The breach is developed by time-dependent linear geometric increments to its assumed final dimensions, and the discharge is computed at each increment using hydraulic principles. DAMBRK [6] and SMPDBK [5] are examples of models that use this approach.

3. Predictor. - Many models exist that are of the form:

$$Q_{bmax} = C \cdot X^m$$

where Q_{bmax} is peak breach discharge and C and m are constants determined from historical data. The parameter X is usually dam height, reservoir volume, or the product of the two. The parameter m has no physical reference. The values of C and m are determined using several different approaches. These approaches, as explained in SCS National Bulletin No. 210-6-19 [13], are:

a. The formal approach would determine the undefined constants C and m using linear regression on the logarithmic transforms of paired data sets of reported Q_{bmax} and X.

b. The semiformal approach might determine m by a regression or other analysis but then evaluate C visually (using plots of Q_{bmax} vs. height, storage, or their product) on the basis of intuition and judgment.

c. The purely empirical approach has no constraints. C and m are arbitrarily selected.

Many different C and m values have been published by different researchers [4, 14, 15, 16, and 17] because the researchers used available historical dam failure data in various ways to arrive at the C and m values. For instance, a data set may have included only embankment dams, or embankment dams within a certain range of height and storage, or only concrete dams, etc. Due to this, much confusion exists as to which predictor models are "best." It is very important to note that no one model is best. Different predictor models are applicable to different situations.

If the analyst chooses to use a predictor model, then he can select the most suitable one for a specific dam by reviewing the data used in its development and determining if the historical data are similar to the situation being analyzed. Also, conservative or liberal estimates can be obtained, depending on the purpose of the evaluation, by choosing predictor models that estimate high- or low-peak breach discharges. For hazard classification purposes, conservative (high) estimates are recommended to be consistent with dam safety philosophy.

Another approach is for the analyst to "customize" the C and m values for the particular dam-breach scenario being analyzed. This is done by using historical failure data (subsec. I.D.) of similar failure scenarios (dam height, reservoir volume, similar construction, etc.) and fitting C and m by applying the approaches explained in this subsection.

3. Comparison. - If the subject dam is very similar in size, construction, and materials to a failed dam with known data, the breach characteristics and peak outflow of the failed dam could be used in estimating the same for the subject dam. Some data on such failures are contained in references [4], [14], and [15].

Determining a peak breach discharge for use in hazard classification is very subjective. There is no "cook-book" method or single procedure that is applicable for all situations. Consequently, it is best to use several different methods for one analysis, compare the results, and choose a peak breach discharge that is most reasonable and/or is similiar among several different methods.

Predicted peak breach discharge can range considerably depending on the method of evaluation. Due to this, one has the choice of being liberal, conservative, or somewhere in between. For hazard classification purposes, conservative estimates should be favored. It is best to "err" and predict more severe inundation and greater lives-in-jeopardy so, should a dam failure occur, the chances of underestimating lives-in-jeopardy and hazard classification will be lessened. That is, the chances of classifying a dam as low- or significant-hazard, when it should have been significant or high, will be less. However, it is not unusual for predicted peak breach discharges to vary greatly among different methods - as much as one order of magnitude. In cases where such a large difference exists, the highest value may not be a good choice for a conservative peak breach discharge; instead, it could be considered an outlier. The engineer performing the analysis must have a strong knowledge of dam failure mechanics and hydraulics and be very familiar with historical dam failures. Only then can the engineer use good judgment in determining a reasonable peak breach discharge.

Fortunately, estimates of peak breach discharge can usually vary considerably without affecting the final results (hazard classification). The difference in flood depths computed from routing different breach discharges downstream diminishes with distance downstream from the dam (fig. A-1) and eventually becomes negligible. This distance is dependent on the difference in discharge at the dam, reservoir storage, and channel configuration, slope, and roughness. This topic is treated quantitatively by Fread [18].

B. Routing Dam-Break Discharge Downstream

The dam-break hydrograph will disperse as it travels downstream resulting in attenuation of the peak discharge. This is illustrated on figure A-2. To determine the amount of attenuation so that the discharge can be computed at selected points of interest (such as possible hazards), the dam-break flood is routed downstream. Normally, for the purpose of hazard classification, only the peak discharge is routed.

Many factors affect attentuation of the dam-break hydrograph; the primary ones are listed below, and their effect is illustrated on figure A-3.

Small attenuation	Large attenuation
Large reservoir volume	Small reservoir
Small channel and overbank storage	Large channel and overbank storage
Steep channel slope	Gentle channel slope
Little frictional resistance to flow	Large frictional resistance to flow
Supercritical flow	Subcritical flow

Many methods and models are available for predicting the flow characteristics of a flood wave resulting from a breached dam. Some of the more popular, state-of-the-art methods are discussed and compared in a recent study by Wurbs [19]. Wurbs concludes "The National Weather Service (NWS) Dam-Break Flood Forecasting Model (DAMBRK) is the optimal choice of model for most practical applications. The computer program

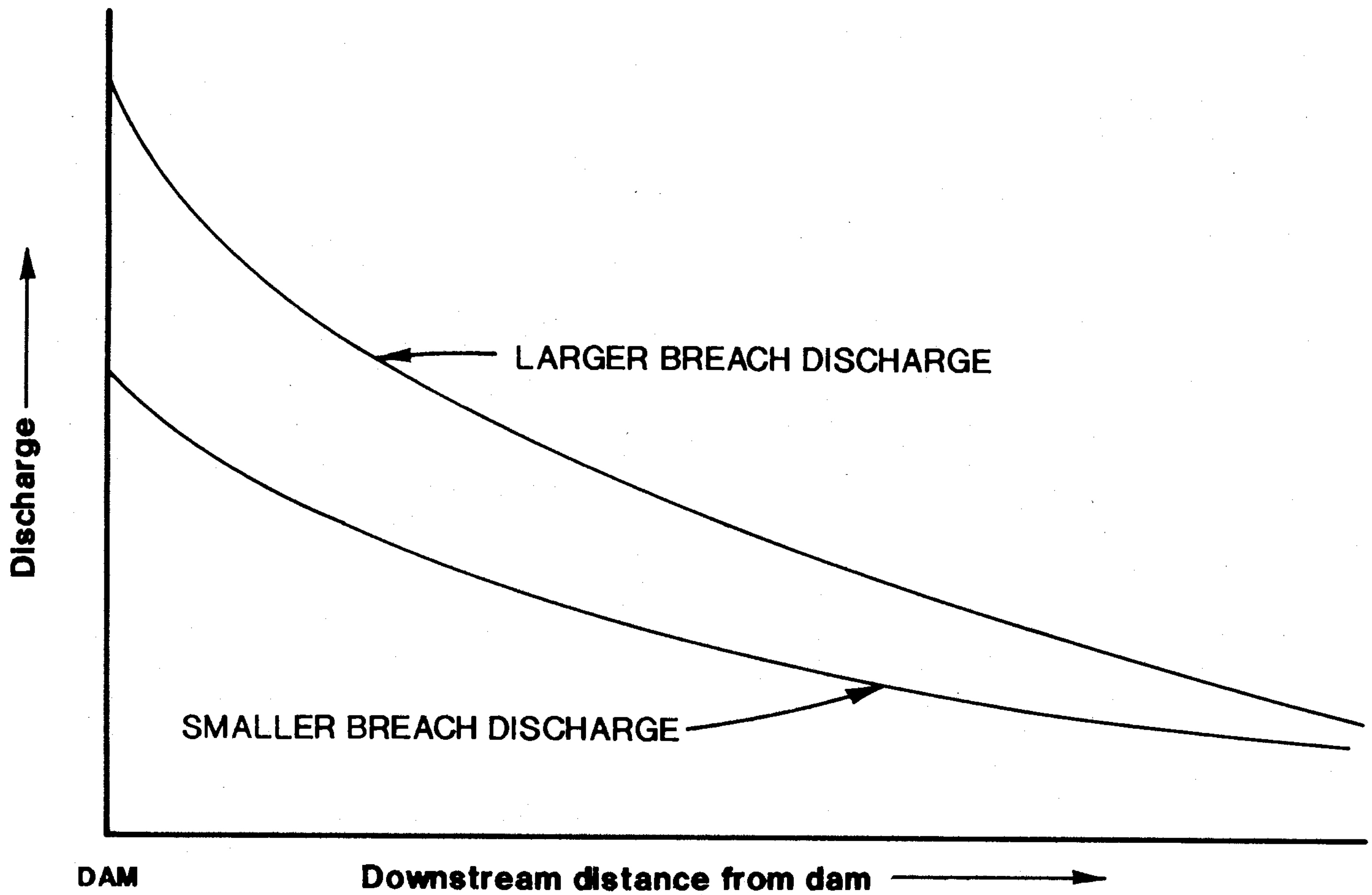

Figure A–1. – Convergence of depths of different size breach discharges routed down same channel.

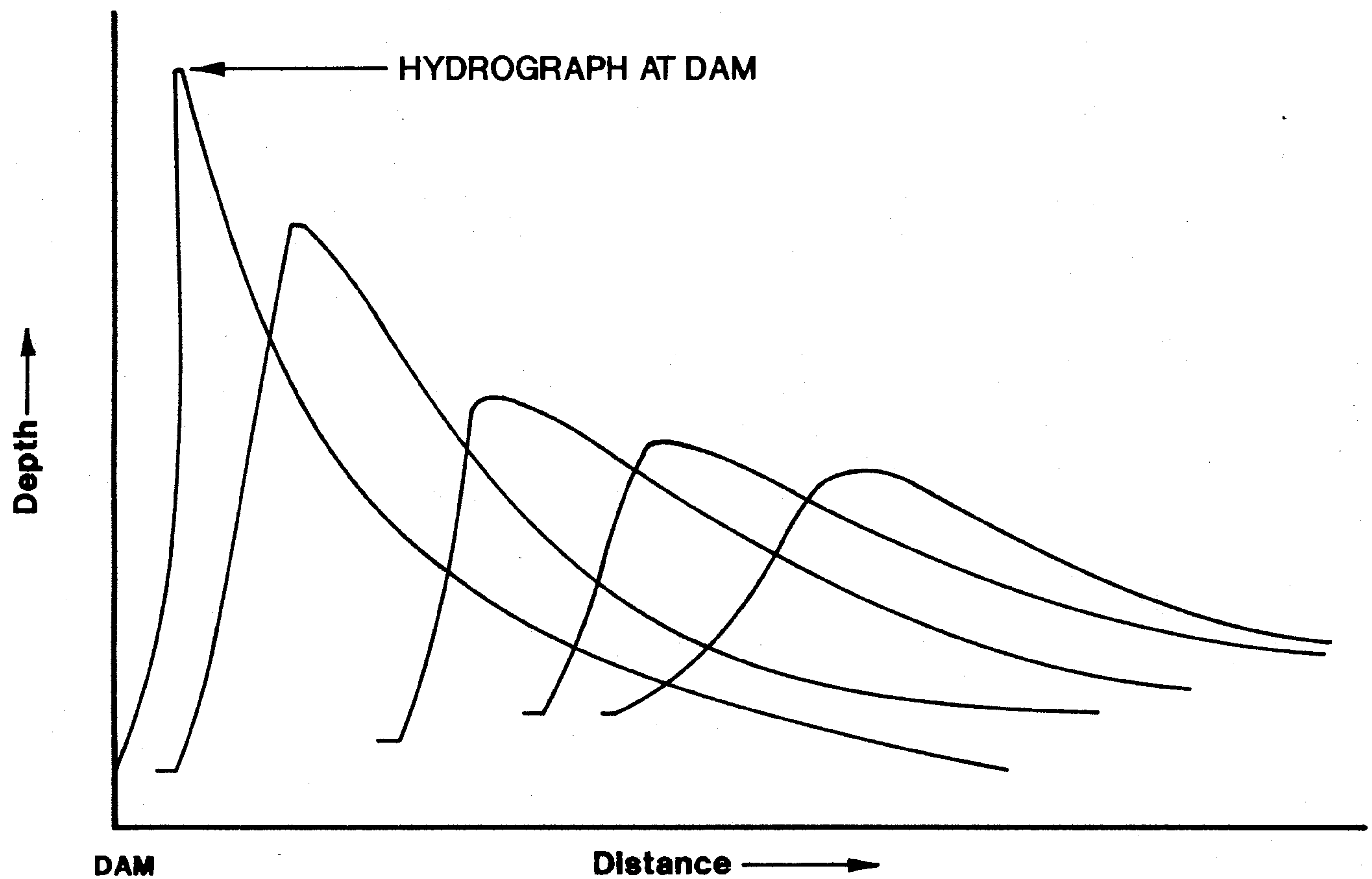

Figure A–2. – Dam–break discharge hydrograph dispersion and attenuation.

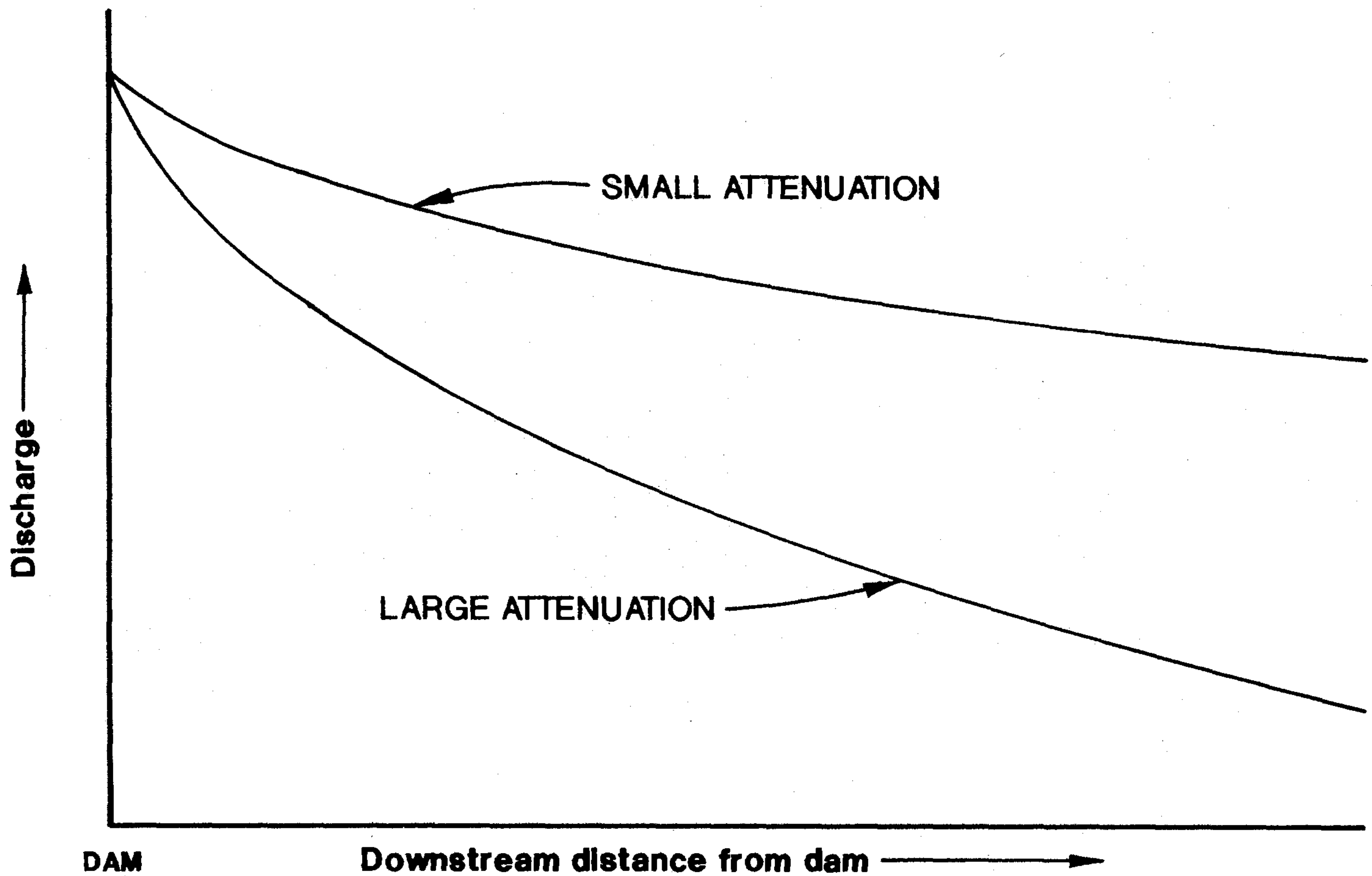

Figure A–3. – Dam–break hydrograph attenuation.

is widely used, well documented, and readily available from the NWS. Some civilian as well as military applications require the capability to perform an analysis as expeditiously as possible. The Simplified Dam-Break Flood Forecasting Model (SMPDBK) is the optimal choice of model for most of these types of applications." After using both models in numerous dam-break/flood routing studies, the author concurs with this conclusion. In addition, both DAMBRK and SMPDBK have microcomputer versions available from NWS.

SMPDBK [5] routes and attenuates the dam-break flood peak by a channel storage technique that uses channel geometry data and attenuation curves developed from DAMBRK [6]. This method is physically based, accurate, relatively easy to use, and not very labor and time intensive. It is an excellent model for hazard classification purposes when complicated channel hydraulics are not involved and the highest degree of accuracy is not needed.

If more accuracy is needed, and/or more hydraulic detail should be accounted for, DAMBRK is a recommended model. This model employs the dynamic wave method of flood routing. Only the dynamic wave method accounts for the acceleration effects associated with the dam-break flood waves and the influence of downstream unsteady backwater effects produced by channel constrictions, dams, bridge-road embankments, and tributary inflows. DAMBRK routes the complete hydrograph, rather than only the peak flow, downstream. The DAMBRK manual states:

> "The hydrograph is modified (attenuated, lagged, and distorted) as it is routed through the valley due to the effects of valley storage, frictional resistance to flow, flood wave acceleration components, and downstream obstructions and/or flow control structures. Modifications to the dambreak flood wave are manifested as attenuation of the flood peak elevations, spreading-out or dispersion of the flood wave volume, and changes in the celerity (translation speed) or travel time of the flood wave. If the downstream valley contains significant storage volume such as a wide flood plain, the flood wave can be extensively attenuated and its time of travel greatly increased."

Most dam-break models (such as DAMBRK and SMPDBK) use some form of the Manning equation for open-channel hydraulic calculations. The Manning equation is discussed in most open-channel flow hydraulics textbooks. One of the input variables that requires special attention due to characteristics of dam-break floods is the Manning roughness coefficient, n. To account for energy losses other than boundary friction, a much higher n-value for dam-break floods is used (or any other large flood) than for typical within-bank flows. The use of traditional values of n will result in significant error because computed discharge is inversely proportioned to n. Trieste and Jarrett [16] discuss this problem and make recommendations for selecting n-values used for open-channel computations of large floods.

A simple flood routing procedure using a regression equation determined from historical dam failure data is discussed in ACER Technical Memorandum No. 7 [3]. The independent variables are peak breach discharge, distance from the dam to the forecast point, and an attenuation parameter. This method is useful if time, computer facilities, and persons having knowledge of open-channel hydraulics are not available.

C. Determining Flood Depths and Inundation Boundaries

The end product in a dam-break/inundation study performed for hazard classification purposes is to determine flood depths at possible hazard sites so that the possible hazards can be confirmed. In some cases, where possible hazards are scattered along a channel reach, inundation boundaries are determined on topographic maps so that the total extent of flooding can be assessed. Inundation boundaries are delineated by plotting the maximum water surface elevation on both sides of the channel using topographic maps as a base.

Maximum water surface is dependent upon many factors. Some of these include peak discharge, channel roughness, channel obstructions and constrictions, and channel slope.

Peak flood depths are standard output data in DAMBRK and SMPDBK and in most other flood routing computer models. If such a computer model is not used but an estimate of peak discharge at the site has been determined, then depths can be readily calculated using Manning's equation, which is widely used and accepted. It is described in hydraulics textbooks such as Chow [20], Henderson [21], and Brater and King [22].

One must use good judgment in interpreting the flood damage and lives-in-jeopardy within the inundation boundaries. Due to small size map scale (e.g., 7-1/2 minute or 15 minute) and large contour intervals (e.g., 40 feet), it is difficult (or impossible) to draw accurate inundation boundaries. The impact of flooding in the vicinity of these boundaries is subject to interpretation and a conservative "benefit-of the-doubt" philosophy is recommended.

D. Errors Associated with Dam-Break Flood Routing Models

Many improvements have evolved in dam-break flood models in the last decade. State-of-the-art methods can simulate dam-break flood discharges and depths within 5 to 10 percent <u>if the key parameters are known</u>. That is, using data from historic dam failures that have been extensively studied (such as Teton Dam), modern state-of-the-art models can very accurately simulate the actual failure flood. Unfortunately, most parameters are not known before a dam-break flood study, and these unknowns result in large error in performing such studies. Some of these unknowns are described by Fread [18]:

- When will a dam fail?
- When and to what extent will a dam be overtopped?

- What is the size, shape, and time of formation of the breach?
- What is the storage volume and hydraulic resistance of the downstream channel valley?
- Will debris and sediment transported by the flood wave significantly affect its propagation?
- Can the flood wave be approximated adequately by the one-dimensional flow equations?

It is very important that the analyst have an understanding of these sources of error so that the results of a dam-break flood study are interpreted properly.

These errors and limitations are presented to emphasize that dam-break/ inundation studies are not exact. The engineer must be very cautious when important decisions regarding hazard classification are based on the results of an analysis. For instance, if the results of a study indicate that water levels from a dam failure will flood a community by 1 foot (for example), a low hazard classification should not be concluded. Sensitivity of various parameters and different dam failure scenarios should be evaluated to determine that if given the right combination of circumstances and model variable values, the flood depths at the community could be significantly greater.

Sensitivity analyses on important and questionable parameters are highly suggested. This is done by varying parameter values within reasonable limits and plotting critical model results (such as breach discharge, downstream discharge, and depths) against the variable. In this way, the analyst can decide if a variable value that initially may be a rough estimate at best requires more care in its selection, and/or if field data are necessary. Also, parameters that are determined to be insensitive can be used with confidence, thus eliminating concern and possible future justification.

APPENDIX B

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GPO 859-233

Technical Manual for Dam Owners

Impacts of Animals on Earthen Dams

FEMA 473 / September 2005

FEMA

(DCR-VSWCB-034) (03/14)

Twenty-five states across the U.S. can write headlines of dam failure caused by nuisance wildlife intrusions, and many dam owners find the struggle to adequately manage nuisance wildlife at their dams a never-ending story. The Federal Emergency Management Agency (FEMA) has funded the development of this manual with the understanding that safe dam operation includes comprehensive, state-of-practice guidance on timely inspection and observation of wildlife damages, accurate wildlife identification and mitigation, and appropriate dam design, repair, and preventive measures. It is hoped that the information and methods contained in this manual will compose the core of dam management routines practiced by dam specialists across the country. Armed with education and diligence, dam specialists can prevent animal intrusion dam failure from becoming headline news.

No. 6

Dam Safety Outlet

DAM SAFETY PROGRAM

September 2002

Montana Department of Natural Resources and Conservation

Rodent Hole Suspected Cause of Dam Failure in Garfield County

An irrigation dam in Garfield County failed on June 23, 2002. The dam was located on Taylor Creek approximately 22 miles southeast of Jordan, Montana. The estimated capacity of the dam when filled to the emergency spillway crest was 1,000 acre-feet. The height of the dam was approximately 32 feet.

Flash flood warnings had been issued the previous night, with a total of 3 to 5 inches of rainfall expected in Garfield County. At 6:00 a.m. on Sunday, June 23, the dam owner went to see how much water had accumulated in the large reservoir. When he arrived, water was running through the emergency spillway and leaking through a gopher hole on the embankment (near the top portion). The owner promptly called all of his downstream neighbors.

The water created a larger leak through this area and by 9:00 a.m. breached the embankment. There was no evidence of dam overtopping.

Fortunately, downstream damage was minimal. Several gravel roads were washed out. Damage also occurred to a bridge on U.S. Highway 200. The basement of one house downstream was flooded. The dam failure also reportedly caused downstream stock dams to break.

Taylor Creek Dam Failure - Photo by Candace Linder, NRCS

(Source: National Weather Service Report, Glasgow, Montana, U.S. Natural Resources and Conservation Service Engineering Trip Report, Glasgow, Montana)

Technical Manual for Dam Owners

Impacts of Animals on Earthen Dams

FEMA

Table of Contents

(DCR-VSWCB-034) (03/14)

1.0 Introduction and Purpose of Manual

1.1 Background

In 1999, the Federal Emergency Management Agency (FEMA) and the Association of State Dam Safety Officials (ASDSO) jointly conducted research and a workshop to shed light on the national problem of animal intrusion damage to earthen dams and the resulting safety issues. The FEMA/ASDSO survey and workshop united dam owners, engineers, state and federal regulators, wildlife managers, foresters, and academia to form an educated and experienced front against the growing problem of earthen dam damage and failures due to animal intrusion. The information generated by roundtable discussions and survey answers indicates that while most states recognize animal intrusion as a problem, only a handful know of guidance on dams and wildlife management practices available to the dam professionals and owners. Based on input from the dam communities, FEMA/ASDSO's mission to develop a guidance manual on the proper management of nuisance wildlife in the earthen dam environment became clear.

To determine the information needs of the dam community—and therefore the most appropriate focus of this manual—FEMA/ASDSO issued a survey in 1999 and used the survey input from the 48 state dam safety officials representatives and 11 federal agencies representing the Interagency Committee on Dam Safety (ICODS). Additionally, a second survey was issued in 2003 to identify the current needs of each state, determine what nuisance wildlife and damages the states encounter, and understand which mitigation methods are being used with success or failure. Four main ideas emerged from the two survey efforts; these ideas consequently steered the direction of this manual:

- Cumulatively, the states indicated a range of problems caused by numerous wildlife species relative to the operation of dams. This manual discusses 23 species with regard to their habitat, behavior, threat to dams, food habits, identifying characteristics, and management options: Muskrat, Beaver, Mountain Beaver, Groundhog, Pocket Gopher, North American Badger, Nutria, Prairie Dog, Ground Squirrel, Armadillo, Livestock (cow, sheep, horse, pig and wild pig), Crayfish, Coyote, Moles and Voles, River Otter, Gopher Tortoise, Red Fox and Gray Fox, Canada Goose, American Alligator, and Ants.

- While the states are fully aware of the potential adverse impacts wildlife activity can have on earthen dams (such as failure), private dam owners and local dam operators are often not aware of potential problems, and thus may

25: number of states that indicate animal activity has caused or contributed to unsafe dam operation or outright failure within the state.

9: number of states aware of information or guidance on the effects of animal activity on dams.

not conduct inspections with wildlife damage in mind. Local dam owners may not typically mitigate existing wildlife intrusion problems or prevent them in the future.

- States want to know how other states are successfully mitigating wildlife damages. Further, mitigation and prevention guidance should be developed and conveyed to the dam communities.

- Guidance booklets for local dam owners are needed to assist dam inspectors in identifying and mitigating animal intrusion issues.

Out of 48 states that responded to FEMA and ASDSO surveys, 25 document nuisance animals as the cause of dam failures or unsafe dam operations in their states. The U.S. Bureau of Reclamation, the National Park Service, and the U.S. Department of Agriculture document several similar cases at the federal level. State dam safety officials and federal agencies agree that animal burrows within dams can cause substantial and costly damage if left unmitigated and are consequently a major concern.

1.2 Target Audience, Purpose, and Application of This Manual

This manual provides technical guidance to dam specialists (including dam owners, operators, inspectors, state dam officials, and consulting engineers) in areas of focus identified through the two survey efforts and workshop. The purposes of this manual are to:

- Assist dam specialists in understanding the impacts wildlife can have on earthen dams.

- Provide dam specialists with basic information on habitat, range, description, and behavior of common nuisance wildlife to aid in their proper identification at the dam.

- Describe state-of-practice methods to prevent and mitigate adverse wildlife impacts on earthen dams.

- Provide state-of-practice design guidance for repair and preventive design associated with nuisance wildlife intrusion.

It is envisioned that the entire dam specialist community will use this manual to augment their routine duties in earthen dam management. This manual is presented as a process toward dam inspection and management that includes wildlife damage identification and control. This manual provides technical information and guidance on:

- How wildlife damage adversely affects the safe operation of earthen dams; specifically, hydraulic alteration, internal and external erosion, and structural integrity losses (Chapter 2.0).

- Dam inspections that incorporate a biological component to sensitize dam specialists to the aspects of their dams that attract wildlife and to understand where nuisance wildlife are likely to occur on the dam (Chapter 3.0).

- Biological data for specific nuisance wildlife to assist the dam specialist in identifying which nuisance wildlife inhabits the dam. Biological data will also assist in controlling nuisance wildlife (e.g., listed food sources can be removed to encourage the animal to leave the area) (Chapter 4.0).

- Dam design specifications and methods that can be incorporated into repair of existing dams or new dam designs to prevent wildlife intrusions (Chapter 5.0).

- Guidelines to determine when wildlife management should occur at a dam (beyond dam repair and prevention actions) and wildlife management methods that can be implemented when control of specific nuisance wildlife populations is deemed necessary. Specific methods discussed include habitat modification, use of toxicants and fumigants, trapping, and shooting (Chapter 6.0).

- The fiscal issues related to appropriate and timely wildlife management at earthen dams (Chapter 7.0).

1.3 Technical Resources Cited

The technical information provided in this manual represents the most current practices in the areas of wildlife data and management and engineering inspection and repair, as they relate to nuisance wildlife and their effects on safe dam operations. While numerous technical sources are cited throughout the document, three main sources form the backbone of this manual's technical understanding and recommendations. The first source is a manual titled *Prevention and Control of Wildlife Damage* (University of Nebraska, 1994). The data contained in the 1994 manual are considered the industry standard for pest control, and the manual is used as the handbook for those testing for licensure as pest control managers. It should be noted that the 1994 manual is under revision and a revised version will be completed February 2005. Until the release of the revised manual, the 1994 edition remains the leading guidance literature in this field and is accepted as the most current practice in nuisance wildlife management (Smith, Pers. comm., 2003; 2004). The second source is a booklet called *Prevention and Control of Animal Damage to Hydraulic Structures* (USDA, 1991). The 1991 booklet adapts some of the 1994 manual data for application to the dam environment. The last source is technical data on remedial dam repair design by Dr. B. Dan Marks, as presented in the 2001 ASDSO West Region Seminar on Plant and Animal Penetrations for Earthen Dams (ASDSO, 2001). Many other sources are also used throughout this manual to provide a cross-reference of data as well as a broad spectrum of information.

2.0 Impacts of Wildlife on Earthen Dams

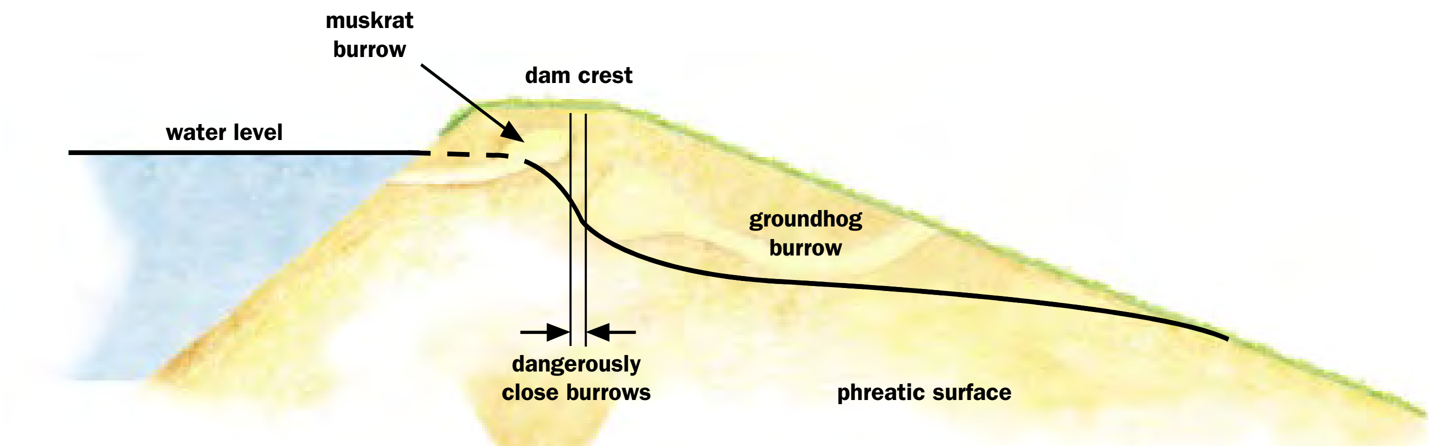


Figure 2-1. Upstream and downstream burrows can become dangerously close, causing internal erosion that may lead to dam failure.

Earthen embankment dams are used by private landowners and state and federal agencies to store farm water supplies, city water supplies, recreational waters, flood waters, and wastewater lagoons. Earthen dams rely on a thick placement of compacted soils to withstand the water pressure of the pool contained behind the embankment. Often constructed outside of developed areas, the earthen dam environment is usually near a water source and can contain a variety of vegetation; given these characteristics, earthen dam environments can be naturally conducive to use by wildlife. Wildlife inhabiting the dam can alter the dam environment through habitat establishment and use—beaver build dams, muskrat excavate dens, livestock feed on stabilizing vegetation. The natural instincts of wildlife to adapt and use their environment toward their survival can compromise the balance of engineered functions that maintain the viability of an earthen dam.

The first step in fortifying a dam against unsafe operations caused by wildlife damage is to understand what could go wrong if wildlife damage is left unchecked. While a dam owner may observe a few small burrows on the upstream and downstream slopes, it is important to understand that potential problems, like those burrows, often run deep below the surface. As such, the purpose of this Chapter is to discuss adverse engineering effects stemming from nuisance wildlife activity. Adverse effects caused by specific wildlife (as well as their identification and mitigation) are discussed in Chapters 4.0, 5.0, and 6.0.

2.1 Background

Embankment dams are vulnerable to damage from wildlife intrusions. Twenty-five states indicate that animal activity has caused or contributed to unsafe operation or outright failure of an embankment dam. Several animal species excavate burrows, tunnels, and den entrances for shelter, while other predatory animals will enlarge these structures via digging in search of prey. Similarly, herbivorous species will forage on vegetation growing on embankment dams. All of these occurrences create open areas in the embankment fill which are detrimental to the safety and performance of embankment dams. Some of these effects can be easily identified, such as surface erosion; other effects such as internal erosion may not become visible until dam safety is jeopardized.

(DCR-VSWCB-034) (03/14)

Homogeneous and zoned embankment dams are equally susceptible to damage from animal intrusions. The ultimate consequence from the intrusions depends on the specific engineering and biological characteristics of an individual dam.

Embankment dams can be generally categorized as either homogeneous (containing one material) or zoned (containing multiple materials). Zoned embankment dams usually contain a central core designed to produce a lower phreatic surface (static water level within a dam embankment) within the downstream slope than the theoretical surface often assumed for homogeneous embankments. Due to the variability of zoned embankments, this manual discusses only homogeneous embankments.

2.2 Hydraulic Alteration

The most significant and often least obvious impact of wildlife intrusions on embankment dams is hydraulic alteration. Hydraulic alteration and its effects can manifest in different ways depending on the type and location of intrusion, including flownet distortion and physical barriers to flow.

A distorted flownet may not be a visible problem but it can have the most dramatic impact. Flownet is a term referring to the theoretical description of water flow through and under an embankment dam. The phreatic surface, equal potential lines and flow lines associated with a flownet are defined by the physical dimensions of the dam, classification of soils in the dam, and variability of the reservoir normal pool. As such, each dam has a unique flownet. The presence of animal burrows, either on the upstream or downstream slope, can distort the established phreatic surface and impact the flownet. As illustrated on Figure 2-2, upstream burrows can allow the normal pool elevation to extend into the dam embankment, forcing the phreatic surface further into the embankment. Likewise, downstream intrusions can allow the phreatic surface to day-light higher on the downstream slope. The overall effect can be a significant alteration to the phreatic surface. Dramatic changes to the phreatic surface can shorten seepage paths, increase seepage volumes, decrease the factor of safety against slope failure, and cause internal erosion of embankment materials (piping).

Of these impacts, piping is most often cited as the greatest concern among dam safety professionals because it is progressive and can rapidly lead to failure of the dam. Piping is the uncontrolled movement of soil particles caused by flowing water. As shown on Figure 2-3, piping will often start in a burrow on the downstream slope. Flowing water moves soil particles from the embankment to the burrow, leaving a void that is quickly filled with soil particles from deeper within the embankment. Because water pressure and flow generally increase further into the dam embankment, the rate of movement of soil particles will also increase. A pipe is rapidly formed extending from the downstream slope to the upstream slope. A dam breach is almost certain to develop in these instances.

External problems can also arise from wildlife activity around an embankment dam. Though hydraulic barriers can result from the activities of several species, beaver cause perhaps the largest array of adverse effects. To create deep waters in which to hide from predators, beavers compact felled tree trunks, limbs, and other materials into a mound to restrict the natural flow of a water source. As a result, the hydraulic function of the dam is altered in several ways. First, beaver mounds may block principal and emergency spillways and riser outlets, resulting in increased normal pool levels and reduced spillway discharge capacity. Second, sudden high discharges from the dam could occur if the beaver dam fails. Third, beaver dams located upstream of the embankment dam can clog water control structures as debris from the beaver dam floats downstream. Finally, erosion of the downstream toe of the dam can occur as a result of elevated tailwater caused by beaver activity.

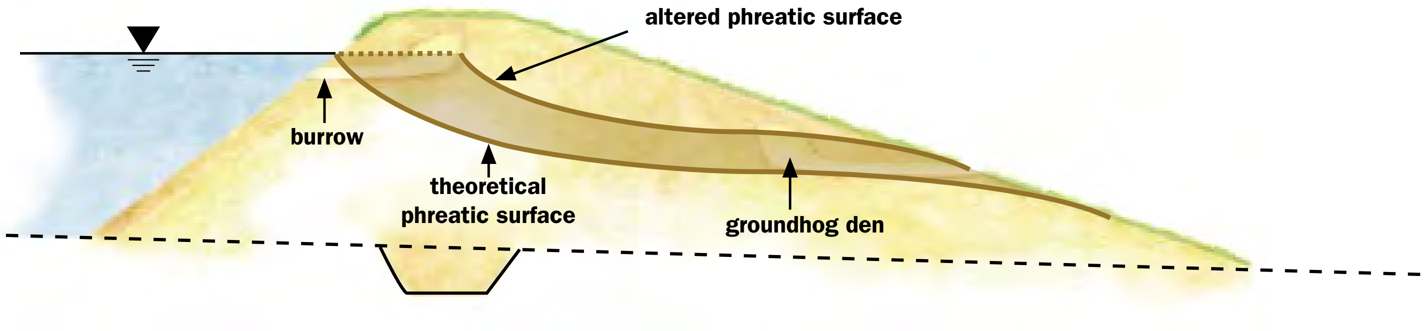


Figure 2-2. Burrows can alter dam hydraulics by shortening seepage paths.

2.3 Structural Integrity Losses

Wildlife excavate dens, burrows, and tunnels within embankment dams, causing large voids that weaken the structural integrity of the dam. Typical voids can range from the size of a bowling ball to a beach ball and much larger. Heavy rain and snow melt loosen soils surrounding a burrow, causing a localized collapse inside the burrow. In addition, a burrowing animal may encounter loose zones in the embankment (due to variability of constructed embankments) during burrow excavation, leading to a localized collapse. Animal dens also erode and collapse under the load of heavy equipment and other vehicles that use the crest of the dam as a throughway.

The collapsing soils will progressively lead to sinkholes or depressions appearing on the embankment surface. Because burrows can be under several feet of soil, the deformation or sinkhole visible at the surface could be several times the size of the original burrow. As illustrated on Figure 2-4, the collapsed soils can represent a significant portion of the dam embankment. Under the right circumstances, localized slope instability can result from a collapsed animal burrow. Depending on the location and number of collapsed burrows, dam safety or operation could be jeopardized. If portions of the crest are affected, a loss of freeboard can result, thus endangering the dam during storm events. Downstream slope failures, regardless of their extent, weaken embankment soils and reduce confinement of surrounding soils, thereby resulting in further weakening of embankment soils. Depending upon site and weather conditions, the process can progress slowly or rapidly, potentially leading to massive slope instability.

2.4 Surface Erosion

The foraging behavior of some animals on open area vegetation associated with dam embankments can reduce or eliminate vegetative cover on a dam. This increased feeding pressure on the dam's vegetative groundcover can lead to erosion paths and decreased soil retention on the dam's crest and slope. In addition, dams that are grazed by live-

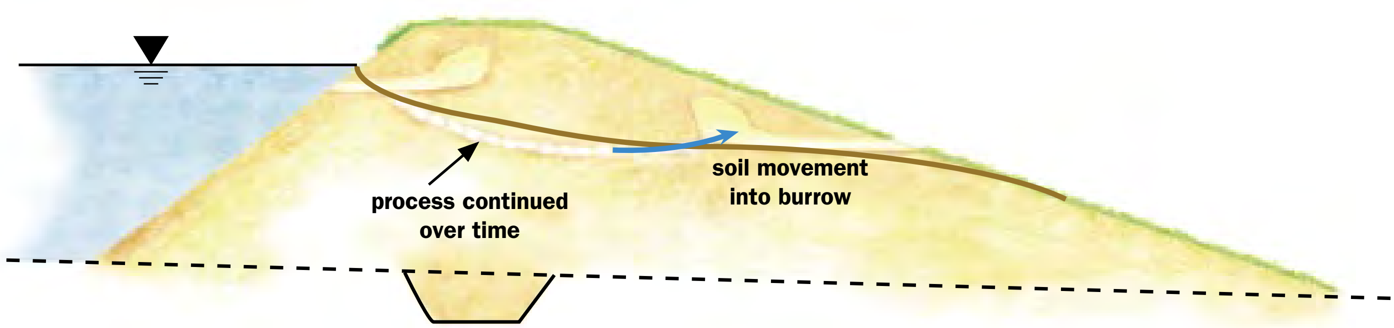


Figure 2-3. Burrows can lead to piping within an embankment.

stock often show increased rates of soil erosion because of the lack of stabilizing vegetation from grazing and trafficking, which can lead to irregular surface erosion and the formation of rills and gullies.

With continued neglect, these areas will require more than simple maintenance. In fact, given enough time, external erosion can lead to a reduction in freeboard and loss of cross section. In turn, these impacts can increase the dam's vulnerability to damage from high water during large storm events.

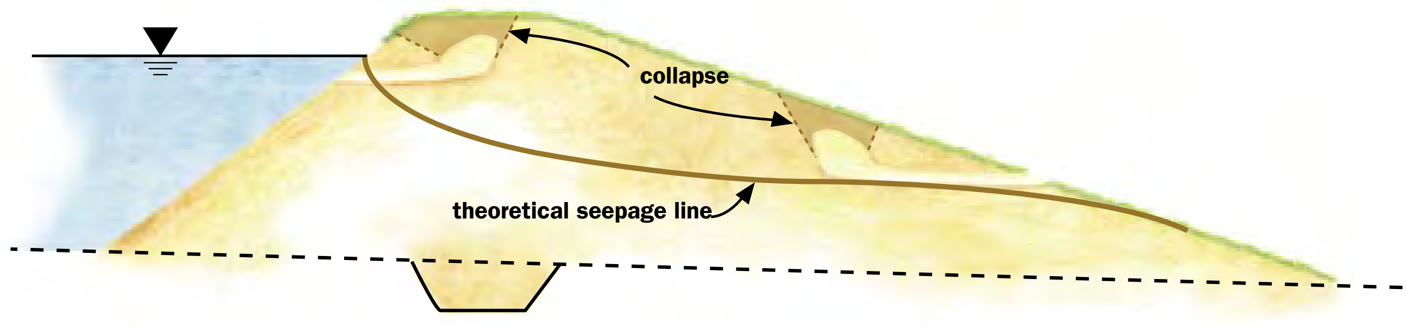
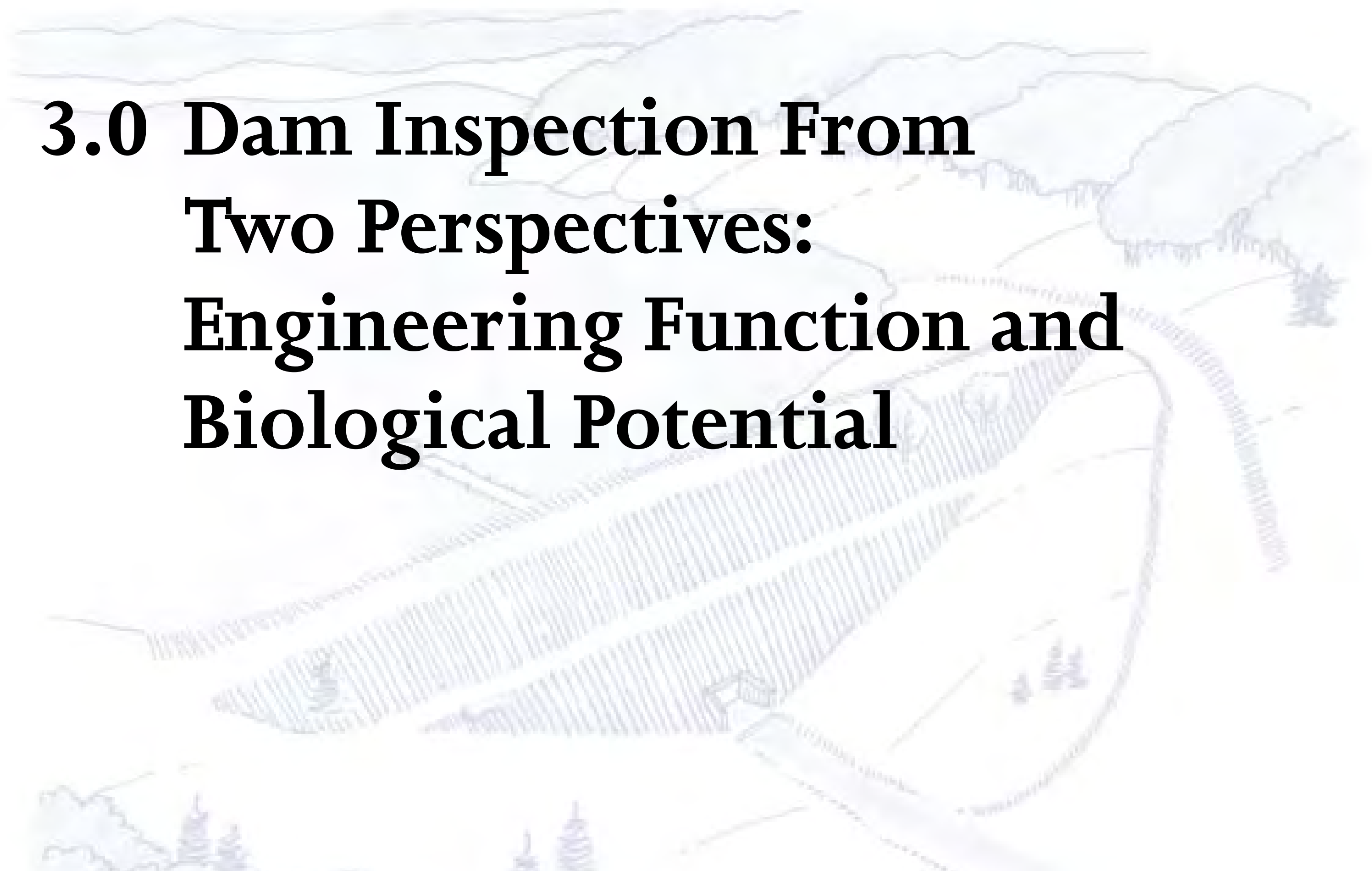


Figure 2-4. Burrows can collapse, leading to formation of sinkholes and loss of structural integrity.

3.0 Dam Inspection From Two Perspectives: Engineering Function and Biological Potential



The second step toward fortifying a dam against the effects of nuisance wildlife damage is the observation of clues left by wildlife in the dam environment. As such, regular inspection of the dam that incorporates wildlife activity recognition must be conducted by the dam owner, who is the first line of defense in protecting earthen dams. While the dam inspection is focused primarily on seepage, deformation, and structural deficiencies, the inspectors must also perceive wildlife clues left behind by dam inhabitants whose presence could cause trouble down the road. Toward this goal, this Chapter details an inspection procedure that pairs engineering inspection with key biological considerations to assist the dam specialist in viewing the dam from both perspectives (this methodology should be applied using the specific wildlife clues data presented in Chapter 4.0 of this manual).

3.1 Wildlife And The Earthen Dam

Through their natural desire to create dens, search for food, or escape predators, wildlife can cause a host of adverse impacts to an earthen dam which can lead to dam failure (refer to Chapter 2.0 of this manual for detail on the adverse impacts of wildlife activities). Though earthen dams are manmade, wildlife interacts with the earthen dam environment as if it were natural field or forest. To protect their dams, dam owners should know the biological potential of their dams—can wildlife find a suitable environment at the dam, and if so, which kind of wildlife will inhabit which locations of the dam? In answering these questions, it is helpful to know the characteristics that compose favorable habitat, and to realize that dams with diverse vegetation and site features often support a wide variety of wildlife. In assessing the dam for its biological potential, review the following relative to the dam area and surrounding areas (adapted from Benyus, 1989):

- **Vegetation Vitality:** Do the dam and adjacent areas contain dense vegetation at all levels (e.g., grass, shrub, and tree)? In general, greater variety of dense vegetation at levels ranging from groundcover to understory to canopy (regardless of vegetation type) allows for a greater variety of wildlife to inhabit the area. Small mammals, such as those discussed in this manual, prefer sites with adequate vegetation cover to hide from predators (see Chapter 5.2 for a discussion on appropriate vegetation at a dam).

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- **Mini-habitats:** Do the dam and surrounding area offer vegetative diversity? Different landscapes such as prairie and forest? Sun and shade? Deep and shallow water? An environment with a mosaic landscape provides several habitat types in one area, which can support a wider variety of wildlife.

- **Transition Zones:** Is there a clear edge between one habitat type and another? At the dam environment, the dam area (a lake/pond environment) may be surrounded by a grassy field environment, a shrub edge, or a forested environment. The junction where two environments meet is called an edge, and edges are the most heavily trafficked areas in an environment (a good place to view the wildlife in and around the dam area) because they provide safe travel corridors between the two habitat types and create a more diverse habitat than either of the two habitat types.

- **Size:** Does the dam environment provide a large land area that allows wildlife to meander without having to cross roadways or come into contact with people? Most species of wildlife prefer large parcels of land that provide habitat variety without human influence.

- **Unique Characteristics:** Does the dam contain unique land features? By its very nature, the dam environment is unique because it contains a water source. Wildlife prefers a constant water source, so dams with a permanent pool will be preferable to those with a fluctuating pool, such as those used for flood control or irrigation. However, any water source will attract wildlife to some degree.

3.2 Two-Perspective Dam Inspection Methodology

The typical dam safety inspection checklist requires observation of every dam feature. The checklist is developed by an individual state's dam safety program or federal organization such as the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, or the Federal Energy Regulatory Commission. All inspections focus on distinct physical regions, although the inspection checklists vary in length, listed inspection items, and required observations. Generally, the features are divided into clear components including:

- Upstream Slope
- Downstream Slope
- Crest
- Embankment-Abutment Contact (Groin)
- Principal Spillway
- Emergency Spillway
- Lake Drain or Outlet Works

Although inspection for animal intrusions is a facet of most if not all state inspection checklists, it is certainly not a major part of the inspection. Specific guidance on identifying animal intrusions or the typical intrusion locations of specific animals is not provided on the checklists. An inspector lacking this information may be unable to adequately inspect their dam for animal intrusions, much less adequately identify and mitigate the nuisance animal. As such, this manual presents an inspection methodology that combines engineering and biological considerations, which when viewed together, allow a dam specialist to view the dam comprehensively.

For the purposes of this manual, the dam is divided into six zones: Upstream Slope, Dam Crest, Upper Downstream Slope, Lower Downstream Slope, Downstream Toe, and Spillway, Outlets, and General Areas (Figure 3-1). The risk posed by animal intrusions is greater in some zones than in others. As such, the zones are overlapped to emphasize the critical nature of the area and to require inspection of the area twice to ensure that biological clues are sighted (ASDSO, 2001). Further discussion of the six zones relative to risk, restoration, and repair of animal intrusions is provided in Chapters 5.3 and 5.4.

When considering animal intrusions, inspection of each zone should consider not only physical evidence of an animal presence (e.g., burrow entrance), but also the habitat and biological factors that attract wildlife to the dam and sustain them once they have become established (Figure 3-2). Understanding both the engineering and biological aspects of animal intrusions into embankment dams is critical in eliminating or at least controlling the intrusions.

3.2.1 Zone 1: Upstream Slope Area

Engineering Perspective: The goal of inspecting the upstream slope of the earthen dam is to see the entire surface clearly. To ensure the inspector views the entire slope surface, the inspector must walk back and forth across the slope utilizing one of two patterns: zig-zag or parallel. In general, the zig-zag method is best for small dams and mild slopes (Figure 3-3, shown on page 17). It may prove difficult to move in a zig-zag pattern on large dams and steeper slopes, and in these cases the parallel pattern is suggested (Figure 3-4, shown on page 17).

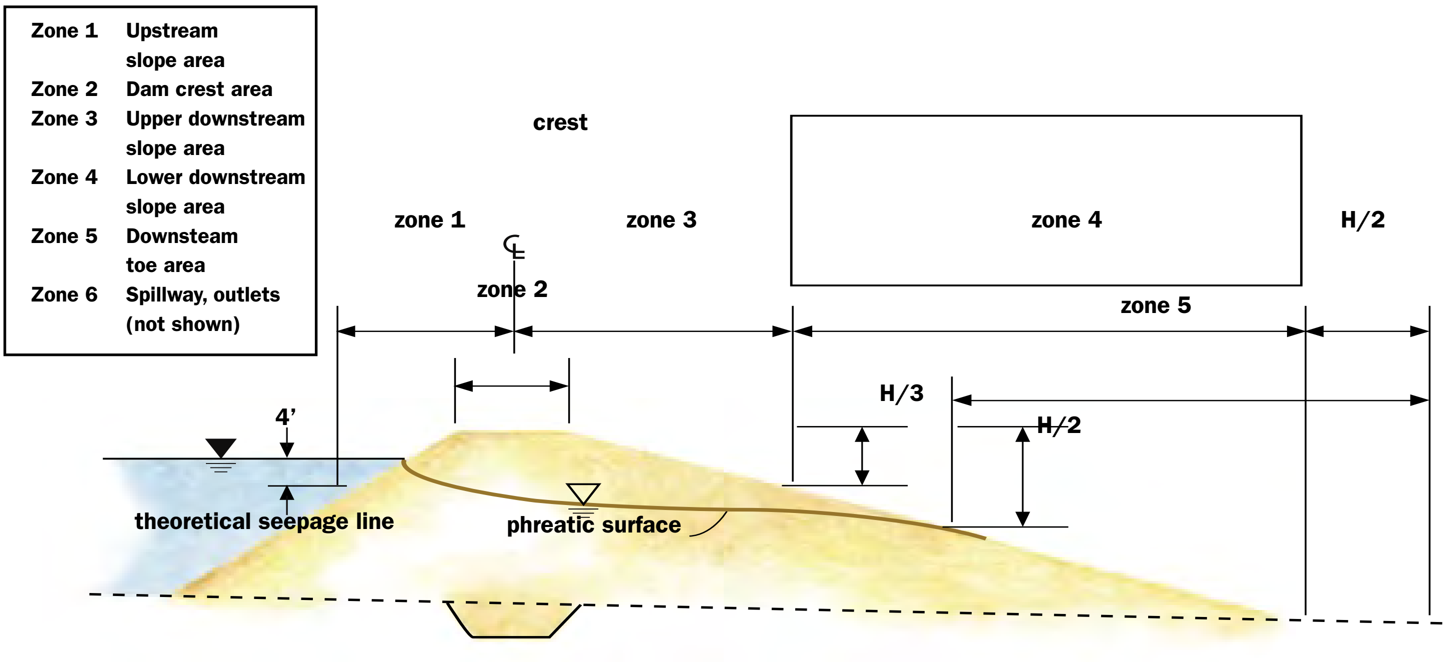

Figure 3-1. Dam Inspection Zones.

While walking the slope, the inspectors should routinely stop and view the alignment of the surface by turning their gaze a full 360 degrees. Checking the slope frequently and from many viewpoints and distances can reveal deficiencies and distortions (such as surface distortions or vegetation changes) that might otherwise go undetected. The inspectors should observe berms on the upstream slope by centering their eyes on the line being viewed and moving their body from side to side to view the line from several angles. This approach will help the inspector identify misalignments.

A typical dam safety inspection report should comment on vegetation, slope protection, erosion, instabilities, and animal burrows observed in Zone 1. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspector should look for the following: animal burrow entrances, mounds of excavated soil, debris (evidence of beaver activity), cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. These conditions often indicate damaging animal activity. The inspection report should note whether the deficiencies warrant monitoring, repair, or further investigation.

Biological Perspective: This zone is primary habitat for aquatic burrowers such as muskrat and beaver, which generally burrow from 6 inches to 4 feet below the water line upward toward the crest. Nutria prefer to dig dens in the zone where land and water meet, which could be dominated by aquatic vegetation. River otters are often found living in abandoned muskrat, beaver, and nutria burrows, and can construct slides on slopes and bare areas where they repeatedly enter and exit the water. Livestock often traverse the upstream slope area—look for hoof tracks, rills, and eroded pathways. Canada geese and livestock feed on embankment slopes causing eroded areas and ruts. Crayfish and alligator may inhabit the banks and shallows of the upstream slope area. Ants may dig tunnels in the slope, loosening existing cracks. Mountain beaver or armadillo may be found along the wet edge of the pond, especially if a forest fringe or wooded area is nearby. Moles may hunt in the moist soils near the reservoir.

3.2.2 Zone 2: Dam Crest Area

Engineering Perspective: Similar to inspecting the upstream slope, the crest can be viewed using either a zig-zag or parallel pattern, with the primary goal being to view the

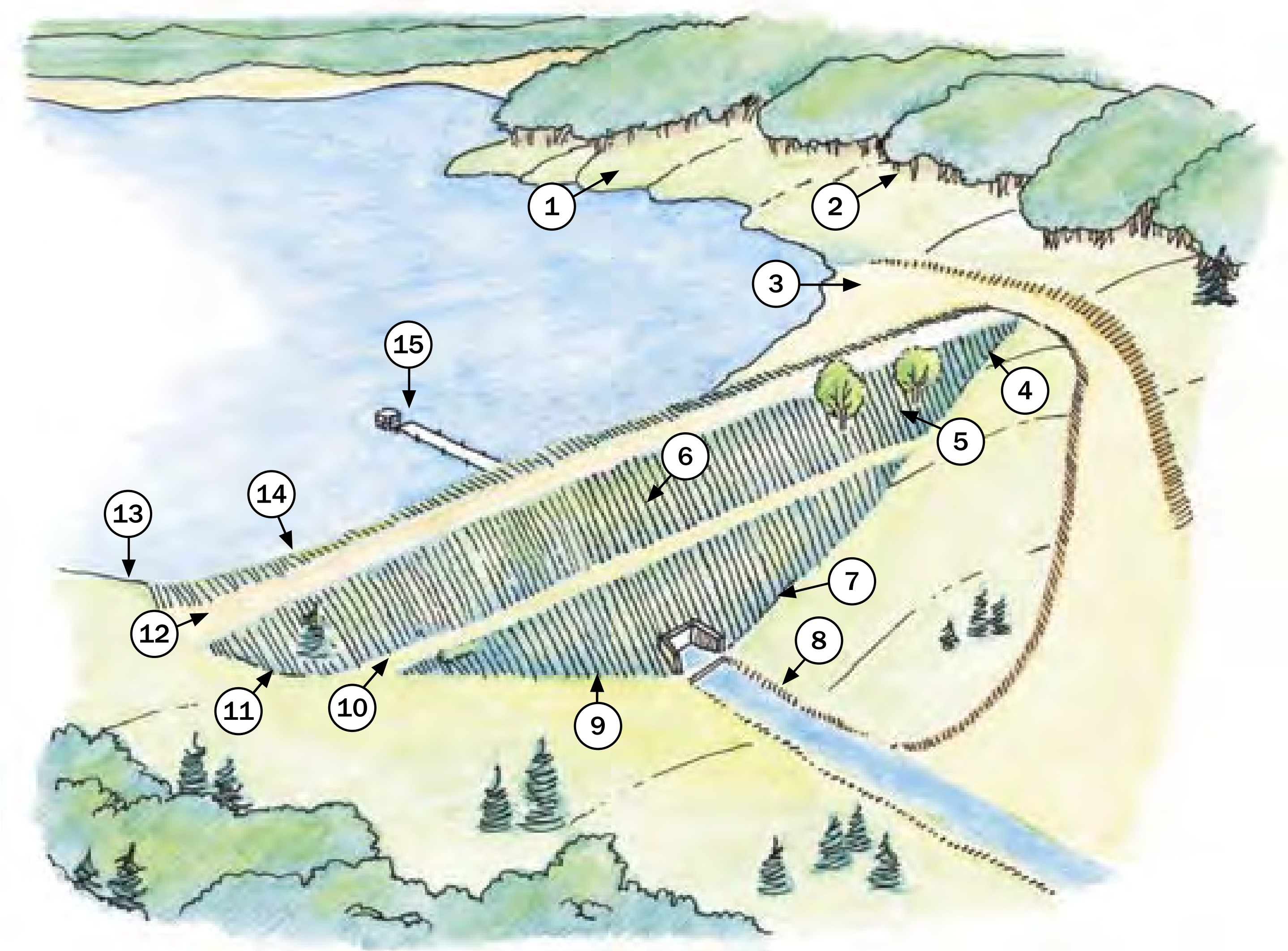

Figure 3-2. The Earthen Dam from Biological and Engineering Perspectives.

1. **Upland Areas.** Many species live in the upland areas, away from the water. Even the downstream slope, abutments, and groin areas of the dam can be considered upland in terms of habitat.
2. **Forest Fringe.** The zone between two environments (the edge) is the best place to observe those species living at and around the dam. The more habitat types at the dam, the greater number of species likely to inhabit the dam. Mountain beaver or armadillo prefer forested/wooded areas.
3. **Emergency Spillway.** Beaver often dam the spillway, causing the pond water levels to rise.
4. **Left Abutment contact.**
5. **Inappropriate Vegetation on Embankment.** Many dams contain vegetation other than mowed grass. Improper vegetation provides cover and food supply, which encourage animals to inhabit the dam.
6. **Downstream Slope.** This area is often the location where groundhogs, coyote, and fox excavate burrows. Canada geese will feed on the downstream slope, which could cause loss of protective vegetative cover and associated erosion. Species that prefer upland areas could be found in this area.
7. **Left Groin.**
8. **Discharge Conduit and Outlet Channel.** Beaver can dam the outlet structure. Aquatic species may inhabit this area depending on water flow and availability of vegetation.
9. **Toe of Embankment and right groin.**
10. **Erosion Pathways on the Embankment.** Livestock traverse the embankment creating erosion pathways.
11. **Right abutment contact.**
12. **Crest.** Livestock traverse the crest which creates ruts. The ceilings of beaver and muskrat burrows in the upstream slope are often just below the dam crest.
13. **Aquatic Fringe.** The zone where the bank meets the pond usually contains aquatic vegetation preferred by many animals such as nutria.
14. **Upstream Slope.** Beaver, muskrat, and nutria prefer the upstream slope for burrow excavation. Alligators, otters, and turtles usually live in the shallow waters near the upstream slope.
15. **Principal Spillway (with riser and trash rack).** Beavers can block principal spillways by constructing dams.

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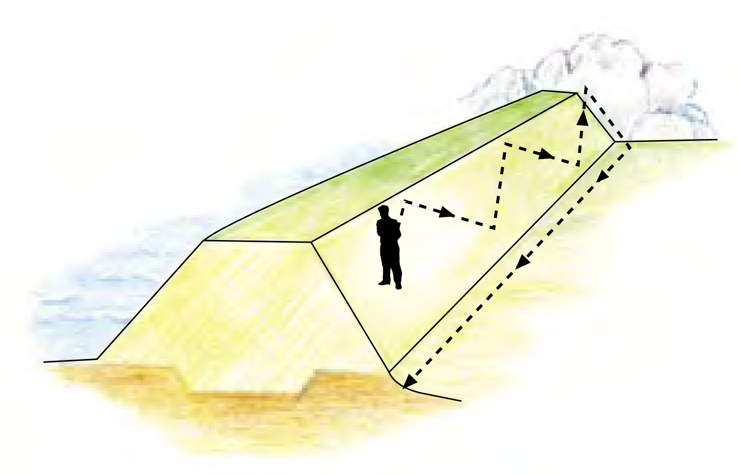

Figure 3-3. The zig-zag method of inspection is best used on small dams and mild slopes.

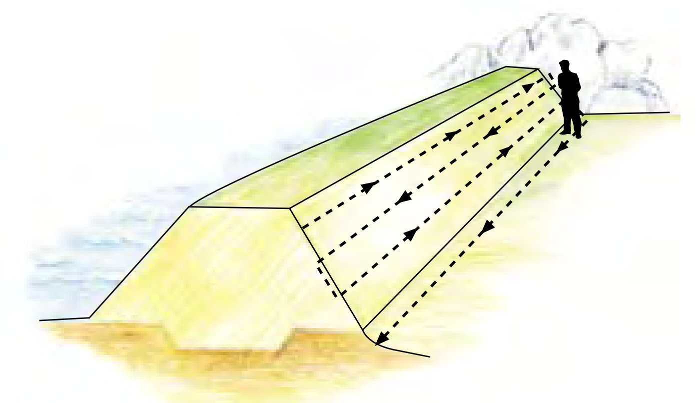

Figure 3-4. The parallel method of inspection is best used for dams with steep slopes.

entire crest from several perspectives and distances. Similar to the upstream slope inspection, the inspectors should center their eyes on the crest line, moving their body from side to side to view the line from several angles. Fixed features that can mark horizontal and vertical points along a dam can be used as reference lines; guardrails, a row of posts, or parapet walls are good reference lines (use caution when using man-made reference lines which can be moved). The reference line must be viewed from several different perspectives; first, the inspectors should sight directly on the reference line and then move their body to either side. This method will assist the inspector in detecting a change in the uniformity of the crest. Zone 2 overlaps Zone 1 on one-half of the crest width. This is intentional, and is meant to emphasize the critical nature of the area by requiring inspection of the area twice (ASDSO, 2001).

A typical dam safety inspection report should comment on width, alignment, vegetation, erosion, instabilities, and animal burrows observed in Zone 2. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspector should observe the following: animal burrow entrances, mounds of excavated soil, cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. As with Zone 1, these issues can indicate animal activity. The inspection report should note whether the deficiencies warrant monitoring, repair, or further investigation.

Biological Perspective: Dens of beaver and muskrat are typically located just below the crest (look for depressions in the crest since the burrow entrance is typically underwater), and livestock often traverse the crest (look for hoof tracks, rills, gullies, and eroded pathways). Terrestrial wildlife such as groundhogs, ground squirrels, pocket gophers, foxes, coyote, and badgers may inhabit or hunt in the crest area. Moles may dig burrows in the dry, upland area of the upper upstream slope/crest that lead to their hunting grounds in the cool, moist soils near the reservoir pool. Vehicular traffic on crests may discourage wildlife establishment. Additionally, the crest is often constructed of well-compacted material, which is not attractive to most burrowing wildlife. Ants may dig tunnels in the crest, loosening existing cracks.

3.2.3 Zone 3: Upper Downstream Slope Area

Engineering Perspective: Inspecting the downstream slope is similar in method to inspecting the upstream slope. It is suggested that the downstream slope be viewed from a distance at a time of day when the angle of the sun is low so that wet areas, which will reflect sunlight, are seen more easily. Zone 2 overlaps Zone 3 on one-half of the crest in order to draw additional attention to the crest area.

A typical dam safety inspection report should comment on alignment, vegetation, erosion, instabilities, and animal burrows observed in Zone 3. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspector should observe the following: animal burrow entrances, mounds of excavated soil, cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. As with the previous zones, these issues can indicate animal activity. The inspection report should note whether the deficiencies warrant monitoring, repair, or further investigation.

Biological Perspective: This zone is the most attractive for terrestrial animal activity and is preferred by groundhog, fox, and coyote for burrow and den sites. Prairie dog, pocket gopher, ground squirrel, and groundhog may inhabit the downstream slope area; if they do, predators such as badger, coyote, and foxes may choose this zone as a hunting ground. Gopher tortoises, which are strictly terrestrial, would prefer this zone as it is dry and located well-above the phreatic surface. Look for large dens, burrows, and piles of dirt outside of small burrows. Ants may dig tunnels in the slope, loosening existing cracks. Livestock and Canada geese may graze on the stabilizing vegetation. Moles may inhabit this area and dig burrows from the slope area to an adjacent outlet or spillway for the moist soils they prefer as a hunting ground. Armadillo, mountain beaver, or voles may inhabit this area if the dam is improperly vegetated with trees, shrubs, or a thick understory.

3.2.4 Zone 4: Lower Downstream Slope Area

Engineering Perspective: Inspection of this zone is similar to inspecting the upstream and upper downstream slopes, but the inspector should give greater scrutiny to the downstream slope below the pool elevation. In most embankment dams, the potential for seepage through the embankment materials day-lighting on the downstream slope increases dramatically further down the downstream slope. As shown on Figure 3-1, the theoretical phreatic surface typical for homogeneous embankment dams intersects the downstream slope. Therefore, the presence of an animal burrow in this area could shorten seepage paths, increase hydraulic gradients, and ultimately cause internal erosion of the embankment materials. A more detailed description of the potential impacts from animal intrusions is provided in Chapter 2.0.

A typical dam safety inspection report should comment on vegetation, erosion, instabilities, seepage, and animal burrows. The potential for uncontrolled seepage through animal burrows in Zone 4 is significantly greater than in the three previous zones. Therefore, seepage observations are important in Zone 4. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspector should scrutinize the following: animal burrow entrances, mounds of excavated soil, concentrated seeps, wet/spongy areas, cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. As with previous zones, these issues can indicate animal activity. The inspection report should also note whether the deficiencies warrant monitoring, repair, or further investigation

Biological Perspective: This zone would also likely support terrestrial wildlife as described under Zone 3. Burrows constructed in lower Zone 4 (where it overlaps with Zone 5) will become saturated depending on depth, which is not preferred by most burrowing animals; therefore, burrows of terrestrial animals (i.e., gopher tortoise, fox, coyote, and groundhog) will occur in upper Zone 4. If a resident beaver constructs a dam that retains water, then muskrat, beaver, and otter will occupy inundated downstream slopes and outlet areas. Moles may hunt in the downstream slope if soils are moist, and the mountain beaver or armadillo may inhabit this area if the vegetation includes trees, shrubs, and a thick understory. Ants may dig tunnels in the slope, loosening existing cracks. Livestock and Canada geese may graze on stabilizing vegetation.

3.2.5 Zone 5: Downstream Toe Area

Engineering Perspective: Inspection of this zone is similar to inspecting the upstream slope and upper/lower downstream slopes, but Zone 5 is the most critical area because of the potential proximity of the phreatic surface to the downstream slope in this zone. Therefore, as in Zone 4, the presence of animal burrows in this area could shorten seepage paths, increase hydraulic gradients, and ultimately cause internal erosion of the embankment materials.

A typical dam safety inspection report should comment on vegetation, erosion, instabilities, seepage and animal burrows in Zone 5. The potential for uncontrolled seepage through animal burrows in Zone 5 is significantly greater than in Zones 1 through 3, and somewhat greater than in Zone 4. Therefore, seepage observations are critical in Zone 5. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspectors should observe the following: animal burrow entrances, mounds of excavated soil, concentrated seeps, wet/spongy areas, cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. As with previous zones, these issues can indicate animal activity. The inspection report should note whether the deficiencies warrant monitoring, repair, or further investigation.

Biological Perspective: Burrows constructed in Zone 5 will become saturated depending on depth, which is not preferred by burrowing terrestrial animals (i.e., armadillo, mountain beaver, vole, mole, gopher tortoise, fox, coyote, and groundhog). If a resident beaver builds a dam that retains water, then muskrat, beaver, nutria, and otter will occupy inundated downstream slopes and outlet areas, if appropriate vegetation has become established. Ants may dig tunnels in the slope, loosening existing cracks. Livestock and Canada geese may graze on stabilizing vegetation.

3.2.6 Zone 6: Spillway, Outlets, and General Areas

Engineering Perspective: The best approach to inspecting spillways and outlets is to view all surface and internal areas by walking closely along or within the structure, observing confined space entry requirements. The inspector should enter the conduit and view the internal structure using a flashlight, providing the conduit is of the appropriate size and in safe repair. The inspector should use binoculars or a camera/video camera with the appropriate lens to document the conduit condition if the conduit is not accessible (e.g., located in the water separated from the shoreline or embankment). Underwater features can be viewed via use of boats or underwater divers. Shorelines and upstream areas should be inspected by walking or using vehicles to traverse the inspection areas. Other appurtenant works should be inspected up-close.

Biological Perspective: Beaver will construct dams at the spillway locations to capture and reroute water flow. Look for gnaw marks in a circular pattern on tree trunks, beaver dams, and otters playing in the beaver dam waters. Aquatic animals such as muskrat and nutria may be found at these locations if the beaver dam retains water, and if sufficient aquatic vegetation has become established. Armadillo or mountain beaver may inhabit the area if a forest fringe or wooded area is adjacent to the water source.

4.0 Overview and Identification of Nuisance Wildlife

The FEMA/ASDSO workshop and 2003 dam safety specialist surveys indicate that several species damage earthen dams across the nation. This Chapter discusses 23 animals identified by the states as presenting the greatest threats to safe dam operations. Tracks, photographs, and range maps are provided for each animal, as well as a description of the specific threats each animal poses to the earthen dam environment, its preferred habitat, food habits, behavior, and field-identifying tips specific to each animal. It should be noted that some information is difficult to present depending on the animal (e.g., crayfish tracks) and in these cases, such information is omitted.

In a general sense, it is envisioned that a dam specialist will use this information to gain a better understanding of the wildlife that inhabits a dam. To a greater degree, it is hoped that this information will go hand in hand with overall dam management to assist a dam specialist in knowing where to look for wildlife damage (e.g., burrow sites), indicate which animals caused the damage via specific descriptors, and lead the dam specialist toward appropriate damage repair, prevention, and wildlife management (see Chapters 5.0 and 6.0 for dam repair, damage prevention, and wildlife management methods).

4.1 The Importance of Accurate Wildlife Identification

During the regular dam inspection detailed in Chapter 3.0 of this manual, the dam specialist will have viewed the dam from both engineering and biological perspectives. In doing so, the specialist may have identified burrows just below the water-line, observed floating rafts of vegetation on the water, trails from the water to the bank, and noted an abundance of aquatic vegetation along the shoreline. Application of the information in this chapter will assist the dam specialist in putting the above clues together to determine which animal is damaging the embankment.

Given the dynamic nature of wildlife and its desire to avoid human interaction, a dam owner will seldom witness wildlife causing damage to dams. However, proper identification of nuisance wildlife is critical so that dam repair and wildlife management methods can be appropriately and lawfully applied to mitigate specific species and their impacts to the earthen dam.

A dam environment that has high biological potential (refer to Chapter 3.1 for discussion of biological potential) will most likely support several nuisance species; however, not all species living at the dam are necessarily in need of management. To apply mitigation that blankets all animals seen at the dam may be a waste of time and money, not to mention unnecessarily damaging to the environment. For this reason it is important to carefully evaluate the biological evidence at the dam to accurately identify the species responsible for the damage. For example, beaver and otters often live in the same environment, and otters often opt to use beaver dens instead of creating their own. In this case, the otter may be seen living in the den, but the beaver is the species actually responsible for the burrowing activity. Therefore, mitigation should be geared toward the beaver, and not necessarily the otter, which will live in hollow logs and rock crevices just as comfortably. On the other hand, several species may be responsible for compromising activities at the dam, and dam repair, prevention action, and wildlife mitigation will need to be geared toward several species. In essence, application of the information provided in this Chapter will assist in accurate identification of the problematic species, which will help the dam specialist appropriately manage the dam without spending unnecessary energy or funds.

Misidentification of a wildlife species may result in inadequate mitigation, which could allow damage to continue, perhaps leading to dam failure. As wildlife identification can be difficult, a dam owner may benefit from using a wildlife specialist or professional trapper to positively identify the species so that proper wildlife mitigation can be developed. Appendix A contains state wildlife contacts, and state trapper information can be obtained at www.nationaltrappers.com.

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4.2 Identifying Nuisance Wildlife

4.2.1 Muskrat Overview

Muskrat(Ondatra zibethicus) are semi-aquatic rodents with brownish-black fur and with a body 10-14 inches long and a tail 8-11 inches long. Muskrats have large, partially-webbed hind feet and a vertically flattened tail, which they use to propel themselves through water.

Threat to Dams: Muskrats dig fairly large burrows that can lead to internal erosion and structural integrity losses in the earthen dam. Muskrats will continue to dig upward into the embankment as the phreatic surface rises; internal burrows can become extensive.

Habitat and Home (Figure 4-1): Muskrat inhabit freshwater and saltwater marshes, lakes, ponds, rivers, and other water-courses, where water is calm or very slowly moving. Musk-rats prefer water courses that are about 3-4 feet deep that don't freeze completely in the winter and contain abundant cattails or aquatic vegetation. Muskrats typically burrow

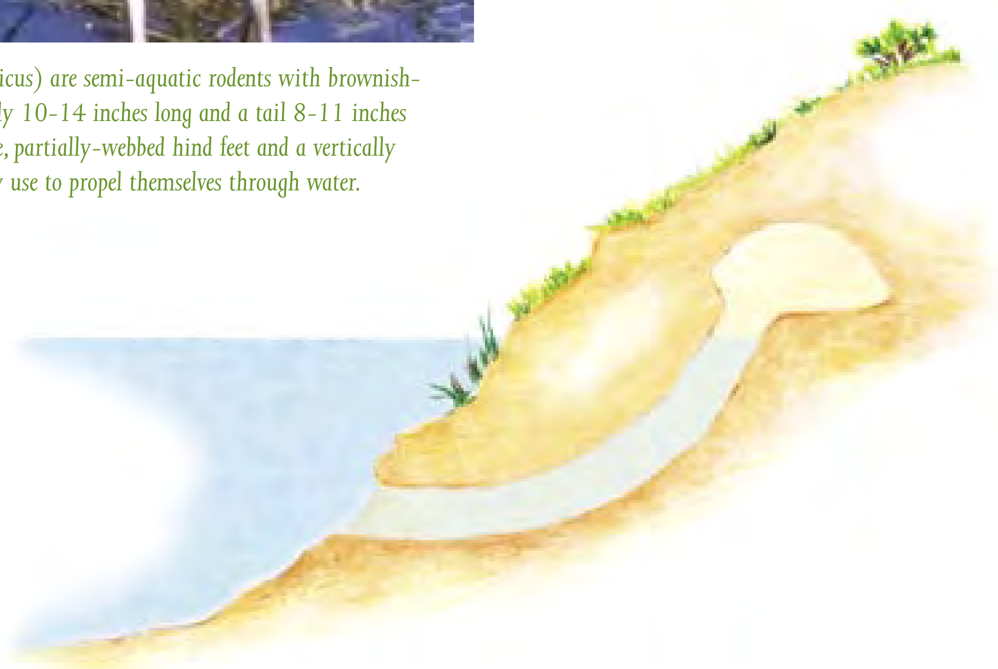
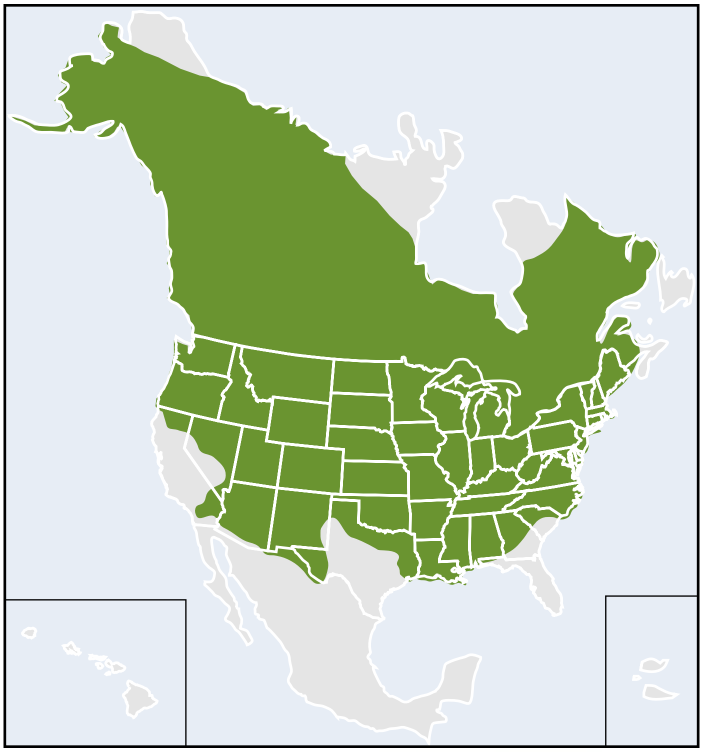
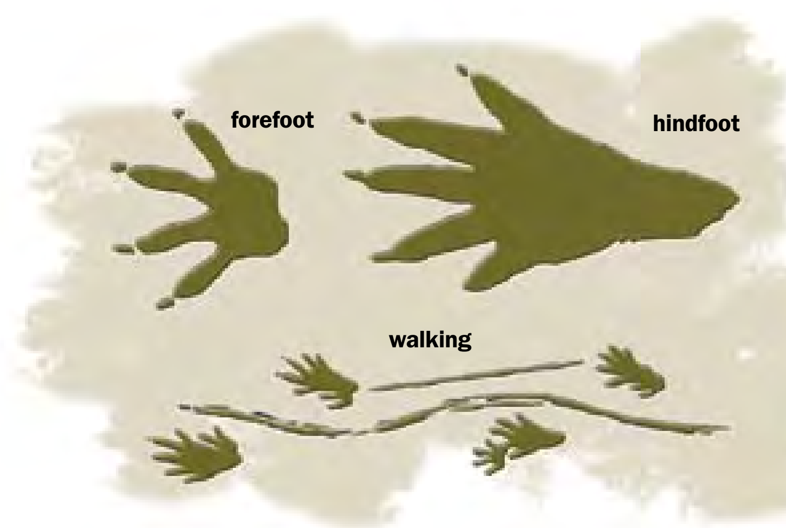


Figure 4-1. Muskrat dig dens in the upstream slope, with the entrance tunnel beginning about 6-18 inches below the water line.



Range of the muskrat in North America.



In very clear tracks, a small fifth toe can be seen on the outside of the front foot pad. All toes, except the nubbin, will show claw prints. The muskrat's vertically flattened, bare tail will create a drag mark in the center of the prints.

into a dam's upstream face. Their burrows begin from 6 to 18 inches below the water surface, and breather holes and escape holes can be observed above the water line. If the water level rises, the muskrat will excavate a dry chamber by digging higher into the embankment at an upward slant. Muskrats also build conical houses out of marsh vegetation, but usually excavate and use burrows when inhabiting earthen dams and other hydraulic structures (USDA, 1991). Detection of muskrat can be difficult if slopes of the dam are improperly vegetated, as their burrows may be covered over (see Chapter 5.2 for a discussion on improper vegetation at an earthen dam).

Muskrats are considered a significant dam safety issue in 71% of the surveyed states.

Food Habits: Muskrats are primarily herbivores and prefer to feed on cattails, grasses, smartweed, duck potato, water lily, sedges, and other aquatic plants. When vegetation is scarce, muskrat will feed on bivalves, crustaceans, insects, and sometimes fish (University of Nebraska, 1994).

Behavior: Muskrats can often be seen swimming at any hour of the day however they are most active at twilight. Muskrats often construct roofs over floating rafts of vegetation so that they have a covered place to eat. These huts can be found floating on the water and are especially important to the muskrat in winter when cooler weather can chill the animal's naked tail and feet (USDA, 1991; Benyus, 1989).

Field Tip: Listen for a loud splash when nearing the water. Muskrats plop into the water when approached to alert other muskrat of human activity. Muskrats sometimes hold their tails out of the water as they swim (Benyus, 1989).

4.2.2 Beaver Overview

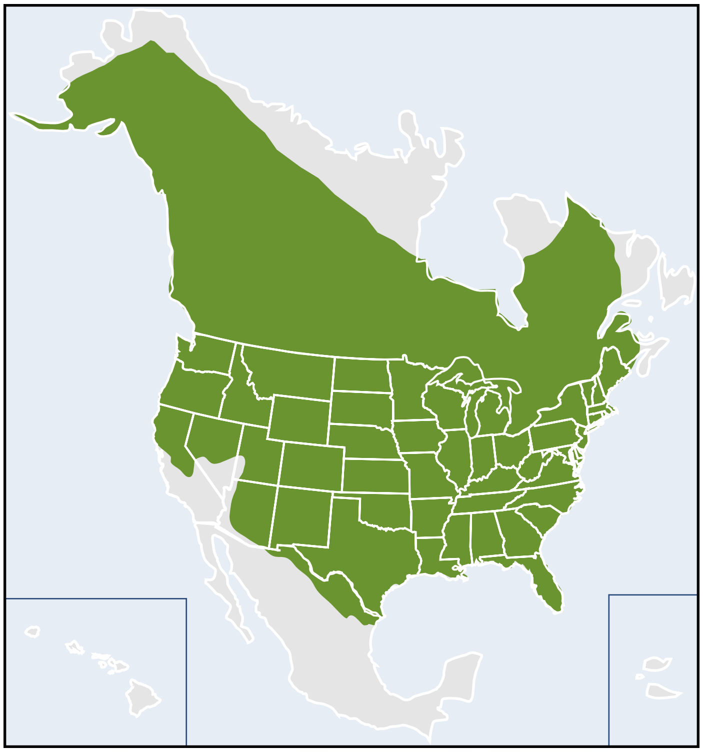
The Beaver (Castor canadensis) is the largest rodent in North America weighing 45-60 pounds, with a body measuring 25-30 inches and a tail measuring 9-10 inches. Beavers are typically aquatic mammals, with webbed feet that are adapted for swimming and a flattened tail. Beavers vary in color but the most common body fur is reddish-brown and the belly fur is usually gray (USDA, 1991).

Threat to Dams: Beaver can cause extensive damage to earthen dams by excavating bank burrows, which can cause internal erosion or structural integrity losses. Beaver dams constructed across spillways can cause adverse hydraulic effects and result in flooding or failure of the spillway or the earthen dam itself. Beavers often clog the intake and outlet structures with their cuttings.

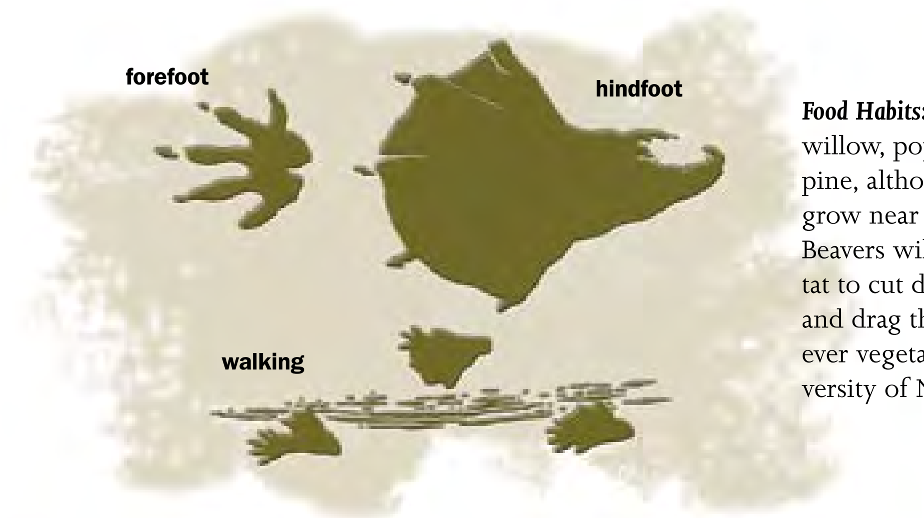
Habitat and Home: (Figures 4-2, 4-3, 4-3A and 4-4): Beaver can be found throughout the continental United States wherever there is a year-round source of water. However, beaver will avoid an aquatic site that does not contain preferred foods or have adequate sites for lodges, dens, or dams (University of Nebraska, 1994). Beaver lodges are easy to identify; they are dome-shaped, built of limbs and

Beavers are considered a significant dam safety issue in 67% of the surveyed states.

Figure 4-2. The ceiling of a beaver den is often just below the crest of the dam.



Range of the beaver in the North America.



Beaver tracks are not a reliable way to identify their presence due to their walking pattern. The beaver's hind foot is placed on top of the front foot's track and the wide tail, which drags along the ground, smears both to a point where identification becomes nearly impossible.

logs, may reach 5-6 feet above the water line, and be 12-14 feet wide (Benyus, 1989). Beavers have also been known to create tunnels and dens. Beaver tunnel entrances have been observed 1-4 feet below the water level. Beavers burrow into the dam from below the water line upwards toward the crest, where the beaver will excavate their den. The entrance to the lodge or bank den is typically under water, with the interior den being several inches above the water surface. All lodges and bank dens have at least two entrances, and perhaps four or more (University of Nebraska, 1994).

Beaver dens are often excavated just below the dam crest within the dam. A den roof collapse at this location can create voids in the crest and upstream slope.

Food Habits: Beaver prefer to eat tree species such as aspen, willow, poplar, cottonwood, sweetgum, blackgum, and pine, although beaver will also eat most woody plants that grow near water, as well as herbaceous and aquatic plants. Beavers will travel 100 yards or more from their water habitat to cut down crops or trees growing in adjacent habitats and drag them back to their pond home. Beaver use whatever vegetation they don't eat for dam construction (University of Nebraska, 1994).


Figures 4-3 and 4-3A. Beaver dams can block emergency spillways causing water levels behind the dam to rise.

Figure 4-4. A lodge can reach 5-6 feet above the waterline.

The ranges for beaver, nutria and muskrat overlap, and their damages can appear similar. Careful examination of the damage, burrows, and proper use of the field tips listed in this manual will assist in accurate species identification and management.

Behavior: Beavers construct dams to create a depth of water suitable for them to hide from predators as they travel to their shore feeding grounds. Beaver use a variety of materials to construct these dams—the use of wood, fiber, metal, wire, and rocks is not uncommon. Beavers leave their lodge at dusk and spend most of the night working (removing shoreline trees, constructing dams, gathering food). However, in the fall season it is not uncommon to see a beaver working in the daytime as they gather food for the winter (Benyus, 1989).

Field Tip: Perhaps the best indication of beaver is their dams. Dams are typically a few feet long, but can be up to several hundreds of feet long. A second indication is the presence of canals, which beaver build in the water to help them transport the trees they fell to construct the dams. Gnaw marks in a circular pattern on tree trunks are also good indicators of beaver, and trees cut by beavers show a distinctive tapered cone at the end of the trunk. An audible sign of beaver is the loud slap of their horizontally flattened tail on the surface of the water to alert other beaver to the presence of predators (Benyus, 1989).

4.2.3 Mountain Beaver Overview

Mountain Beaver (*Aplondontia rufa*) is typically found in Washington, Oregon, and portions of California. Mountain beaver neither prefer mountainous habitat nor are true beavers. These rodents have short, heavy bodies and are dark brown above and lighter brown below; they resemble a tailless muskrat. Mountain beavers have long, strong claws, which they use to create burrows up to 19 inches in diameter in wet soil near dense water-side vegetation.

Threat to Dams: Mountain beavers divert waterflow by blocking water with vegetation. The shallow location of the extensive burrows will often cause the ground to cave in. The mountain beaver's activities could result in hydraulic alteration and structural losses.

Habitat and Home: Mountain beavers prefer habitats in forested areas where the canopy is open enough to allow dense understory vegetation. If a dam is covered with trees and thick understory, then a mountain beaver will likely find a comfortable habitat. Within this area, mountain beaver prefer moist gullies, and vegetated hillsides or flat areas that are not prone to flooding. Habitats dominated by red alder, salmonberry, huckleberry, and bracken and sword ferns are preferred by the mountain beaver. Mountain beavers dig extensive burrows that can cover a quarter-acre, are usually located near vegetative cover, and are generally 1-6 feet deep with 10-30 open entrances. The burrows contain deep (1-9 feet) nesting and food chambers usually located about 3 feet below ground surface; the chambers can be large, usually measuring 2 feet in height and 2 feet in diameter. Mountain beavers do not like their burrows to be wet and will leave a burrow once it is flooded (University of Nebraska, 1994) (Figure 4-5).

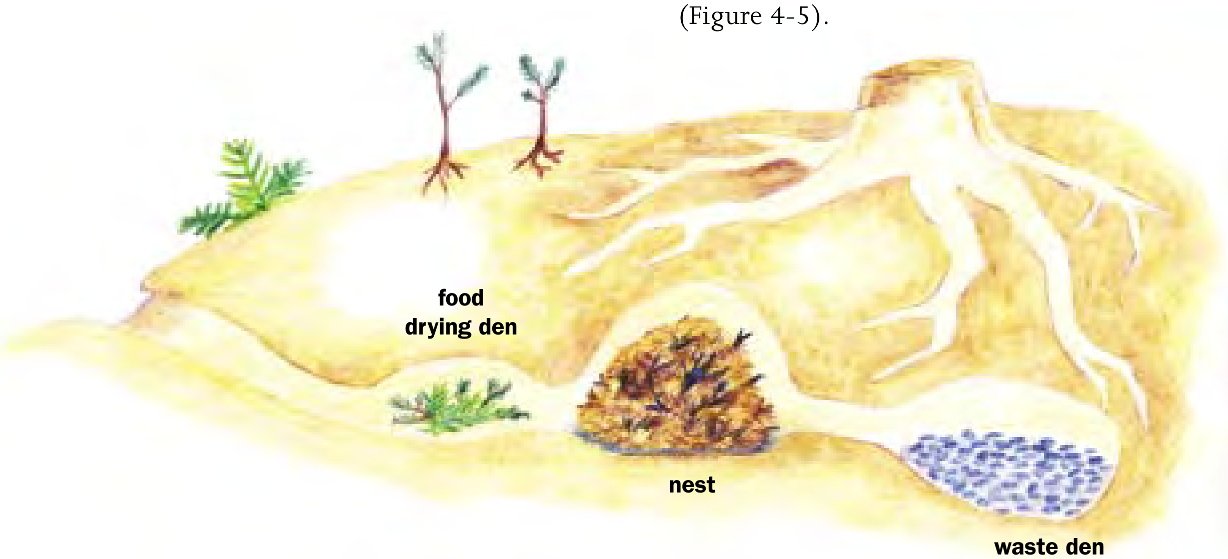


Figure 4-5. The mountain beaver only leaves its den to forage or create new dens.

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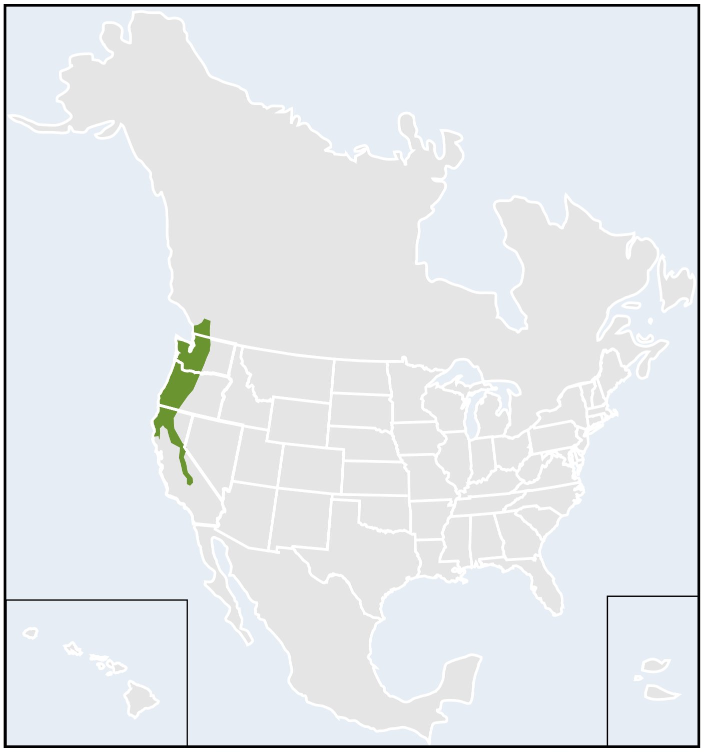
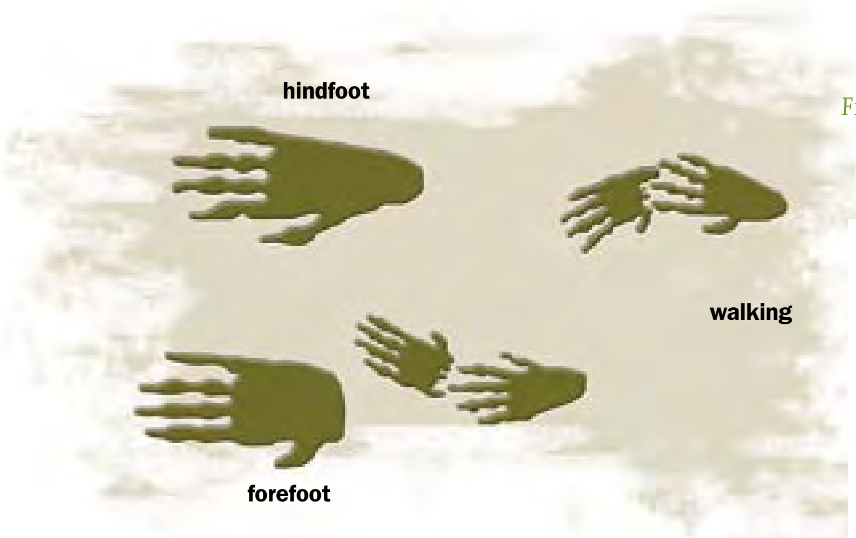


Range of the mountain beaver in North America.



The identifying characteristic of a mountain beaver track is a front foot print that has a square heel and a hind print that displays a tapered heel.

Food Habits: Mountain beavers are herbivores and eat any type of succulent vegetation, with sword fern and bracken fern being favorites (University of Nebraska, 1994). Mountain beavers will also girdle the base of trees and feed on small stems (Figure 4-6). Plants that are gathered by the mountain beaver are often dried near the burrow and are probably used for storage or nesting material. Mountain beavers dry their food by stacking vegetation on a nearby log or rock, which is termed "haystacking" (Figure 4-7). Mountain beaver usually feed on plants located within 50 feet of their burrows (University of Nebraska, 1994).

Figure 4-6. Mountain beavers girdle trees and feed on small stems.

Figure 4-7. Mountain beavers dry their vegetation on logs, known as "haystacking," before moving it into their burrows. Haystacks can be up to 2 feet high.

(DCR-VSWCB-034) (03/14)

Figure 4-8. Ferns and Douglas fir branches placed in a burrow is a reliable field sign of mountain beaver.

Behavior: Mountain beavers are nocturnal animals. They are superb diggers and spend much of the night digging and maintaining their labyrinth of burrows. Mountain beavers often stack cut vegetation in a burrow entrance, presumably to lower the vegetation's moisture content before storing it in the burrow (University of Nebraska, 1994).

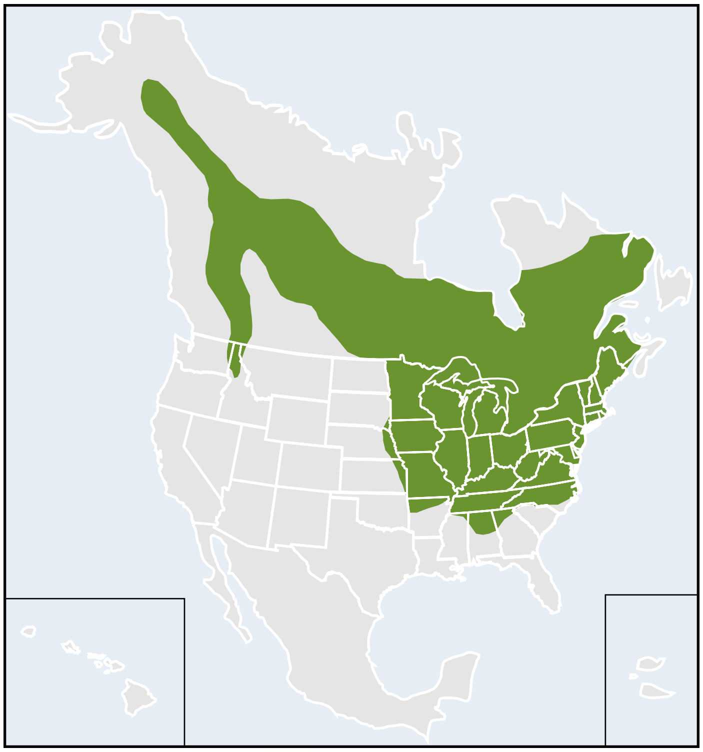
Field Tip: Stem and branch cutting within the vicinity of the dam may be a positive sign of mountain beavers. Signs of mountain beaver include freshly dug soil and chewed vegetation in proximity to a 6 to 8-inch diameter hole. Look for haystacks near the burrow entrance and vegetation piled in the burrow entrance (Figure 4-8).

4.2.4 Groundhog Overview

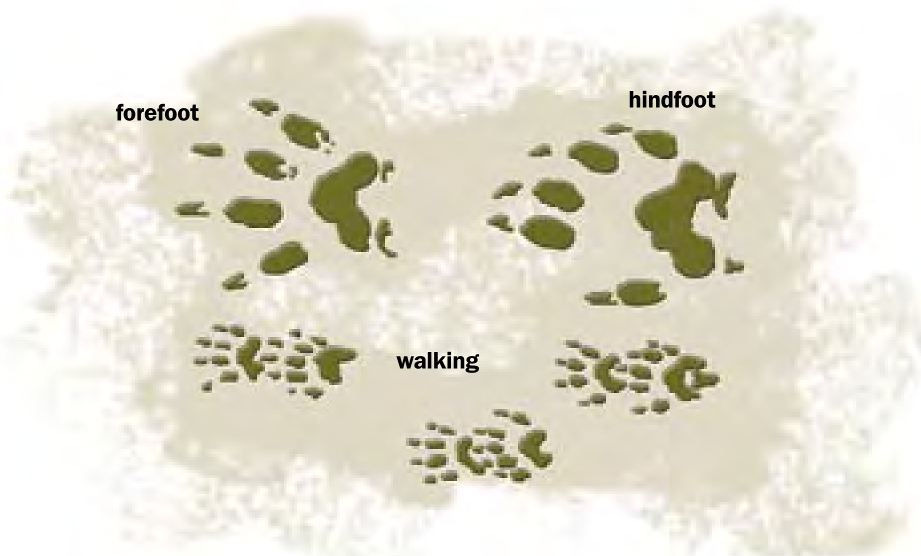
Groundhog (Marmota monax) (also known as Woodchuck or Rockchuck) are large burrowing rodents that weigh an average of 5 to 10 pounds and have an average body length of 16-20 inches. Groundhogs are usually grizzled brownish gray, although white and black individuals may occasionally be found. The groundhog's forefeet have long, curved claws that are well adapted to digging burrows (University of Nebraska, 1994).

Threat to Dams: Groundhog burrows in earthen dams can weaken the embankment and act as a pathway for seepage.

Habitat and Home: The groundhog generally prefers open farmland and woody or brushy areas adjacent to open land. Groundhog burrows are usually located in fields or near grassy pastures or meadows, along fence rows, stone walls, roadsides, and near building foundations or the bases of trees (University of Nebraska, 1994) (Figure 4-9, shown on page 31). Groundhogs will burrow into earthen dams, generally on the downstream side of the dam, as this environment can be similar to their preferred habitat (Michigan State University Extension, 1998). Their burrows can be distinguished by the large mound of excavated earth deposited by the main entrance. Two or more entrances generally exist for each burrow system. Burrows are often well-hidden and may be difficult to locate.



Range of the groundhog in the North America.



It may be difficult to tell the front and back tracks apart because when a groundhog walks, it puts its hind foot in the track of its front foot.

Food Habits: Groundhogs are strict herbivores. They feed on a variety of vegetables, grasses, and legumes, including beans, peas, carrot tops, alfalfa, and clover. Groundhogs prefer to feed in the early morning and evening hours (University of Nebraska, 1994).

Behavior: Groundhogs are usually only active during the day. During warm periods, they can often be found basking in the sun near their burrows. Groundhogs are one of the few mammals that enter a true hibernation period. Hibernation generally occurs from late October or early November to late February or March, although the exact timing depends on the latitude (University of Nebraska, 1994). New burrow construction occurs in late summer (USFS, 1994).

Field Tip: When approached or startled, a groundhog will often emit a shrill whistle followed by a low, rapid warble (University of Nebraska, 1994). An indicative sign of a groundhog burrow is the spring cleaning performed by the groundhog, which results in a mound of fresh dirt outside the burrow entrance. Adjacent trees may be girdled or clawed (Indiana Department of Natural Resources, 2003). Look for burrow construction in the late summer months.

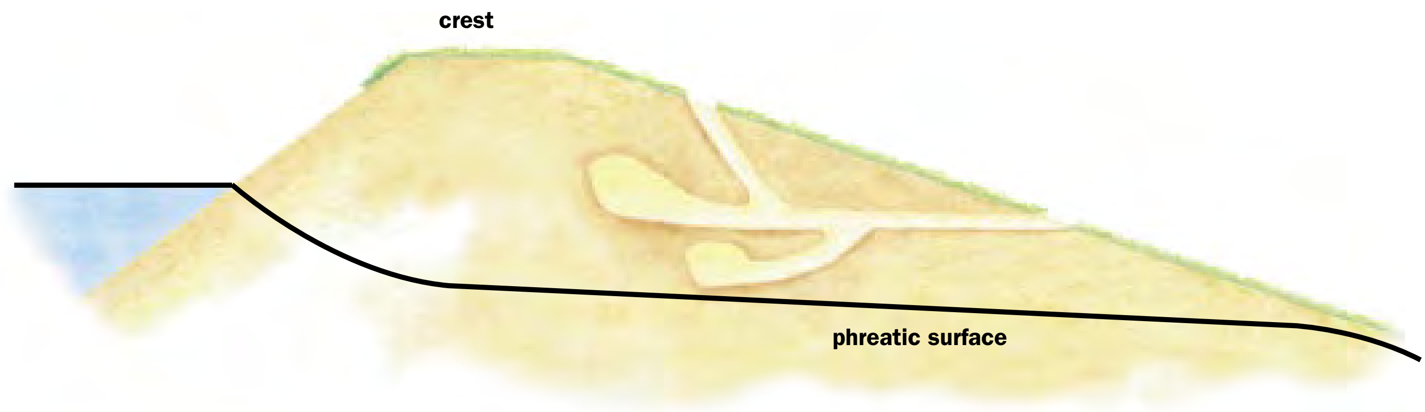


Figure 4-9. Groundhog burrows are extensive and irregular in pattern.

4.2.5 Pocket Gopher Overview

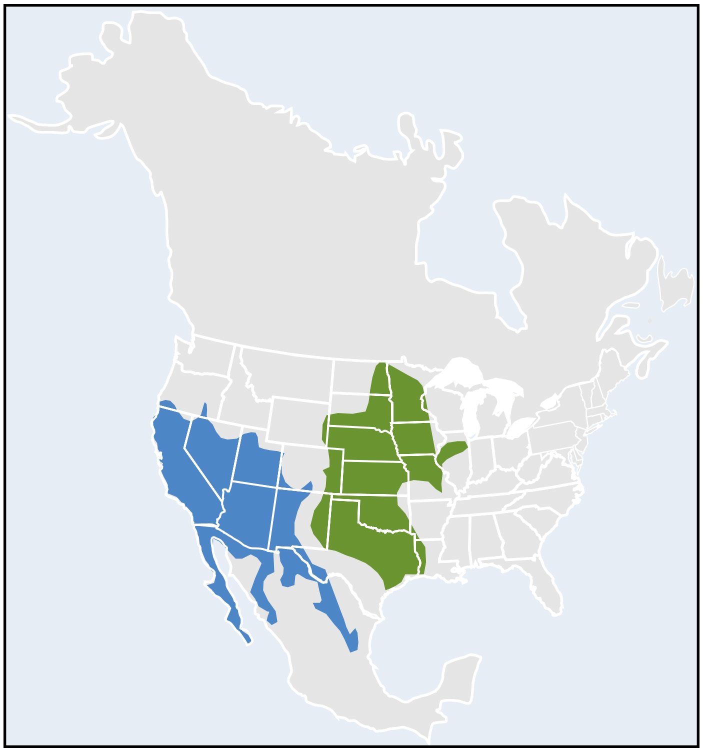
Pocket gophers are considered a significant dam safety issue in 23% of the surveyed states.

Pocket Gopher (Geomys spp., Thomomys spp., and Pappogeomys castanops) are medium-sized burrowing rodents that weigh an average of 3 to 20 ounces and have an average body length of 5 to 14 inches. Their fine fur is highly variable in color, ranging from nearly black to pale brown to almost white. Pocket gophers have fur-lined pouches outside of the mouth that are used for carrying food. They have yellowish-colored incisor teeth that are always exposed, even when the mouth is closed.

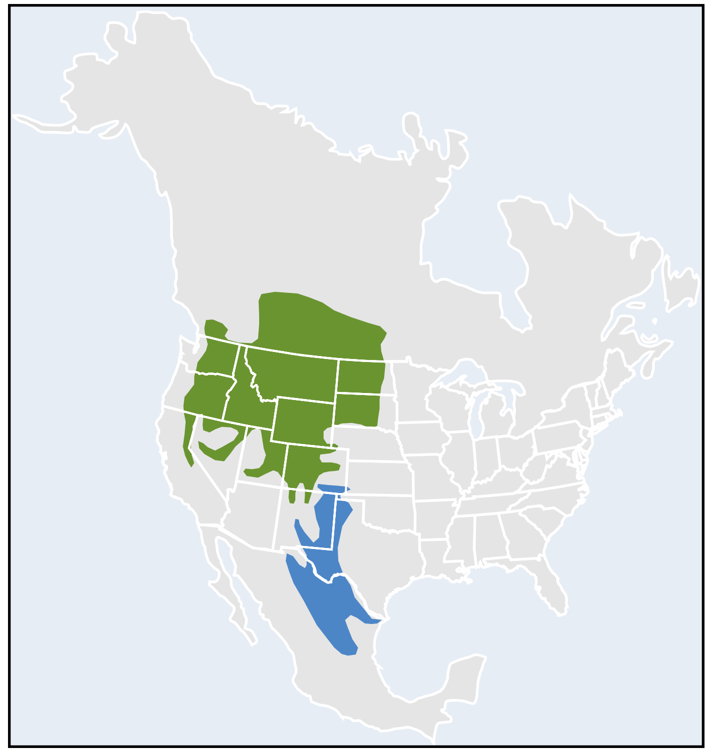
Threat to Dams: Pocket gophers are generally only a threat to small earthen dams. They dig burrows that can lead to internal erosion and structural integrity losses in the dam. The presence of pocket gophers also increases the likelihood of badger activity. Badgers are one of the primary predators of pocket gophers. Badgers will attempt to dig gophers out of their burrows, which can be very destructive to earthen dams (See Chapter 4.2.6 for a discussion on badgers). Pocket gophers can also damage underground utilities, such as irrigation pipes or electric cables (USDA, 1991).

Habitat and Home: There are 10 species of pocket gopher with substantial populations in the United States, but only one species is typically found in an area (USFS, 1994). They can occupy a wide range of habitats, from low coastal areas

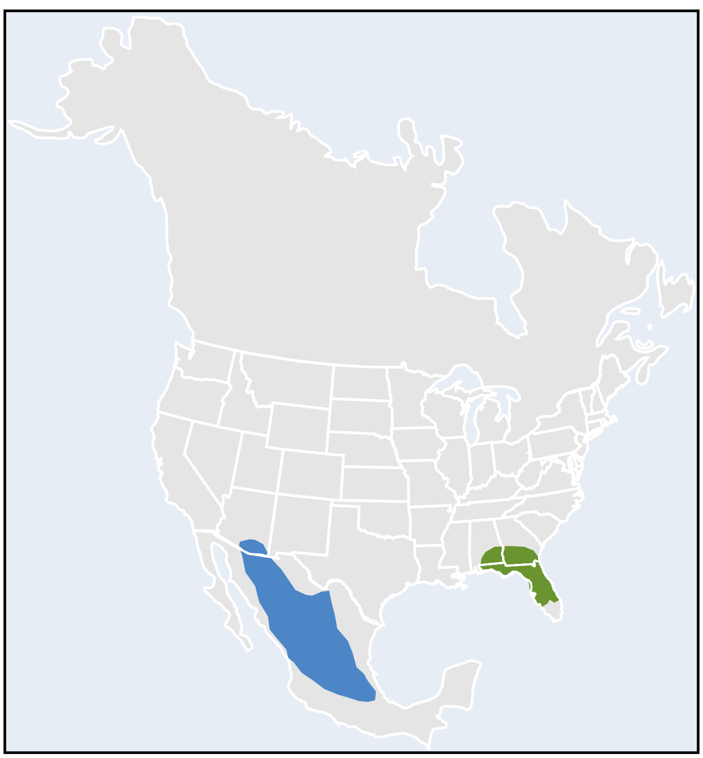
Range of the pocket gopher in North America.



Plains (Geomys bursarius), and Botta (Thomomys botta) Pocket Gophers



Northern (Thomomys talpoides), and Yellow-Faced (Pappogeomys castanops) Pocket Gophers

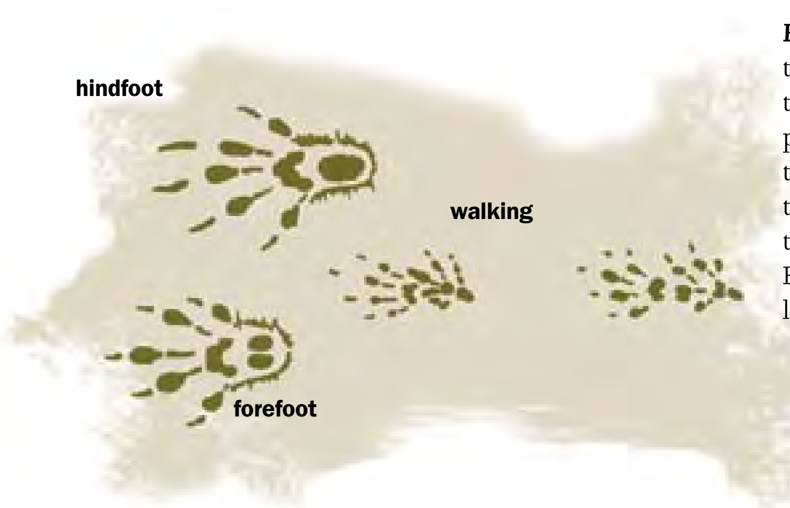


Southeastern (Geomys pinetis), and Southern (Thomomys umbrinus) Pocket Gophers

to mountains (USDA, 1991). Horseshoe-, fan- or kidney-shaped mounds of soil are characteristic evidence of pocket gopher burrows. Their burrows are nearly always kept closed with an earthen plug (University of Nebraska, 1994) (Figure 4-10).

Food Habits: Pocket gophers are strict herbivores, eating all types of forbs, grasses, shrubs, and trees. Roots are the major food source, although during the growing season, pocket gophers will also eat the above-ground portions of plants (University of Nebraska, 1994).

Behavior: Pocket gophers are solitary animals that spend much of their time underground. There is typically only one gopher per burrow, except during breeding season (USDA, 1991).



Pocket gopher tracks will show five toes on the hindfoot and four toes on the slightly smaller forefoot. Claw marks are usually well-defined.

Field Tip: Pocket gopher activity can be distinguished from that of other burrowing animals by their burrow characteristics, particularly the fan-shaped mounds of soil and plugged burrow entrances. Pocket gophers will tunnel through the snow, pushing soil from below ground into the snow tunnels. When the snow melts, the soil "casts" or tubes can be found on the ground surface (USFS, 1994). Horseshoe-shaped mounds of soil are created in summer or late fall.

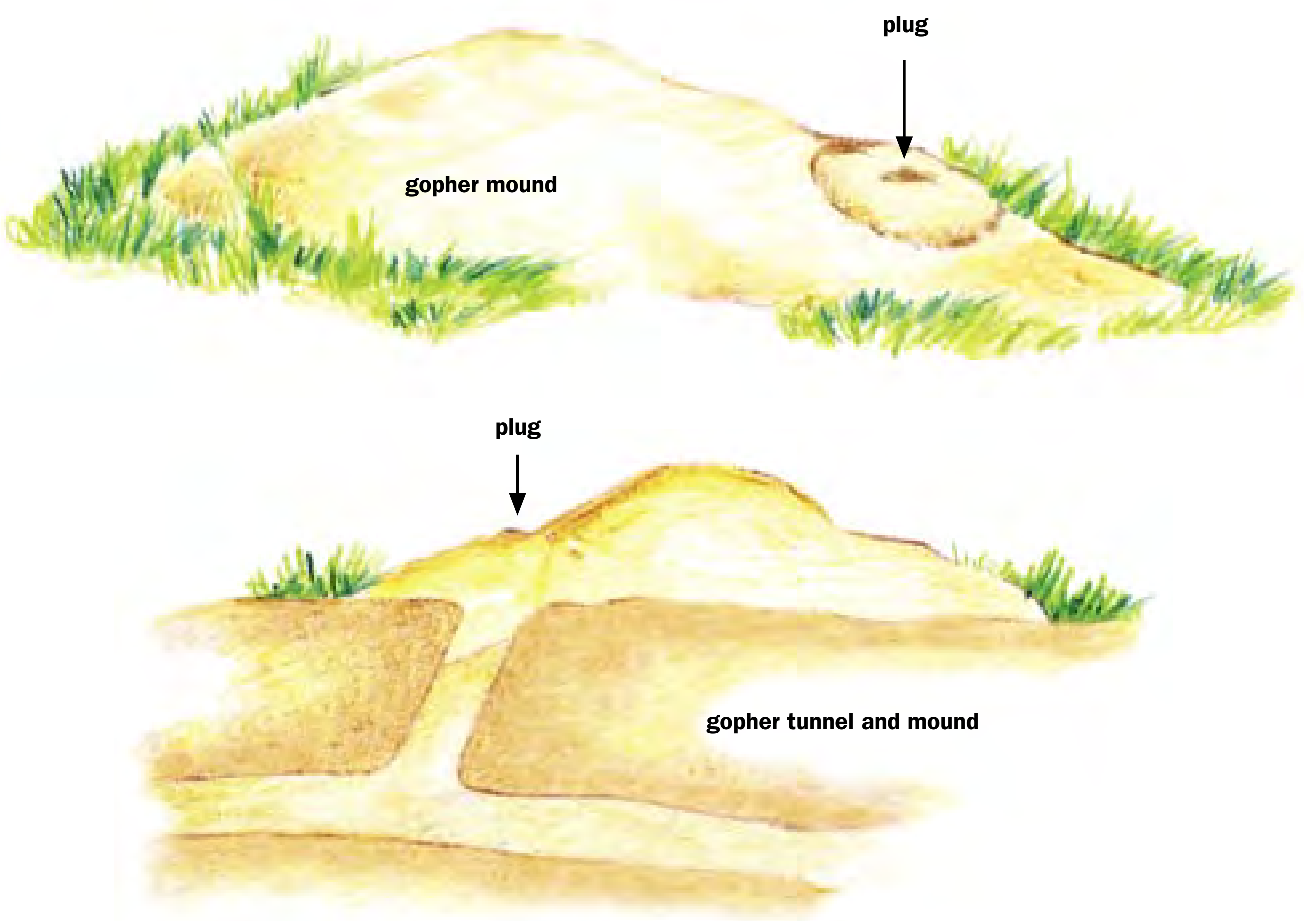


Figure 4-10. Lateral burrows of the pocket gopher end in a soil mound or a soil plug.

4.2.6 North American Badger Overview

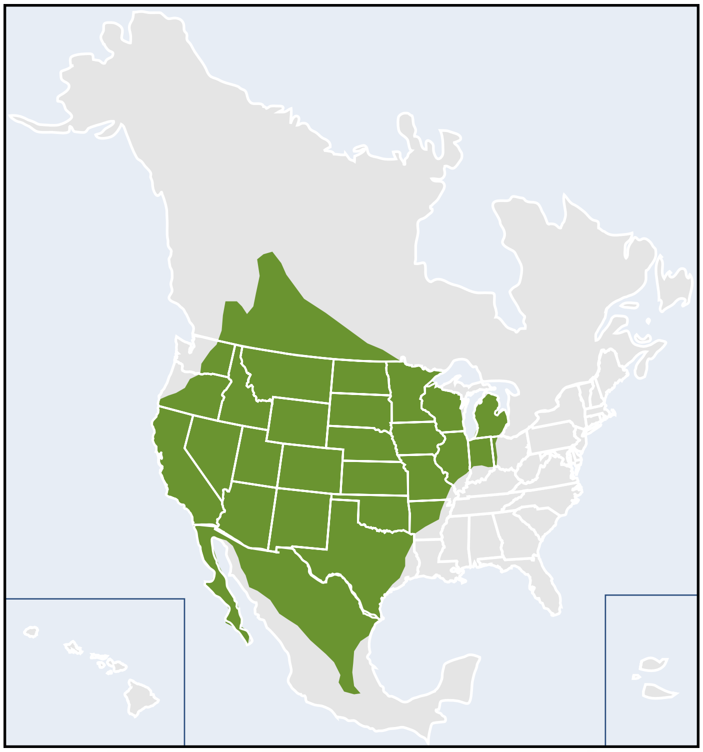
The North American Badger (Taxidea taxus) is a stocky animal that can grow up to 30 inches long. It has grayish yellow fur with pale underparts, long claws, a short, bushy tail, and black feet. Badgers can weigh from 19 to 30 pounds and can be identified by a white stripe that runs from its nose to the back of its head (University of Nebraska, 1994).

Threat to Dams: Badgers are especially adapted for digging and dig in pursuit of prey and to construct dens for shelter. Badgers can cause severe damage to hydraulic structures. Badgers can exacerbate internal and external erosion in an earthen dam by enlarging existing burrows of prairie dog, pocket gopher, or ground squirrels, all of which can inhabit an earthen dam and are a preferred food of the badger. Badger dens create large voids in the earthen dam, compromising structural integrity.

Badgers are considered a significant dam safety issue in 17% of the surveyed states.

Habitat and Home: Badgers prefer pastures or rangelands with light to moderate cover and few trees. Habitats with sandy or porous soils are preferred. Female badgers dig large burrows (5-30 feet long) with a large chamber 2-3 feet below the ground surface for birthing. Dens have one entrance that is usually elliptical in shape (University of Nebraska, 1994).

Food Habits: North American badgers are opportunist omnivores that feed on earthworms, mammals, birds, reptiles, grains, and fruits. Prairie dog, pocket gopher, and ground squirrels are common in badger diets.



Range of the badger in North America.

Badger tracks are similar to coyote tracks, but are distinct in the long claw marks on the front feet and the presence of five toes. Badger tracks are typically turned inward toward each other, and the hindprints are narrower than the foreprints.

Behavior: Badgers are adept at pursuit and capture of ground-dwelling prey. A typical burrow dug in pursuit of prey is shallow and about 1 foot in diameter (University of Nebraska, 1994). Badgers are mostly nocturnal but will be active during the day if the area is quiet. Badgers are usually solitary.

Field Tip: Large piles of dirt and rock left near animal burrows can indicate badger hunting activity. Badgers maintain the condition of their claws by sharpening them on trees or fence posts; claw marks can indicate badger presence (University of Nebraska, 1994).

Badger tunnels and dirt mounds resulting from prey pursuit can cover an area the size of a car.

4.2.7 Nutria Overview

Nutria (Myocastor coypus) With an average weight of 8 pounds and a body length of 24 inches (tail is an additional 16 inches long), nutria are larger than muskrat, but much smaller than beaver. With a preferred habitat that includes permanent water, nutria are excellent swimmers with webbed hind feet, but move awkwardly on land.

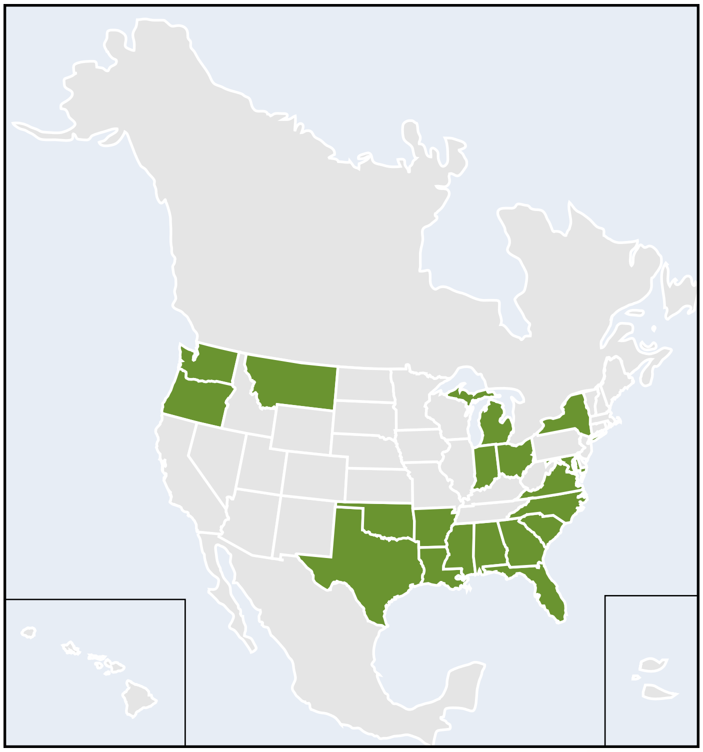
Threat to Dams: Nutria construct extensive burrows as shelter in the upstream slope. Burrows can weaken an earthen dam to the point of collapse when soil becomes saturated by precipitation or high water, or when heavy vehicles cross the crest. Nutria are notorious for breaking through water-retaining levees in Louisiana and Texas (University of Nebraska, 1994).

In some cases, nutria tunnels have been so extensive that water flowed unobstructed through the embankment necessitating its complete reconstruction.

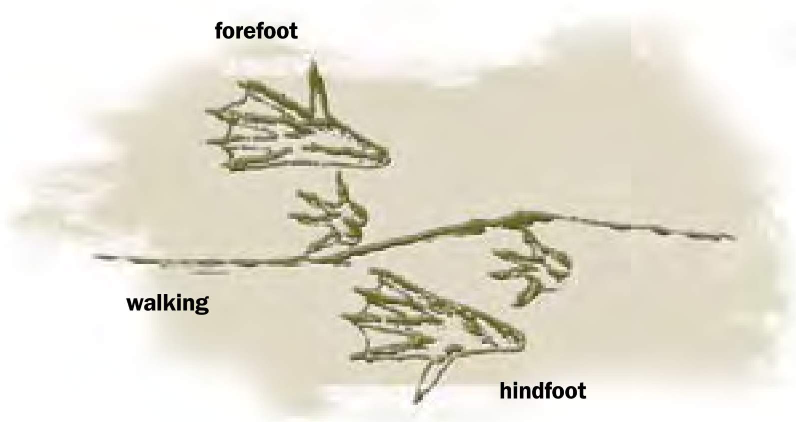
Look closely! Nutria are aquatic rodents often misidentified as either a muskrat or beaver.

Nutria are considered a significant dam safety issue in 4% of the surveyed states.

Habitat and Home: Nutria can adapt to a variety of habitats, but prefer a semi-aquatic environment and particularly, the zone between land and permanent water. This zone is preferred for its abundance of aquatic vegetation. For the most part, any substantial nutria populations in the United States occur in freshwater marshes of coastal areas (University of Nebraska, 1994). Nutria are ground-dwellers during the summer, preferring to live in dense vegetation. The rest of the year nutria live in burrows they have dug, or that have been abandoned by armadillos, muskrat, or beaver. Nutria construct burrow entrances in vegetated banks of dams and waterways; a bank that has a slope greater than 45 degrees is a preferred location (University of Nebraska, 1994). Nutria burrows can be simple or complex; a complex burrow may have several tunnels and entrances at different levels in the bank. A burrow system will contain compartments (ranging from 1-3 feet across) for resting, feeding, and shelter from the weather and predators. Tunnels can be 4-6 feet in length.



Range of the nutria in North America.



Tracks left by nutria may also have tail drag marks, or sometimes chest marks, as a nutria may drag its chest when on land.

Food Habits: Nutria prefer aquatic plants such as sedges, rushes, cattails, and arrowheads, however the bark of black willow and bald-cypress may be eaten in the winter. Nutria eat food in a number of places including feeding platforms on the water (floating mats of vegetation or even on top of beaver and muskrat houses), in the water itself, or on land.

Behavior: Nutria feed at night when food is plentiful, but will feed during the day if food is limited. Nutria can scratch or bite aggressively if captured or cornered.

Field Tip: Unlike muskrat or beaver, a nutria's tail is round with scant hair, the whiskers are long (around 4 inches) and whitish, and nutria have prominent red-orange incisors. Trees girdled by nutria will show no teeth marks.

Nutria construct platforms of floating vegetation used for loafing, grooming, birthing, and escape, which are often mistaken for muskrat houses.

4.2.8 Prairie Dog Overview

Prairie Dogs (Cynomys spp.) are squirrel-like, burrowing rodents with squat, muscular bodies and short tails and ears. Their fur is sandy brown to cinnamon in color with grizzled black and buff-colored tips. Adult prairie dogs grow to a length of 13 to 17 inches and weigh approximately 2 to 4 pounds (USDA, 1991).

Prairie dogs are considered a significant dam safety issue in 8% of the surveyed states.

Threat to Dams: Prairie dogs dig burrows that can lead to internal erosion and structural integrity losses in earthen dams.

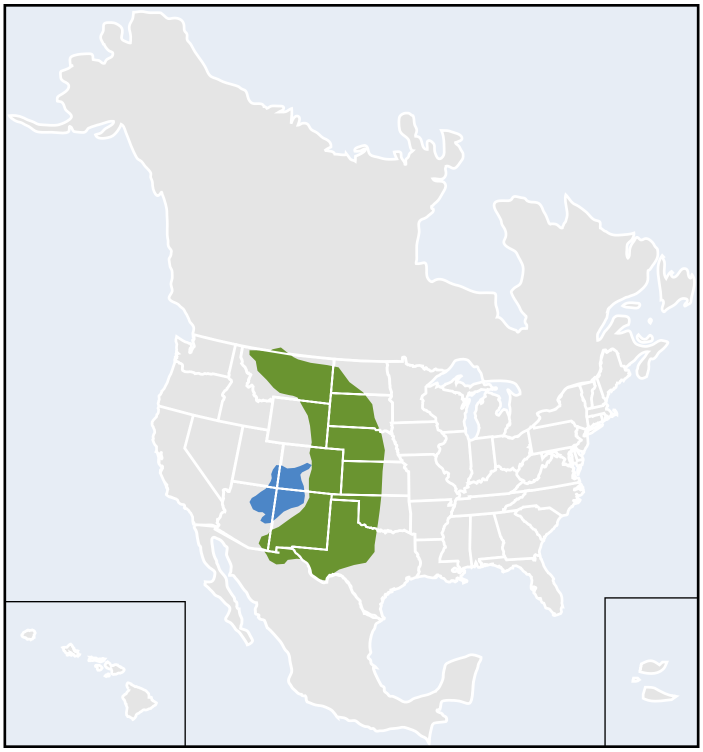
Habitat and Home: Prairie dogs prefer grassland or short shrubland habitats. They often establish colonies near intermittent streams or water impoundments (USDA, 1991). Prairie dog burrows are found in open areas with low vegetation. Their burrows are distinguished by relatively large holes and cone-shaped mounds. Prairie dogs remove the vegetation from around their burrows and use it for food or nesting material (USDA, 1991). Other animals often make their homes in prairie dog burrows, including the federally protected black-footed ferret and burrowing owl.

Food Habits: Prairie dogs eat mostly grass, although they will also eat flowers, seeds, shoots, roots, and insects when available (University of Nebraska, 1994).

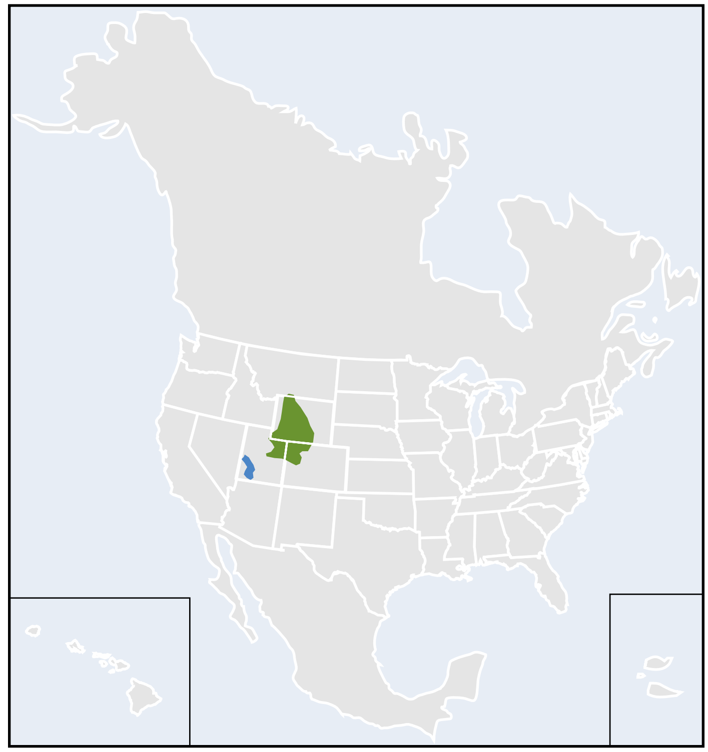
Behavior: Prairie dogs live in large colonies known as "towns." Each town is made up of a complex series of tunnels and may have as many as 20 to 50 burrow entrances. Prairie dogs are social animals that are most active during the day (University of Nebraska, 1994).

Field Tip: Look for mounds of earth about 1 to 2 feet high that resemble miniature volcanoes.

Range of the prairie dog in North America.



Black-Tailed (Cynomys ludovicianus), and Gunnison (Cynomys gnnisoni) prairie dogs



White-Tailed (Cynomys leucurus), and Mexican (Cynomys mexicanus) prairie dogs

Prairie dog tracks will show five toes on the hindfoot and four toes on the slightly smaller forefoot.

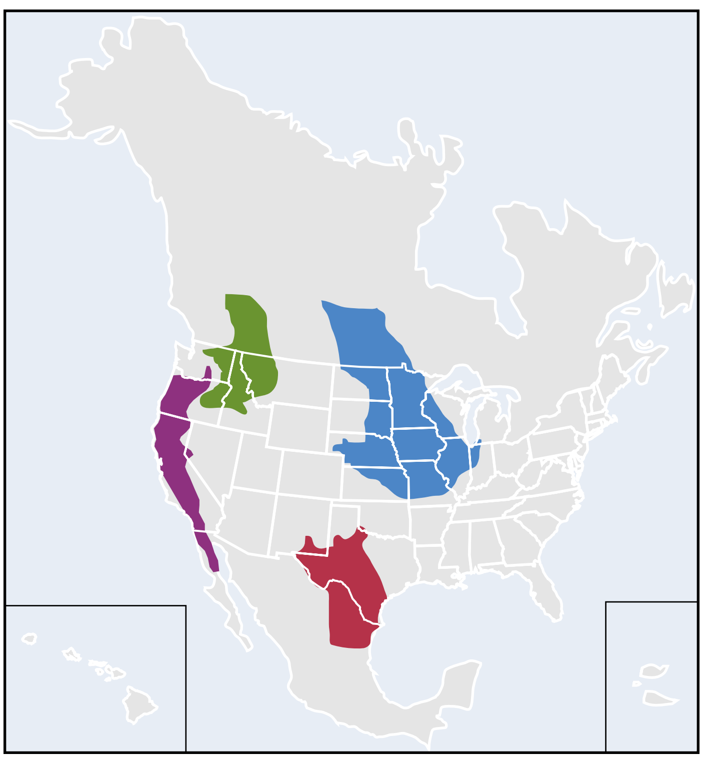
4.2.9 Ground Squirrel Overview

Ground Squirrel (Spermophilus spp.) are small to medium-sized burrowing rodents. Twenty-three species of ground squirrels live in the United States (University of Nebraska, 1994). They vary is size, with lengths ranging from 6 to 20 inches and weight ranging from 0.25 to 2.5 pounds. They also vary in color, ranging from brown to reddish brown to gray. Some species have markings, such as spots or stripes. Some species have long bushy tails, while others have short tails with short hair (USDA, 1991).

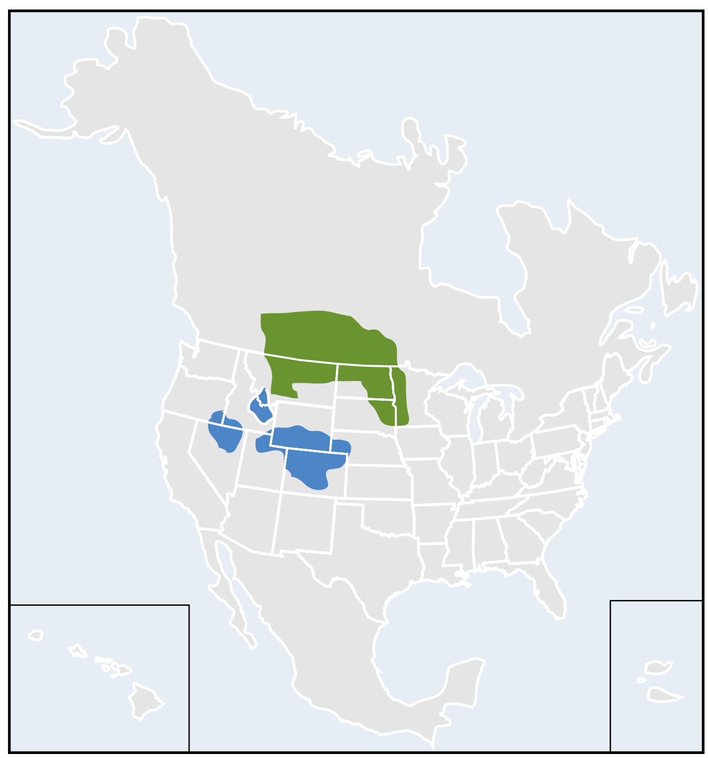
Threat to Dam: Ground squirrels dig burrows that can lead to internal erosion and structural integrity losses in earthen dams. The presence of ground squirrels also increases the likelihood of badger activity. Badgers will pursue ground squirrels into their burrows, which can be very destructive to earthen dams (USDA, 1991).

Habitat and Home: Ground squirrels can be found in at least 27 states west of Ohio. They occupy a wide range of habitats from low coastal areas to mountains. Ground squirrels keep their burrows unplugged. Specific burrow design varies with species, soil type, habitat and climate. Some species of ground squirrels are colonial, which means that several individuals live in the same burrow system. These systems consist of clustered, above-ground mounds that resemble prairie dog burrows. They are generally easier to spot than the burrows of solitary ground squirrel species, which tend to be scattered and inconspicuous (USDA, 1991).

Range of the ground squirrel in North America.

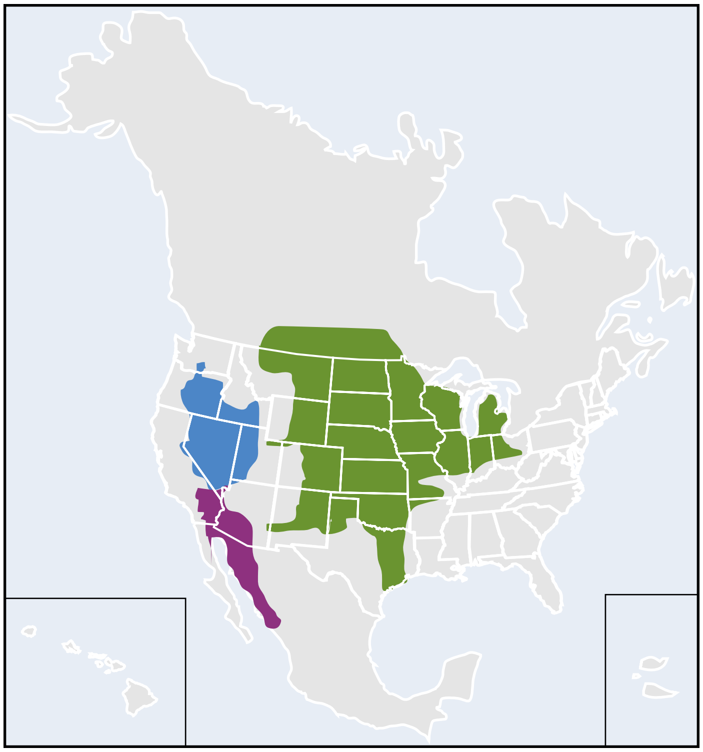


Columbian (Spermophilus columbianus), Franklin (Spermophilus franklinii), California (Spermophilus beecheyi), and Mexican (Spermophilus mexicanus), ground squirrels

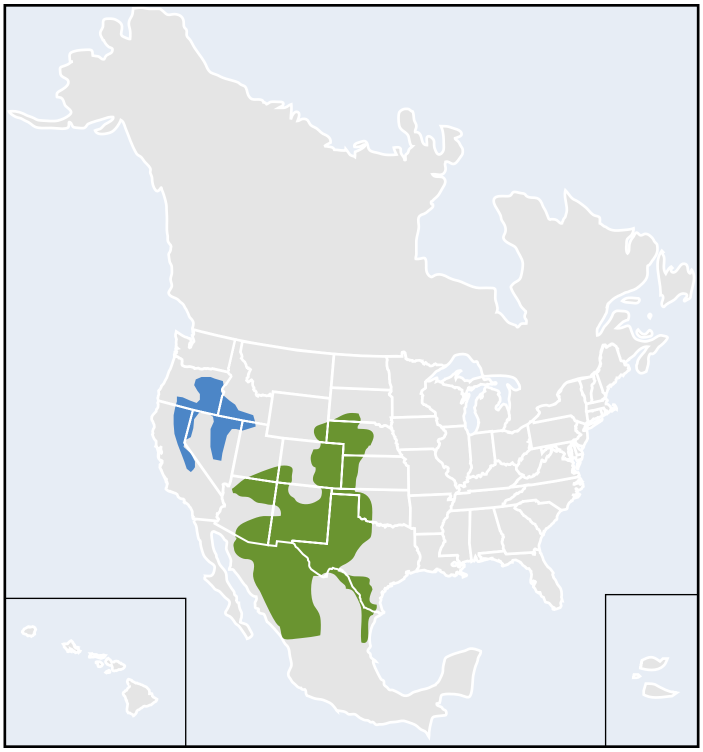


Richardson (Spermophilus richardson), and Wyoming (Spermophilus elegans) ground squirrels

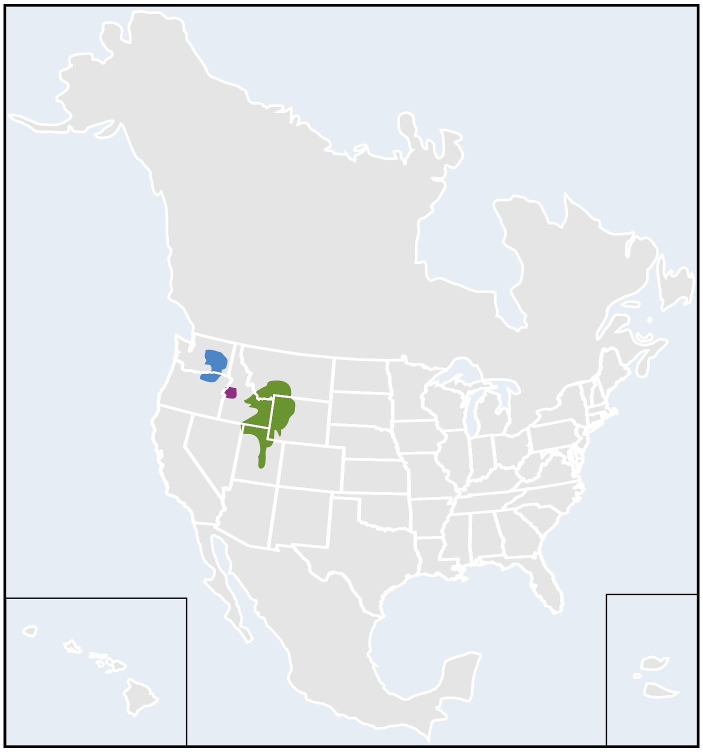
Range of the ground squirrel in North America (continued).



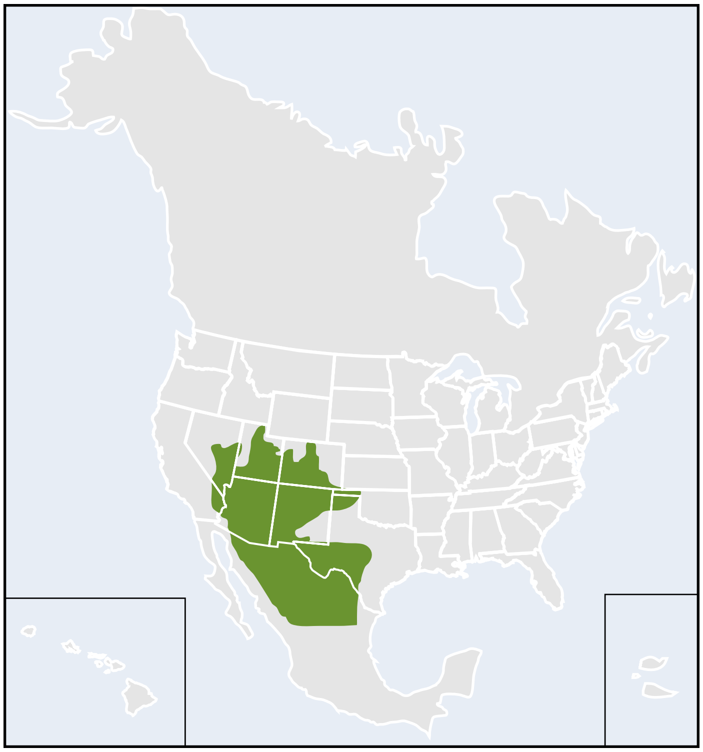
Townsend (Spermophilus townsendi), Thirteen-lined (Spermophilus tridecemlineatus), and Round-tailed (Spermophilus tereticaudus) ground squirrels



Belding (Spermophilus beldingi) and Spotted (Spermophilus spilosoma) ground squirrels



Washington (Spermophilus washingtoni), Idaho (Spermophilus brunneus), and Uinta (Spermophilus armatus) ground squirrels



Rock (Spermophilus variegatus) ground squirrels

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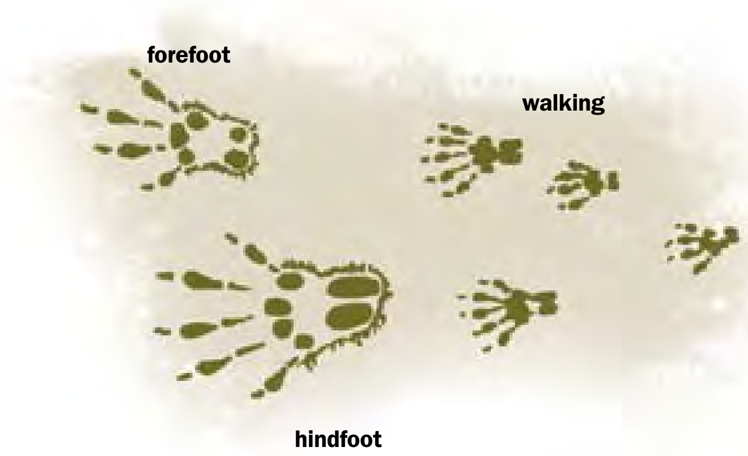


Although ground squirrel tracks will vary in size, they generally show five toes on the hindfoot and four toes on the smaller and rounder forefoot.

Food Habits: Ground squirrels mostly eat plant material, although some species may also eat insects, eggs, carrion, and other animal material (USDA, 1991).

Behavior: Ground squirrels are only active during the day, and they are most active during mid-morning and late afternoon. They hibernate in the winter, and most species estivate in summer as well (USDA, 1991).

Field Tip: During warm months, ground squirrels are quite active during the day and can be easily spotted. Unplugged burrows are a distinctive characteristic of ground squirrel inhabitation (USDA, 1991).

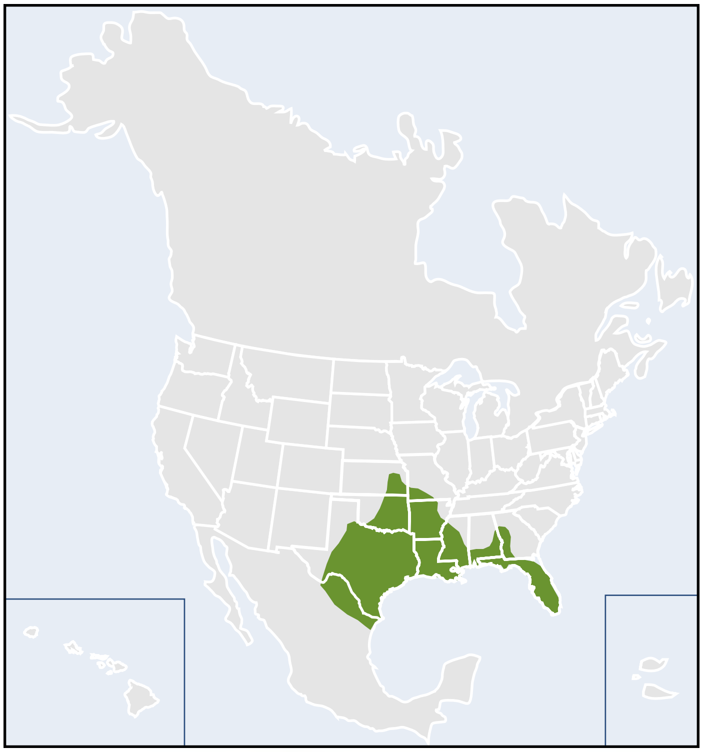
Ground squirrels are considered a significant dam safety issue in 15% of the surveyed states.

4.2.10 Armadillo Overview

The Armadillo (Dasypus novemcinctus) is a medium-sized animal, about 8 to 17 pounds, with a protective, armor-like shell on its head, body, and tail. It has nine movable bands across its back, and the tail is covered with a series of overlapping rings. The armadillo has a small head with a long, narrow, piglike snout (University of Nebraska, 1994).

Threat to Dams: Armadillos dig burrows that can result in internal erosion and structural integrity losses in dams.

Habitat and Home: It prefers forest, woodland and brush habitat, as well as areas near creeks and rivers. The armadillo will also inhabit areas with rocks, cracks, and crevices that are suitable for burrows (University of Nebraska, 1994). Armadillos generally dig burrows 7 to 8 inches in diameter and up to 15 feet in length. They can be found in rock piles, around stumps, brush piles, or terraces around brush or dense woodlands. Armadillos usually have more than one den in an area (University of Nebraska, 1994).



Range of the armadillo in North America.

Armadillos have four toes on their forefeet and five toes on their hindfeet, although not all toes may show up in their tracks. Sharp claw marks are often visible.

Food Habits: The armadillo primarily eats insects and their larvae. They also feed on spiders, earthworms, scorpions, and other invertebrates. To a lesser extent, they may eat some fruit and vegetable matter (University of Nebraska, 1994).

Armadillos are considered a significant dam safety issue in 4% of the surveyed states.

Behavior: During the summer, the armadillo is active from twilight through early morning hours, but in the winter, it is usually only active during the day. The armadillo has poor eyesight, but a keen sense of smell. It can run fast when in danger and is also a good swimmer (USDA, 1991).

Field Tip: Characteristic signs of armadillo activity are shallow holes, about 1 to 3 inches deep and 3 to 5 inches wide, dug in search of food (University of Nebraska, 1994).

4.2.11 Livestock Overview

Livestock can include cattle, horses, sheep, goats, and pigs of all varieties, domesticated and wild. Livestock exist widely across the United States and utilize earthen dams and farm ponds for grazing and drinking.

Threat to Dams: Livestock can damage an earthen dam by removing stabilizing vegetation through grazing, trampling, and rooting. External erosion can occur without vegetative cover, and erosion pathways can be created as livestock traverse the embankment (Figures 4-11 and 4-12). Damages are most severe in arid regions, and damage is often not noted until the wet season when precipitation collects in holes and along erosion pathways. Livestock carcasses could alter or block water flow if located at control structures. Wild pigs commonly damage farm ponds and can cause substantial damage to a grassy area in a single night (University of Nebraska, 1994).

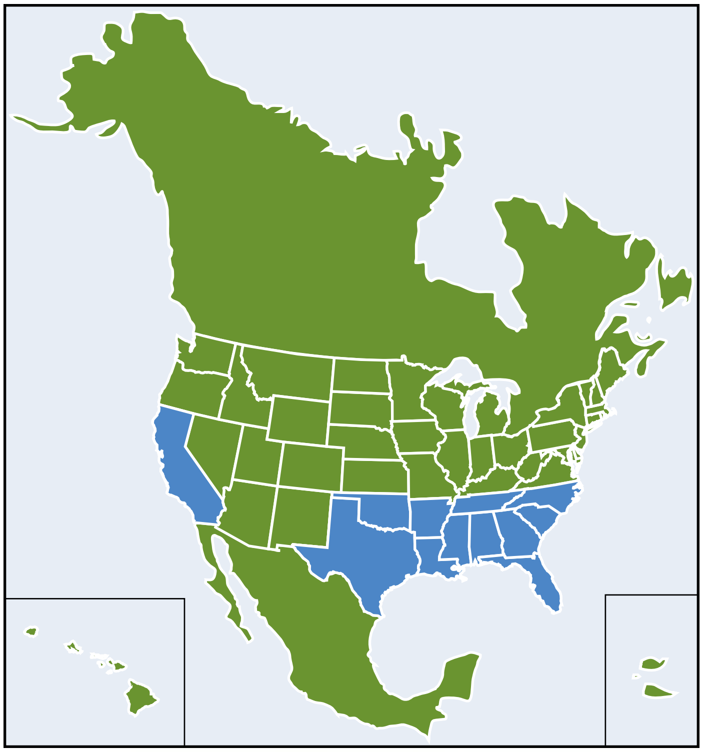
Livestock are considered a significant dam safety issue in 25% of the surveyed states.

Habitat and Home: Livestock can occur anywhere in the United States. In some cases, several livestock species will graze in one area. Wild pigs can exist in a variety of habitats but prefer dense brush or marsh vegetation as cover. Wild pigs are often found inhabiting livestock-producing areas (University of Nebraska, 1994).

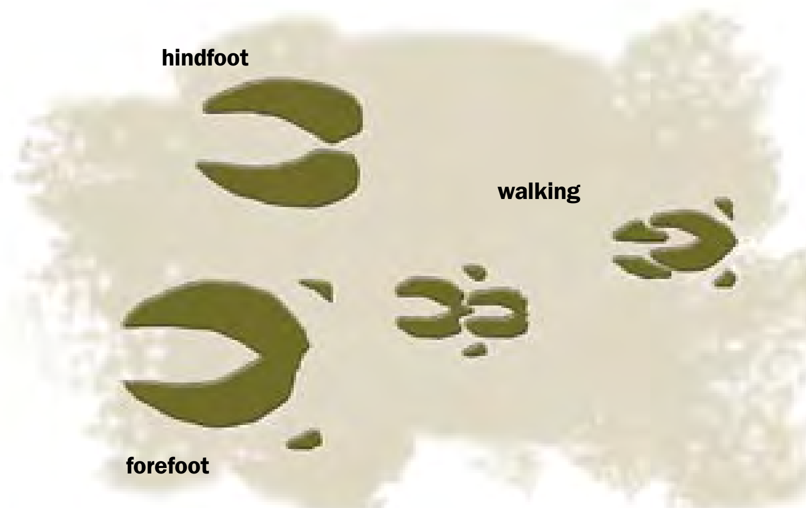
Food Habits: Most livestock, including cows, sheep, goats, and horses, are grazers. Pigs, however, generally root for underground vegetation, in addition to feeding on acorns and other mast. Livestock disturb soil and vegetation through their feeding methods.

Behavior: Location to a water source is considered the primary influence on livestock's activity within a given grazing area, followed by desirable forage and topography of the grazing area. In hot weather, pigs will wallow in ponds, springs, or streams that contain or are near vegetative cover.

Field Tip: Livestock are easily identified as they are often intentionally grazed on lands near farm dams. Wild pigs are obvious if observed, otherwise look for wallows.



Range of livestock, and wild pigs in North America.



Tracks can be used to identify wild pigs. Tracks are generally not needed to identify other types of livestock since they are often intentionally grazed on lands near farm dams.

One milk-producing Jersey cow can drink up to 12 gallons of water a day. Herds of dairy cows typically include 50 to 100 animals. That's a lot of hoof-traffic at an earthen dam!

Figure 4-11. Livestock can cause external erosion by creating ruts and erosion paths via hoof traffic.

Figure 4-12. Livestock can remove stabilizing vegetation through grazing and hoof traffic.

(DCR-VSWCB-034) (03/14)

4.2.12 Crayfish Overview

Crayfish (Cambarus spp.) resemble miniature lobsters. There are over 300 species of various sizes, shapes, and colors in the United States (University of Nebraska, 1994).

Crayfish are considered a significant dam safety issue in 4% of the surveyed states.

Threat to Dams: Crayfish burrow into earthen dam embankments; extensive burrowing may cause internal erosion and structural integrity losses.

Habitat and Home: Crayfish are found in a variety of fresh water habitats, including streams, rivers, ponds, lakes, swamps, and wet meadows (Peckarsky et al, 1990). Crayfish burrows are usually located along the shoreline close to the water's edge. They may be anywhere from a few inches to three feet deep. The opening is generally about ¼ to 2 inches in diameter with a cone-shaped mound, known as a "chimney," plugging the burrow (Virginia Cooperative Extension, 2001a) (Figure 4-13).

Food Habits: Crayfish eat both living and dead plant and animal material. Almost half of their diet consists of bottom-dwelling worms and insects. The rest of their diet consists of

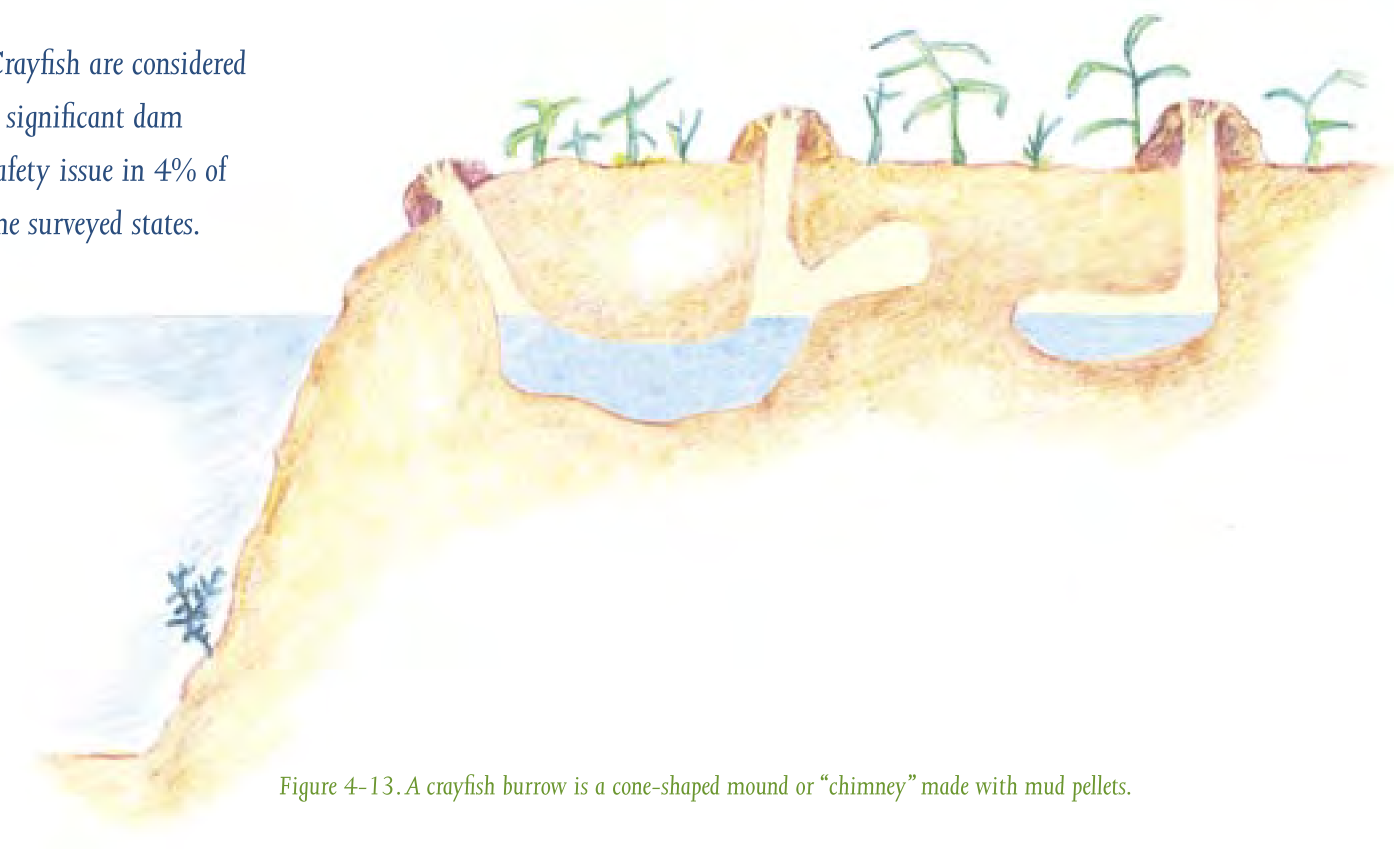


Figure 4-13. A crayfish burrow is a cone-shaped mound or "chimney" made with mud pellets.

Range of the crayfish in North America.

living and decaying aquatic vegetation (Virginia Cooperative Extension, 2001a).

Behavior: A crayfish will molt several times in its short lifespan. They can be quite aggressive towards each other and toward anything they perceive as a threat (Peckarsky et al, 1990). Most crayfish dig burrows to use as a refuge from predators and as a resting place during molting and inactive periods (Virginia Cooperative Extension, 2001a).

Field Tip: Crayfish stay in their burrows or in mud bottoms during cold weather. They will emerge, and be easier to spot, once the water warms up (Virginia Cooperative Extension, 2001a).

4.2.13 Coyote Overview

The Coyote (Canis latrans) is a member of the dog family, and in size and shape, it resembles a small German shepherd, with erect pointed ears, slender muzzle, and a bushy tail. Coyotes are generally brownish-gray with a lighter colored belly, although this varies widely across local populations. In the west, adult males typically weigh 25 to 45 pounds and adult females typically weigh 22 to 35 pounds. Coyotes in the east are usually larger, with adult males weighing about 45 pounds and adult females weighing about 30 pounds (University of Nebraska, 1994).

Threat to Dams: Although coyotes do not pose a large threat to earthen dams, den construction or enlargement, and digging out prey that live at the dam can cause structural integrity losses.

Coyote are considered a significant dam safety issue in 4% of the surveyed states.

Habitat and Home: Coyotes exist in virtually any type of habitat, arctic to tropic. High densities of coyotes even appear in the suburbs of major western cities such as Los Angeles and Phoenix. Their dens are often found in steep banks, rock crevices, sinkholes, and underbrush, as well as open areas. Dens are usually located close to water. Coyotes will often dig out and enlarge burrows of other animals. Size of coyote dens varies from a few feet to 50 feet, and each den often has several openings (University of Nebraska, 1994).

Range of the coyote in North America.

Badger tracks are often confused with coyote tracks, but note that coyotes only have four toes on each foot, while badgers have five toes.

Food Habits: Coyotes eat a variety of animals, insects, fruits, and vegetables (University of Nebraska, 1994).

Behavior: During hot summer months, coyotes are most active at night and during the early morning hours. During cooler weather, and in areas with minimal human activity, coyotes may be active throughout the day. Coyotes have good eyesight and hearing and a keen sense of smell. Their adaptable behavior and social system allows them to survive, and even flourish, in the presence of humans (University of Nebraska, 1994).

Field Tip: Coyotes can often be identified by their tracks, although it should be noted that regular dog tracks are often mistaken for coyote tracks. Coyote dens are often located in the downstream slope.

4.2.14 Moles and Voles Overview

Moles (Scapanus spp.) are small insectivores that are often confused with voles, shrews, and pocket gophers. Moles, however, can be distinguished by their hairless, pointed snout, small eyes, and webbed forefeet. There are seven different species of moles living in the United States. Adult males grow to a length of about 7 inches and weigh about 4 ounces; adult females are slightly smaller (University of Nebraska, 1994).

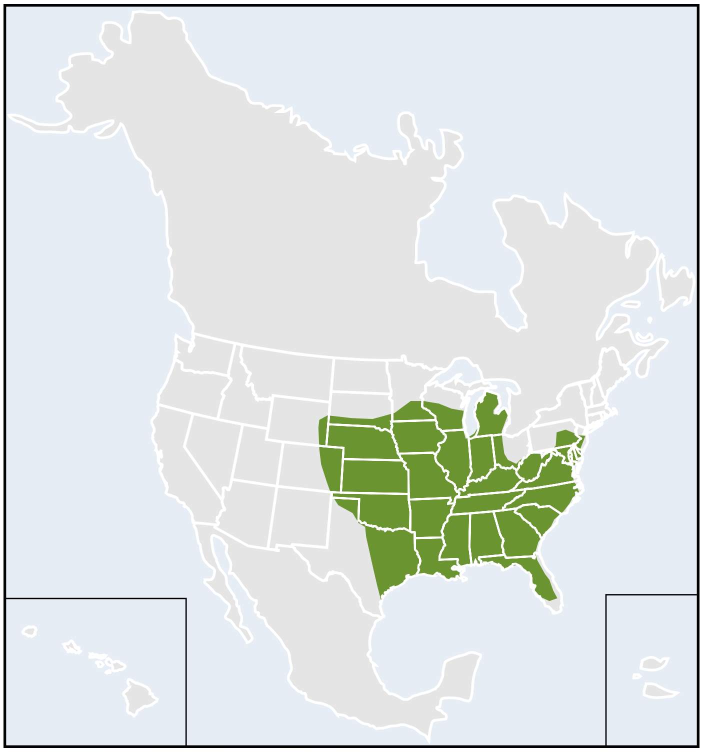
Voles (Microtus spp.) also known as meadow mice or field mice, are compact rodents with short legs and short tails. There are 23 species of voles in the United States. Most are gray or brown, and about 4 to 8 inches long; although both size and coloration varies across species.

Threat to Dams: Earthen dams may provide good hunting grounds for moles. Although they usually make their home burrows in dry, upland areas, they prefer to hunt in areas that are cool and moist. They construct tunnels from their dens to their hunting grounds. If located in an earthen dam, these tunnels may cause internal erosion and structural integrity losses. When present in large numbers, voles may also cause damage to earthen dams. They dig extensive burrow systems that could lead to internal erosion and structural integrity losses in the dam (University of Nebraska,1994).

Moles and voles are considered a significant dam safety issue in 10% of the surveyed states.

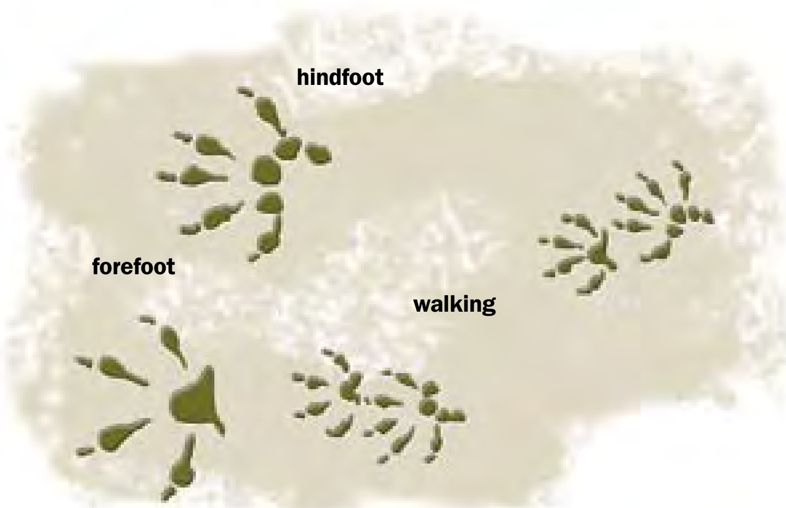
Habitat and Home: Moles can be found across most of the United States. As mentioned above, they generally construct their burrows in dry, upland areas. Deep runways connect their dens to their hunting grounds (University of Nebraska, 1994) (Figures 4-14 and 4-15, shown on page 51). Voles can also be found across most of the United States. They prefer areas of heavy ground cover, although they can survive in a wide variety of habitats. Burrow systems consist of a series of tunnels and surface runways, and often have several entrances (University of Nebraska, 1994) (Figure 4-16, shown on page 51).

Food Habits: Moles primarily eat insects, grubs, and worms. Voles are mostly herbivorous, primarily eating grasses and forbs. Voles will also occasionally eat snails, insects, or animal remains (University of Nebraska, 1994).



Range of the mole in North America.

Range of the vole in North America.



Vole tracks.

Behavior: Moles are solitary animals, and they spend most of their time underground. They are active through all seasons of the year. Voles are also active throughout the year, both day and night. They are excellent swimmers and often try to escape from predators through the water (University of Nebraska, 1994).

Field Tip: Moles push up volcano-shaped mounds of soil when they are building tunnels. The mounds may be anywhere from 2 to 24 inches tall. Surface tunnels or ridges are also an indication of mole activity. Voles can be identified by their extensive surface runway systems. These runways are generally 1 to 2 inches in width.

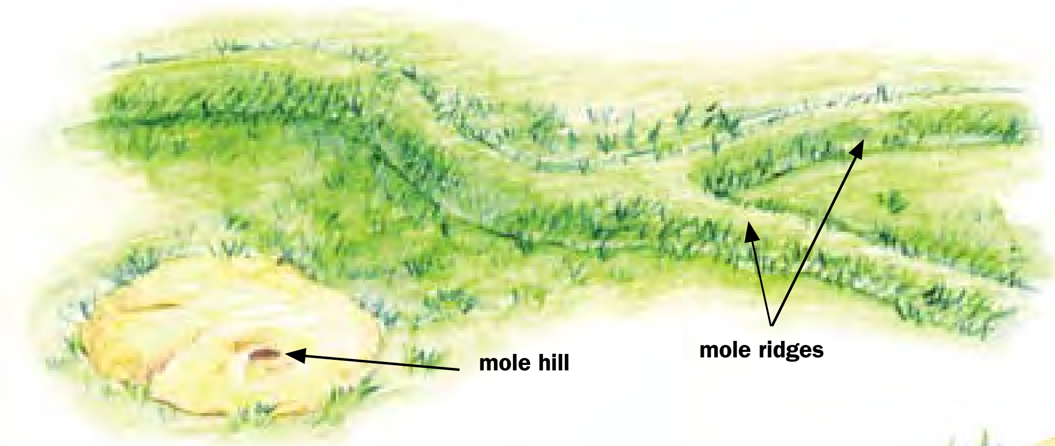


Figure 4-14. Mole burrows form ridges visible from the surface.

Figure 4-15. Moles push dirt vertically to the surface, which forms a mound.

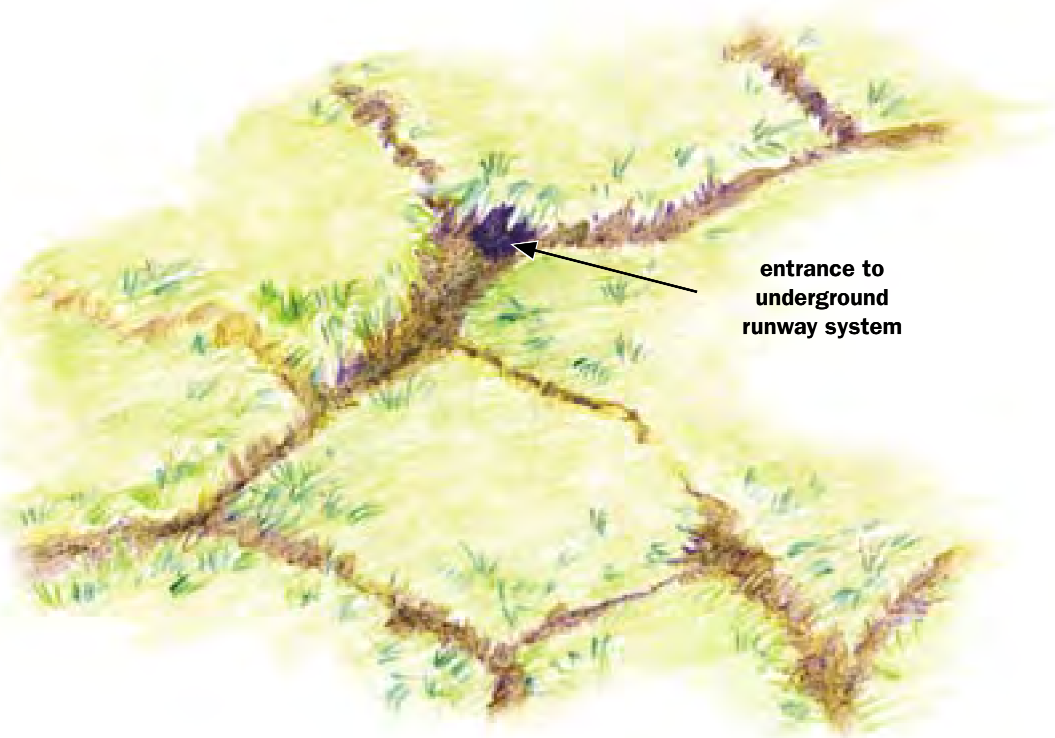


Figure 4-16. Voles are most easily identified by an extensive surface runway system with many burrows.

4.2.15 River Otter Overview

The River Otter's (Lutra canadensis) sleek body, short legs, webbed toes, and tapered tail help it thrive in its aquatic environment. Otter fur is thick and shaded from brown to near black on most of the body, with a lighter brown to beige on the belly, chin, throat, cheeks, and chest (University of Nebraska, 1994).

River otters are considered a significant dam safety issue in 4% of the surveyed states.

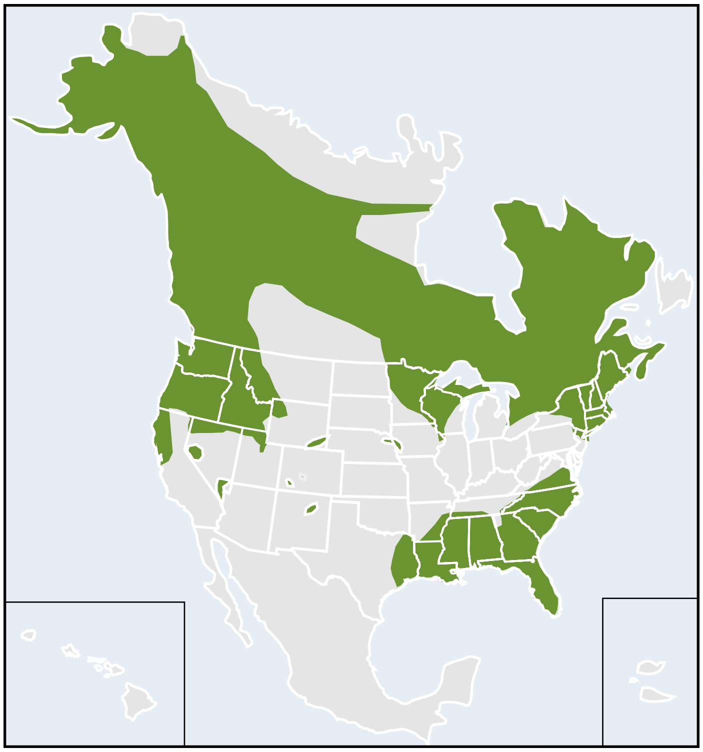
Threat to Dams: Otters sometimes dig bank dens for shelter with an underwater entrance for use in the winter and an above-water entrance for use in the summer (Benyus, 1989). Dens can cause large voids in the dam embankment, and underwater entrances provide pathways for internal erosion and wave action if water levels rise into the embankment den.

Habitat and Home: Otters are associated almost invariably with water environments no matter the water type: fresh, brackish, or salt. Water quality, available fish forage, and available den sites are the most important factors in determining otter habitat. Otters can be found in lakes, rivers, streams, bays, estuaries and associated riparian habitat. Otters most often utilize existing bank dens and lodges constructed by beaver, muskrat, and nutria. Otherwise, otters use hollow logs and rock crevices as their shelter and construct natal dens on small streams that lead to major drainages (University of Nebraska, 1994).

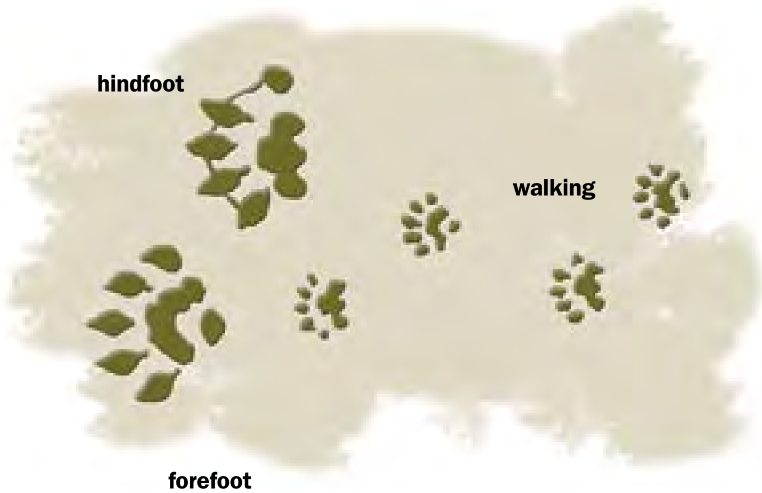
Food Habits: Otters prefer fish of several varieties, but also feed on shellfish, crayfish, reptiles, and amphibians.

Behavior: Otters spend most of the day feeding and participating in group play. Otters are superb swimmers and very alert.

Field Tip: Look for slides into the water or snowbank (in winter) where otters play. Look for "haul-outs," worn areas along the bank where otters consistently pull themselves out of the water. If this area is indeed a haul-out, there will be a trail leading away from the haul-out to a patch of trampled vegetation where otters roll around to dry themselves after a swim or to leave their scent (Benyus, 1989). Listen for the blow and sniff sounds of a surfacing otter.



Range of the river otter in North America.



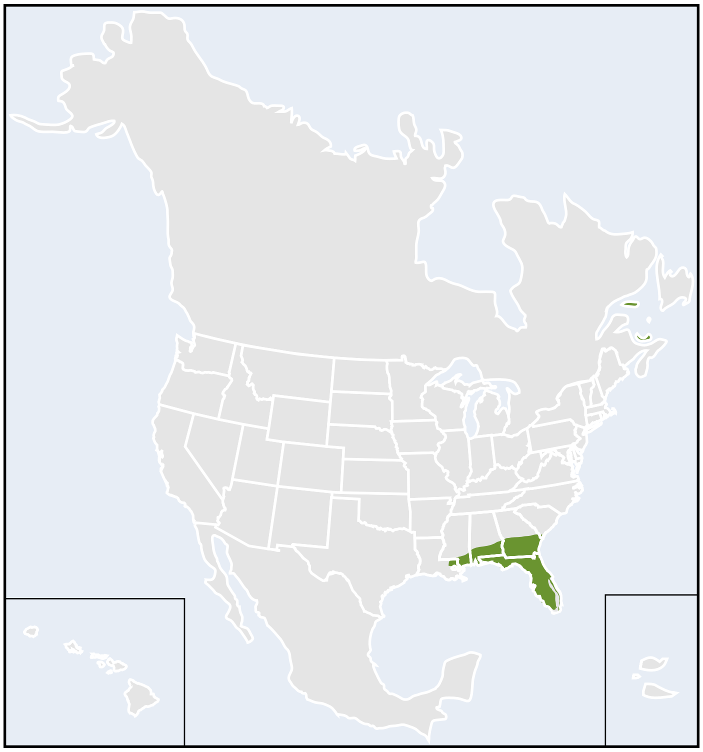
The inner toe of the otter's hind paw juts out to the side.

4.2.16 Gopher Tortoise Overview

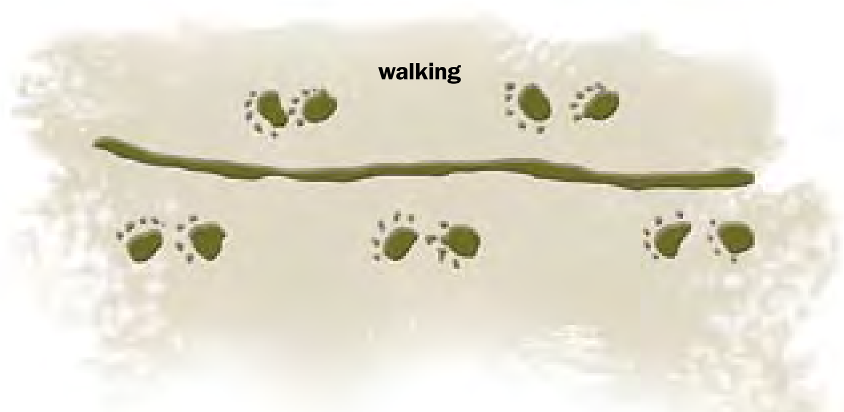
Gopher Tortoise (Gopherus polyphemus) are large, terrestrial tortoises with a shell length of 10 to 15 inches that weigh about 9 pounds. The gopher tortoise is a protected species and a permit is always required to possess, study, remove, or relocate a specimen (Gopher Tortoise Council, 2001). The burrows of the gopher tortoise are also protected by law. Over 360 animal species have been documented inhabiting a gopher tortoise burrow so use caution when investigating a burrow. Many of the species which coexist in or use gopher tortoise burrows are also protected by state and federal laws, such as the burrowing owl and indigo snake.

Threat to Dams: The gopher tortoise's strong claws make it an effective burrower. Burrows can be 40 feet long and 10 feet deep and will include a spacious chamber used to cool off during the heat of the day (Gopher Tortoise Council, 2001). Gopher tortoise burrows can cause structural integrity losses.

Tortoises are considered a significant dam safety issue in 4% of the surveyed states.



Range of the gopher tortoise in the United States.



The shell of the gopher tortoise may obliterate some of the track as it drags.

Habitat and Home: Gopher tortoises prefer to dig their burrows in dry, upland habitats especially where saw-palmetto is present in the understory and sandy soils dominate. Gopher tortoises can live in grassy areas, pastures, and old fields as long as there are well-drained sandy soils, herbaceous plants, and sunny, open areas for nesting and basking (Gopher Tortoise Council, 2001). Look for burrows on the southeastern side of sandy hills (such as old dunes that are covered in vegetation) at a 30-degree angle from the surface (Benyus, 1989; Enchanted Forest Nature Sanctuary, 2003). The burrow entrance, or "apron," will be marked by a characteristic mound of loose sand. The downstream slope and toe of a dam may be suitable for gopher tortoises, as might a forest fringe in a dam area.

Note: In some cases, snapping turtles may hibernate or lay eggs in an existing muskrat den and as such, are often identified as the responsible burrowing animal. In truth, turtles are more correctly simply associated with burrowing animals, rather than responsible for burrows. Depending on its size, the snapping turtle may enlarge an existing muskrat den.

An east-central Florida study indicates that a male gopher tortoise constructs and uses an average of 17 burrows. Some males construct and use as many as 35 burrows.

Food Habits: Primary food sources of the gopher tortoise include low-growing grasses, herbs, and berries.

Behavior: Gopher tortoises emerge from their burrows in the morning to feed and return to the burrows if temperatures get too hot or cold.

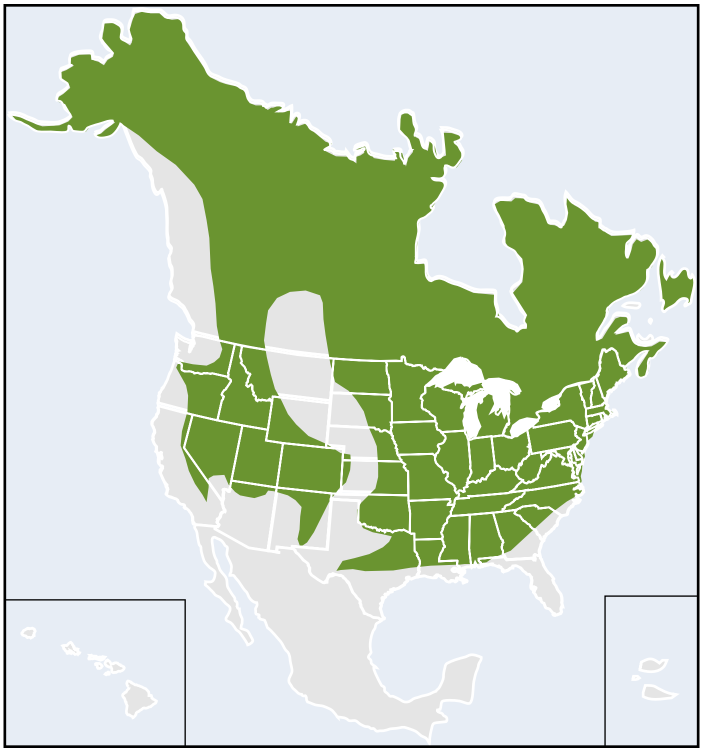
Field Tip: Look for large mounds of loose sand created as the gopher tortoise digs its burrow.

4.2.17 Red Fox and Gray Fox Overview

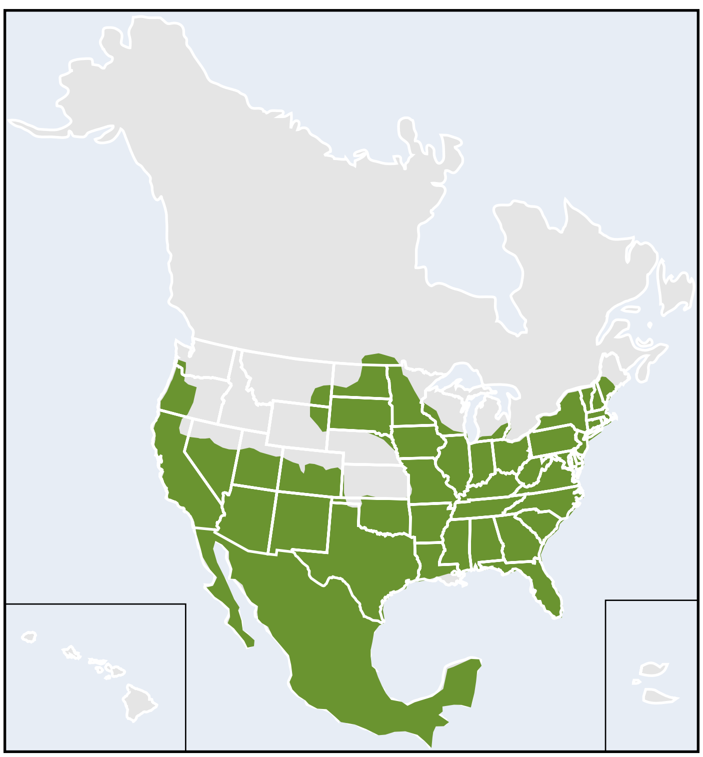
The Red Fox (Vulpes vulpes) is dog-like in appearance with large pointed ears and an elongated pointed muzzle. It typically has a light orange-red coat with lighter colored underfur, black legs, and a white-tipped tail. Coat coloration can vary from red to gray to black, but the tail tip is always white. Adult red foxes can weigh anywhere from 7.7 to 15.4 pounds; males are about 2.2 pounds heavier than females (University of Nebraska, 1994).

The Gray Fox (Urocyon cinereoargenteus) has a long, bushy tail with a black tip. It is salt-and-pepper gray over most of its body, with some rusty yellow spots on the sides of the neck, back of the ears, legs and feet. Adult gray foxes weigh about 7 to 13 pounds, and measure about 32 to 45 inches from nose to tip of tail (University of Nebraska, 1994).

Fox are considered a significant dam safety issue in 4% of the surveyed states.



Range of the red fox in the North America.



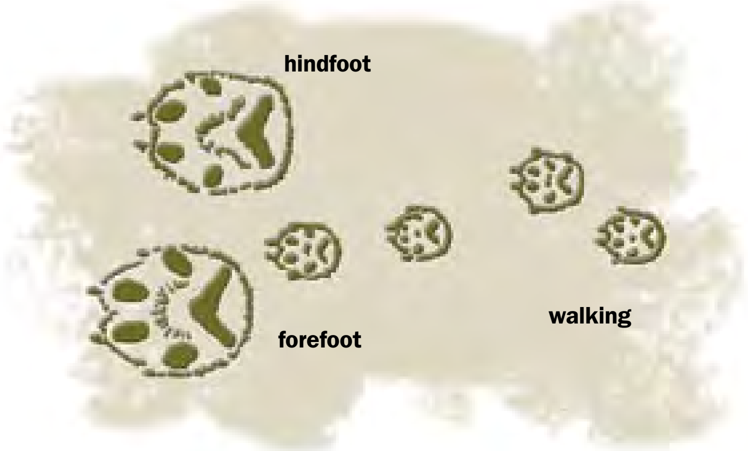
Range of the gray fox in North America.

Threat to Dams: Foxes do not pose a great threat to earthen dams. It is possible that they could cause damage by digging out burrowing animals for food. This type of damage may be prevented with good rodent control and vegetative management.

Habitat and Home: The red fox prefers open country with moderate cover, although it is generally adaptable to any habitat within its range. Red foxes are commonly found in urban areas. They may either dig their own dens or use abandoned groundhog or badger burrows. The gray fox prefers areas of dense cover such as swamp land or thickets. Gray foxes can also be found in urban areas. They commonly use wood piles, rocky outcrops, or hollow trees as den sites (University of Nebraska, 1994).

Food Habits: Foxes mostly eat rabbits, mice, bird eggs, insects, and fruit (University of Nebraska, 1994).

Behavior: Foxes are solitary animals that are most active during twilight and early morning hours. They have a variety of calls that sound like barks, screams, howls, yaps, growls, and hiccups (University of Nebraska, 1994).



Tracks of red fox.

Field Tip: Fox dens may be identified by several 10-inch wide entrance holes, with sandy aprons of soil spilling from them (Benyus, 1989).

Tracks of gray fox.

4.2.18 Canada Goose Overview

The Canada Goose (Branta canadensis) is a large bird that grows to a height of 2 to 3 feet and weighs approximately 10 to 12 pounds. It has a grayish-brown body and wings; black feet, bill and neck; a white underside; and a white patch on each cheek (USDA, 2003). There are 11 subspecies that live in the United States (Virginia Cooperative Extension, 2001b).

Threat to Dam: Canada geese build their nests near water. If they choose to nest on or near an earthen dam, their nesting and feeding activities could cause external erosion.

Canada geese can cause erosion from over-grazing similar to that caused by livestock.

Habitat and Home: Canada geese are found across the United States. Many Canada geese spend their summers in Canada and migrate south to the United States during the winter. Some geese, known as resident Canada geese, spend most of the year in the same general area and fly only far enough to find food or open water (Virginia Cooperative Extension, 2001b). Canada geese nest in areas near open water, such as swamps, marshes, meadows and lakes. Nests are typically made from weeds, twigs, grass, moss, and pine needles (University of Michigan Museum of Zoology, 2002).

Food Habits: Canada geese eat a variety of grasses and aquatic plants. They will also eat crops such as corn, soybeans, and wheat. Young Canada geese require more protein, and will consequently eat insects, small crustaceans, and mollusks (Virginia Cooperative Extension, 2001b).

Behavior: Canada geese are social animals that communicate to each other through a series of calls. They tend to be aggressive birds, particularly the males. They will vigorously defend their territory, nests, and eggs from intruders (University of Michigan Museum of Zoology, 2002).

Field Tip: Canada geese can be easily identified by the white patches on their cheeks. In absence of the birds themselves, Canada geese can be identified by their long, black, cylindrical droppings.

Range of the Canada goose in North America.

Tracks of the Canada goose.

4.2.19 American Alligator Overview

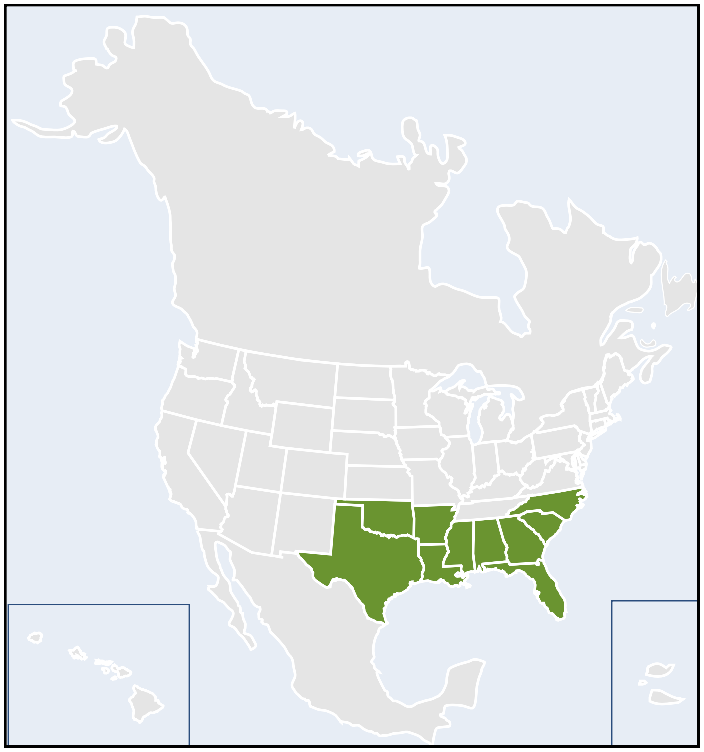
The American Alligator (Alligator mississippiensis) is one of the largest animals in North America. Adult males can grow to a length of 14 feet and weight up to 1,000 pounds. Adult females can grow to a length of 10 feet and weigh up to 250 pounds. They have a rounded snout and black and yellow-white coloration (University of Nebraska, 1994). Alligator hunting is allowed in several states under strict quota or licence guidelines.

Threat to Dam: Alligators sometimes dig burrows or dens for refuge from cold temperatures, drought, and predators. These burrows can cause internal erosion and structural integrity losses in earthen dams (University of Nebraska, 1994).

Habitat and Home: Alligators can be found in almost any type of fresh water, including wetlands, lakes, canals, and streams. They will occasionally inhabit brackish or salt water environments (University of Nebraska, 1994).

Alligators are considered a significant dam safety issue in 2% of the surveyed states.

Food Habits: Alligators will prey upon whatever creatures are most available, including fish, turtles, birds, mammals, and other alligators. Alligators are opportunistic feeders and will eat carrion if it is available and they are sufficiently hungry. If they are near human environments, they may also eat pets and livestock (University of Nebraska, 1994).



Range of the American alligator in North America.

Behavior: Because they are cold-blooded, alligators are most active when the temperature is warm. When the temperature drops below 70⁰F, alligators will stop feeding, and when the temperature drops below 55⁰F, they become dormant. Alligators are not typically aggressive toward humans, but they can and will attack if provoked (University of Nebraska, 1994).

Field Tip: Alligators are large animals, but they blend into their surroundings. It is important to be vigilant and cautious around any water body in the alligator's range.

4.2.20 Ants Overview

Ants (Formicidae spp.) are small insects that live in large colonies. The body of an ant is clearly divided into three sections. Many different species of ants live in the United States. Color and size varies widely across species (University of Florida Cooperative Extension Service, 2002).

Threat to Dam: Ants often build their homes underground. Their colonies consist of a complex series of tunnels that excacerbate existing cracks and can "soften" the embankment, threatening the structural integrity of an earthen dam.

Habitat and Home: Ants can be found across the United States in a variety of habitats. Most ants live in the soil, although some also live in wood or in the cavities of plants (University of Arizona, 1997).

Ants are considered a significant dam safety issue in 4% of the surveyed states.

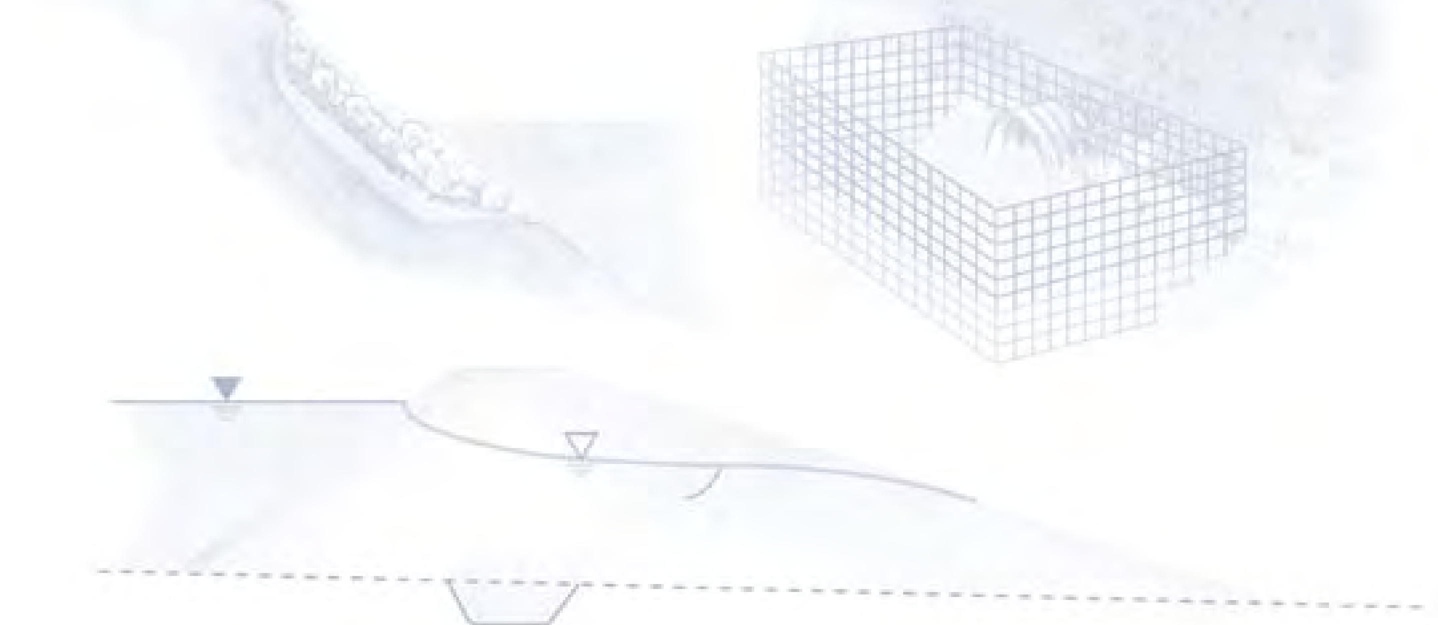
Range of the ant in North America.

Food Habits: Ants eat a variety of foods, including plants, sugars, seeds, and small insects (University of Florida Cooperative Extension Service, 2002).

Behavior: Ants are social animals. They live in colonies comprised of one or a few queens and many workers. Some ants have a potent sting (University of Arizona, 1997).

Field Tip: Small mounds of soil are often indicative of ant inhabitation.

5.0 Dam Repair And Intrusion Prevention Through Design



Once the inspection is completed according to the guidelines (refer to Chapter 3.0) and considering the biological perspectives presented in Chapter 4.0, the dam specialist will need to take action relative to damages found at the dam. Specifically, the dam owner will need to repair burrow or beaver dam damage, and determine the appropriate level and type of prevention action (e.g., reinforced concrete wall and slab system on upstream slope to prevent muskrat burrows). This Chapter first outlines burrow repair procedures, followed by a discussion of each earthen dam zone (which corresponds to the zones described in Chapter 3.3 of this manual) with regard to the relative priority of prevention action for each zone. Lastly, design options to mitigate and prevent future animal intrusions are presented for each wildlife species. The prevention methods in this chapter relate to modification of the dam or its structures; a discussion of prevention through animal control methods (e.g., trapping) is presented in Chapter 6.0.

The majority of the prevention action design criteria of this Chapter are meant to be incorporated when major features of the dam can be easily altered such as during new dam construction or dam repair construction, when the majority of the dam or a large portion of the dam will be reworked.

The input of a professional engineer is required to ensure proper design and construction of prevention actions.

5.1 Conformity to the Clean Water Act of 1972

The Clean Water Act of 1972 (CWA) is the primary guidance for protecting surface water quality in the United States. The goals of the CWA are to restore and maintain the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." Towards these goals, the CWA sets water quality standards for waterbodies, which are upheld by antidegradation policies and programs, ambient monitoring, and pollutant load reduction strategies as necessary.

In the dam environment, extensive vegetation removal, burrow excavation and repair, and dam restoration measures could trigger the CWA if dredged or fill materials could be deposited into wetlands or Waters of the United States. As such, all remediation activities must be completed in accordance with the CWA and its provisions, and coordination with the State Dam Safety Official and the State Water Resources Agency is required.

5.2 The Role of Vegetation Management

Proper vegetation management is a cornerstone of effective wildlife intrusion management. In most cases, wildlife will not inhabit an earthen dam that does not provide vegetation for food supply, protective cover, or shelter. If a variety of vegetation exists at the dam, then wildlife will choose to inhabit the earthen dam environment over other areas lacking in vegetation or without a water supply. Ideally, the earthen dam environment will contain appropriate grass species maintained such that dam inspections can be conducted easily without visual obstruction of the embankment and other appurtenant structures. Vegetation such as dense groundcover and thick, woody trees and shrubs not only hinder dam inspections, but can also obscure indicators of potential performance problems such as animal burrows, settlement, depressions, cracks, and similar issues. If vegetation is too thick, animal burrows can go undiscovered and proper animal intrusion mitigation may not occur.

In general, it is advised to limit vegetation at the earthen dam to low-growing native grass that is mowed regularly, and to keep the embankment and spillway inlet and outlets free of vegetation. Vegetated emergency spillways should be maintained in a similar fashion as the dam embankment. Maintained grass will accommodate thorough inspections and limit the number of wildlife species that can easily inhabit the dam. If a dam contains vegetation other than appropriate grasses, then the dam owner should complete mitigation and management as outlined in the FEMA document, *A Technical Manual on the Effects of Tree and Woody Vegetation Root Penetrations on the Safety of Earthen Dams* (FEMA, 2002) and the FEMA brochure, *Dam Owner's Guide to Plant Intrusion of Earthen Dams* (FEMA, 2003).

5.3 Burrow Repair Procedures

Repair actions can be separated into two categories: restoration measures and preventive measures. As the names imply, restoration measures address repairing a deficiency, whereas preventive measures prevent or avert future damage in the area. Specific restoration and preventive measures applicable for various locations in the dam are discussed below.

5.3.1 Restoration Measures

Damage from animal intrusions can occur throughout the dam. The damage can include removal of surface vegetation, rutting, and burrowing. Regardless of the damage location, applicable restoration options depend upon the judged severity of the damage.

Filling Ruts and Near Surface Deformation

Ruts, near surface deformation, and loss of vegetation can be the result of frequent animal crossings, most likely by livestock. Repair of these deficiencies is generally considered not critical. However, if left unattended for a sufficiently long period of time, these deficiencies can result in a progressive loss of vegetation and surface soils due to erosion. In extreme cases, the damage can lead to increasing amounts of erosion in localized areas, jeopardizing performance and requiring significant maintenance. Timely repair of ruts and vegetation loss can save considerable effort and expense later.

The repair methodology for ruts, surface deformation, and vegetation loss includes the following steps:

1. Fill the rut with soil of a similar type to that of the dam embankment. Overfill the rut slightly to account for compaction of the fill material.

2. Compact the soil using hand held or walk behind equipment. In order to achieve reasonable compaction, the fill material should not contain particle sizes greater than 1 inch in diameter. For larger ruts, and ruts created by vehicles, larger diameter material may be acceptable. The compacted surface should be smooth and level with the surrounding ground.

3. Revegetate the area with grass species appropriate for the region (see Chapter 5.2).

Filling Burrows

Methods for repairing or filling an animal burrow are essentially limited to two basic types. The first method considers filling the burrow without excavation while the second method considers excavating the burrow and backfilling the area. Details for each method are discussed below.

Observed burrows without signs of embankment distress (e.g., cracking, slumping) in the area may simply require filling with an impervious material or cementious grout. To fill the entire burrow, a process often referred to as "mud-packing" can be applied. This method consists of placing one or two lengths of metal stove or vent pipe vertically into the burrow. When the pipe is properly sealed, a slurry of 90% earth and 10% concrete, plus an appropriate amount of water to make the slurry flow, is placed in the pipe and allowed to flow into the burrow (Virginia Dam

Safety Program, 2003). The last 6 inches is filled with dirt that will support grass growth.

On the other hand, signs of embankment stress surrounding a burrow may indicate massive soil movement into the burrow. In these cases and at the owner's discretion, complete removal of the burrow is preferred. Shovels or backhoes could be necessary during excavation depending upon the burrow location, size, and depth. Excavation limits will be defined by the burrow size and location as well as the density and type of embankment material. Prior to excavation, dam safety professionals and dam owners should examine potential consequences of soil removal, including slope instability and increased hydraulic gradient. The completed excavation should be thoroughly inspected for adequate removal of the animal burrow. Voids remaining from an animal burrow can develop into potential internal erosion pathways or sinkholes.

Once excavation is complete, the resulting hole must be properly backfilled in a timely manner. Acceptable backfill material should consist of soil types (e.g., sand, clay, etc.) similar to that of the surrounding embankment. If desired, laboratory index testing such as grain size and Atterberg Limits of the backfill and embankment materials may be performed. To achieve adequate compaction of the backfill materials, necessary laboratory testing of backfill materials should include a maximum dry density determination by either the Standard or Modified Proctor test (ASTM D-698 or ASTM D-1557). Backfill material should be compacted to a minimum of 95% of the maximum dry density and within +/- 2% of the optimum moisture content, as determined by ASTM D-698. The completed backfilled surface should be smooth and approximately level with the surrounding ground surface. Backfill should be placed and compacted in lifts of no more than 8 inches thick. A 2 to 4-inch gap can be left between the top of the completed backfill surface and surrounding ground surface to accommodate topsoil.

A local dam safety professional should be notified prior to any excavation activities in an embankment dam.

The final step is to revegetate the disturbed area. Native grass species appropriate for embankment dam slopes should be provided (see Chapter 5.2).

5.3.2 Preventive Measures

For a specific animal intrusion or animal related deficiency, appropriate preventive measures are highly dependent on the affected area's location on the dam. Therefore, common preventive measures are discussed in the context of the Repair Zone in the following section. The use and effectiveness of preventive measures should be assessed by the dam owner in conjunction with a dam safety professional. It may not be cost effective to employ these measures for treatment of animal intrusions alone; however, coincident benefits such as protection against wave erosion and plant intrusion may make the measure more fiscally viable.

5.4 Dam Repair Zones

As discussed in this manual, a variety of animals can damage an embankment dam. The damage can be surfical with minor impact to dam safety or performance, or the damage can directly threaten the integrity of the dam, potentially leading to failure. However, all animal impacts should be considered undesirable and must be repaired. Dam regulators, owners, and engineers should develop an understanding of the potential impact of an animal intrusion to properly evaluate its impact on the safety and performance of the dam (refer to chapter 2.0 for a discussion on animal intrusion impacts).

Prioritization of necessary repairs is critical to maintain a proactive approach to repair and maintenance of a dam. With limited available capital, many dam owners may delay or avoid necessary dam repairs. In addition, routine safety inspections by either regulatory personnel or consulting engineers tend to overwhelm dam owners by listing all observed deficiencies without a clear indication of the relative importance or seriousness of each deficiency. The relative importance and criticality of a specific deficiency depends on the size and nature of the observation (length, width, depth, area, etc.) as well as its location.

Developing a well-defined methodology for evaluating observed deficiencies will permit dam safety professionals to accurately communicate repair prioritization to dam owners. Chapter 3.0 describes an inspection process that considers both engineering and biological perspectives for a dam divided into five distinct zones. These dam zones cor-

(DCR-VSWCB-034) (03/14)

respond to specific physical areas of the dam as illustrated on Figure 5-1 (ASDSO, 2001). The intent of the zones is to differentiate and prioritize animal intrusion damages based on their potential impact to dam safety or performance. Depending on the type of animal intrusion or deficiency observed, one or more zones may be considered critical and require near term or immediate repair. However, these critical zones will vary with the dam as well as the dam inspection. Therefore, the zones are not ordered by their importance; rather they are simply ordered from upstream to downstream.

The following sections provide a description of each repair zone, potential damage from animal intrusion, and suggested preventive measures. These descriptions are limited to animal intrusions and their impact to embankment dams. However, other deficiencies such as plant intrusion and erosion can occur within each repair zone. Where appropriate, restoration and preventive measures should consider all observed deficiencies in the area.

5.4.1 Dam Repair Zone 1

Zone 1 begins on the upstream slope at a point approximately 4 vertical feet below the normal pool elevation and extends to the center of the crest. A 4-foot vertical distance was recommended by Marks, et.al. (ASDSO, 2001) to account for average fluctuations in the normal pool and typical underwater animal burrows. The size of Zone 1 can vary significantly from dam to dam because it depends upon the distance between the crest elevation and the normal pool elevation. This distance is often referred to as freeboard.

The relative importance of Zone 1 depends upon the crest width and freeboard. For a dam with a wide crest and large freeboard, animal intrusion within Zone 1 becomes less critical. However, as the crest narrows and freeboard lessens, the importance of repairing deficiencies in Zone 1 increases rapidly.

The most common animal intrusions within Zone 1 are muskrat burrows in which the burrow entrance is underwater as shown on Figure 5-2. However, other intrusions are possible depending upon the specific characteristics of the

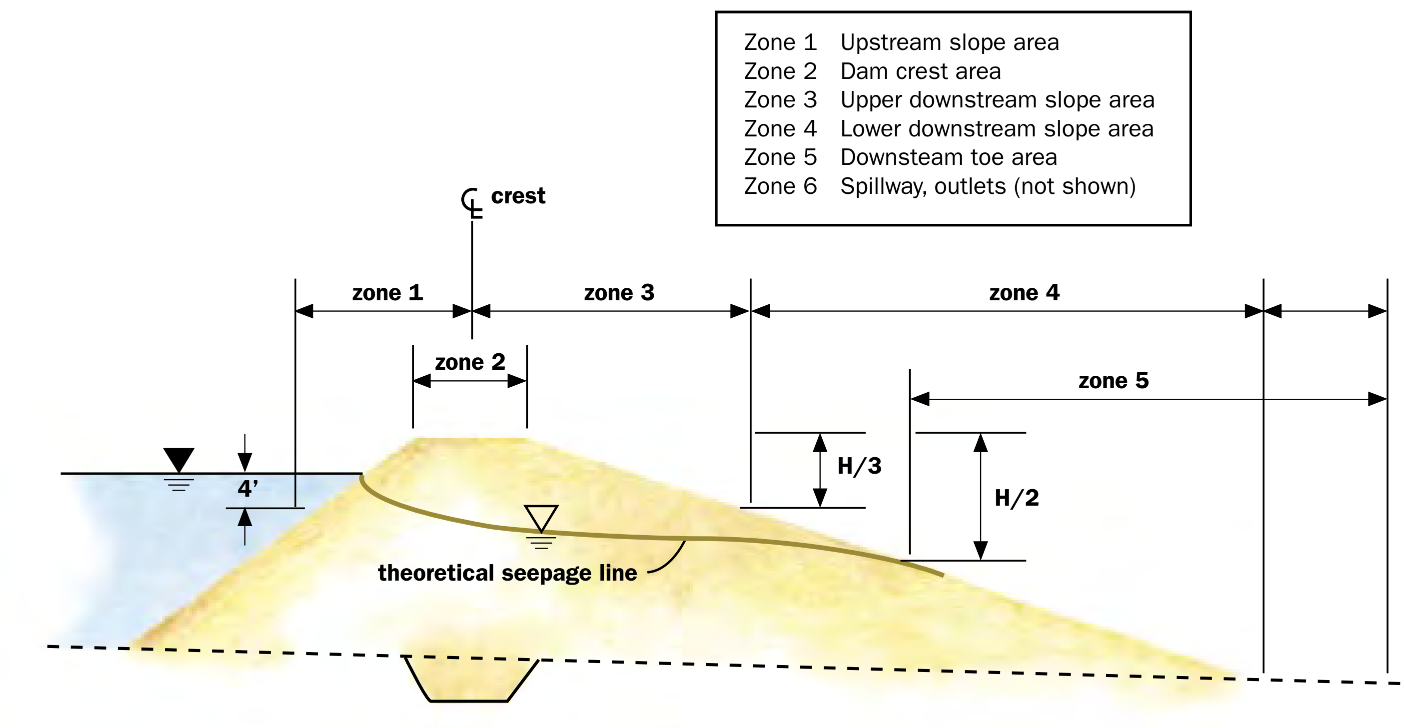


Figure 5-1. Remedial dam repair zones.

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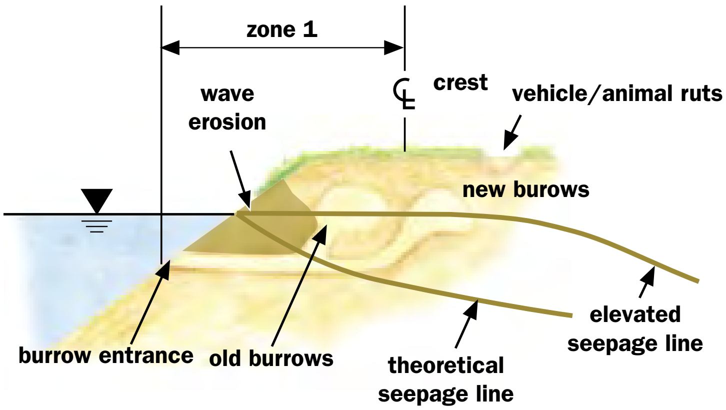

Figure 5-2. Zone 1 Pentration Problems.

dam and reservoir that include geographic location of the dam, proximate vegetation, and prevailing weather patterns. Zone 1 is also susceptible to other forms of deterioration including wave erosion, vehicle access, surface water erosion, and plant intrusion.

To effectively repair animal intrusions in Zone 1, the reservoir pool must be lowered as far below the observed deficiencies as necessary to allow proper access during construction. If the dam owner is unable or unwilling to lower the reservoir pool, then the repair costs will likely increase dramatically to account for necessary water management and diversion.

Preventive measures acceptable for use along the upstream slope generally consist of hardened or structural features. The intent is to provide a physical barrier to the animal, thus making the area much less attractive as a burrow site. These features include riprap, concrete facing, revetment mats, gabions, large gauge wire mesh, and mechanically stabilized earth walls among others. With proper design and installation procedures, each of the methods can be successful. Two of the more common measures are riprap and concrete facing because they are relatively simple to design and provide protection from wave action and plant intrusion as well as animal intrusion.

- A typical cross section of riprap, shown on Figure 5-3 (Ohio DNR, 1999) should consist of a layer of rock riprap overlying bedding material and filter material or a geotextile separator. Limits of the protection should extend at least 4 feet below the normal pool elevation and several feet above depending on estimated wave heights and average reservoir fluctuation. Rock size and layer thickness will vary significantly from dam to dam depending on the reservoir size, prevailing winds and other physical characteristics of the area. Therefore, material (e.g. riprap, bedding and filter) sizes and layer thickness, must be based on the anticipated wave action, ice thickness, and compatibility with neighboring materials. A number of guidelines including Technical Release No. 69 developed by USDA, Natural Resources Conservation Service can assist dam safety professionals in detailed design for riprap slope protection.

- A typical cross section of concrete facing as shown on Figure 5-4 (Ohio DNR, 1999) will resemble riprap in that the concrete will overlie a filter material. As with riprap, the concrete facing limits should extend at least

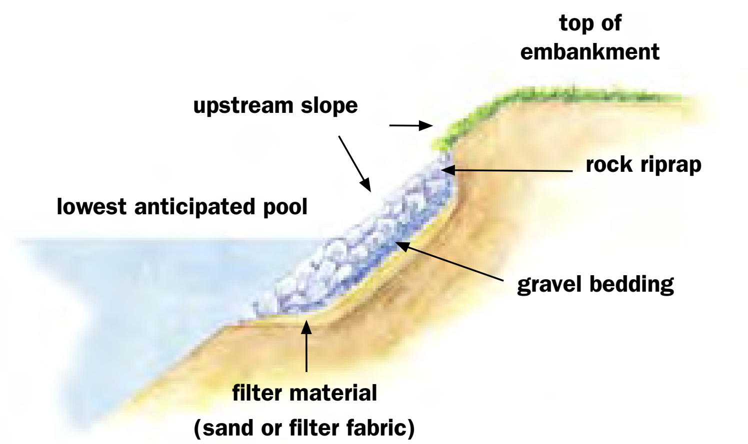

Figure 5-3. Riprap Repair in Zone 1.

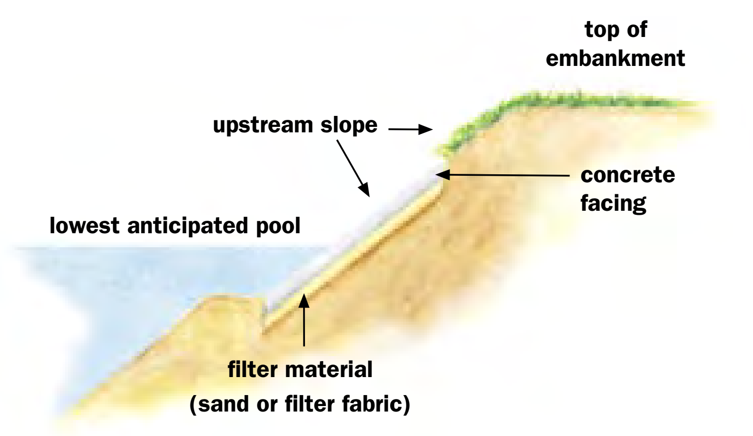

Figure 5-4. Concrete Facing in Zone 1.

4 feet below the normal pool elevation and several feet above, depending on estimated wave heights and average reservoir fluctuation. Concrete thickness, compressive strength, and reinforcing depend on wave action, freeze/thaw cycles and other factors.

Regardless of the measure selected, proper implementation requires specific design recommendations from a qualified dam safety professional.

5.4.2 Dam Repair Zone 2

Repair Zone 2 corresponds to the limits of the dam crest and, therefore, overlaps with Zone 1 by one-half of the crest width. Overlapping a portion of Zone 1 with Zone 2 emphasizes the importance and critical nature of both zones. This overlap essentially suggests that both zones be inspected twice during a dam safety inspection.

As with Zone 1, the relative importance of Zone 2 depends upon the crest width and freeboard. For a dam with a wide crest and large freeboard, animal intrusion within Zone 2 becomes less critical. However, as the crest narrows and freeboard lessens, the importance of repairing deficiencies increases rapidly. These intrusions may include terrestrial animal burrows such those made by groundhog, but most typically include ruts and other minor deformations. Zone 2 is also susceptible to other forms of deterioration including vehicle access, surface water erosion, and plant intrusion.

Restoration of animal penetrations within Zone 2 should follow the guidelines presented in Chapter 5.3. Any excavation activities within a dam embankment should be coordinated with a dam safety professional.

Applicable preventive measures for Zone 2 include hardening the crest surface with stone, concrete, or asphalt. These measures tend to prevent rutting from animal and vehicular traffic. Design of these measures depends upon the specific characteristics of the dam and expected loading conditions.

5.4.3 Dam Repair Zone 3

Repair Zone 3 begins at the crest centerline and extends to a point on the downstream slope equivalent to one-third the structural height of the dam below the dam crest elevation. As with Zone 2, Zone 3 overlaps Zone 2 by one-half of the crest width to emphasize the importance of the dam crest area. However, the remaining portion of Zone 3 is typically considered the least critical dam repair zone relative to dam safety issues (ASDSO, 2001). The phreatic surface and zone of saturation within the embankment are generally below the depths of average animal burrows and should not interfere with restoration activities.

Zone 3 is the most attractive area for burrows of terrestrial animal, including groundhog, fox, and coyote. Similar to all other zones, Zone 3 is also susceptible to other forms of deterioration including vehicle access, surface water erosion, and plant intrusion.

Restoration of animal penetrations within Zone 3 should follow the guidelines presented in Chapter 5.3.1 and as shown on Figure 5-5. Any excavation activities within a dam embankment should be coordinated with a dam safety professional.

Applicable preventive measures for Zone 3 (beyond the limits of Zone 2) are limited. Use of hardening materials such as stone, riprap, or concrete is generally discouraged by dam safety professionals because they obscure the surface and prevent detailed inspection. Installation of wire mesh or fencing (e.g., chain link fencing) directly on the ground surface can effectively deter to burrowing animals. With properly sized openings, the wire mesh deters animal intruders and accommodates inspection of the area. However, these materials can represent an obstacle to routine maintenance activities such as mowing and be viewed as a tripping hazard.

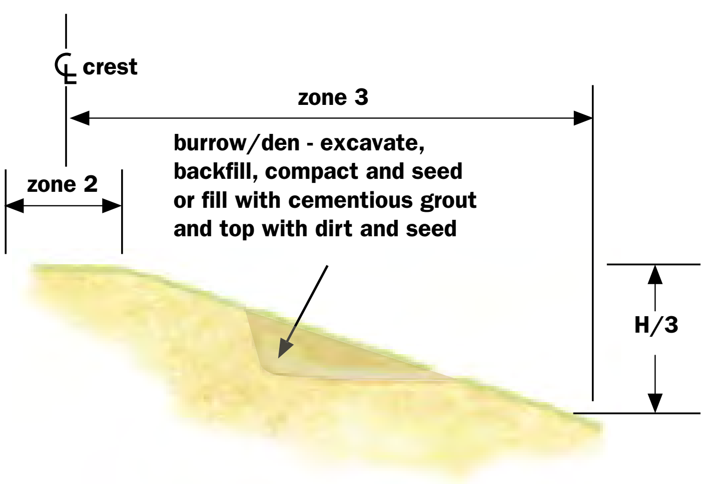

Figure 5-5. Zone 2 and 3 Repair Procedures.

5.4.4 Dam Repair Zone 4

Repair Zone 4 extends from the point on the downstream slope that is one-third the dams' structural height below the crest to the toe of the downstream slope. Zone 4 is one of the two most critical dam repair zones relative to dam safety issues because of the proximity of the phreatic surface and zone of saturation to the embankment slope.

Animal and plant intrusions within this repair zone should be of major concern to dam owners and dam safety professionals. Any animal intrusion or dam penetration should be thoroughly evaluated for potential impact to dam safety and for the required repair.

Restoration of animal burrows within Zone 4 should follow procedures presented in Chapter 5.3. However, due to the proximity of the phreatic surface to the animal burrow, the increased potential of soil migration and, therefore controlling water in the restored burrow must be considered. As shown in Figure 5-6, the use of filter materials within the backfilled burrow can control internal erosion, and with small diameter plastic piping, can manage the flow of water in the area.

Similar to Zone 3, use of hardening materials such as stone, riprap, or concrete is generally discouraged by dam safety professionals because they obscure the surface and prevent detailed inspection. The use of wire mesh or fencing as discussed for Zone 3 is also applicable to Zone 4. It is essential that restoration and preventive measures in Zone 4 undergo review from a dam safety professional prior to implementation.

5.4.5 Dam Repair Zone 5

Repair Zone 5 begins at the mid-height of the downstream slope and extends to a distance of one-half of the dam's structural height horizontally beyond the downstream toe. Zone 5 overlaps a large portion of Zone 4 to emphasize the most critical portions of both zones and heighten scrutiny during inspection. Zone 5 is typically considered the most critical zone relative to dam safety issues (ASDSO, 2001) because the interception of the phreatic surface and downstream slope is typically located in this zone for homogeneous dams.

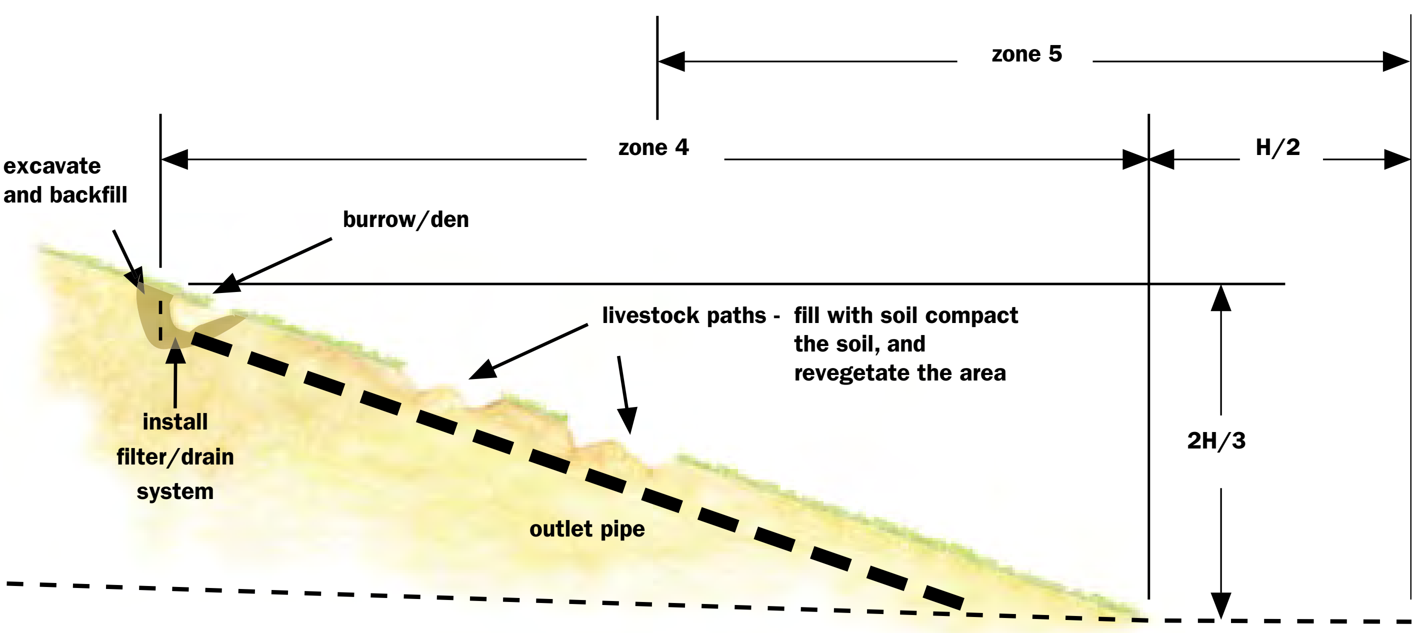

Figure 5-6. Zone 4 and 5 Repair Procedures.

Animal and plant intrusions in this zone often develop into serious conditions involving seepage and piping that are progressive and can lead to dam failure if left untreated. The installation of filter and drain systems to control soil migration and manage seepage must be considered in Zone 5. Similar to Zone 3 and 4, the use of wire mesh of fencing to deter animal intruders can also be considered in Zone 5. It is essential that restoration and preventive measures in Zone 5 undergo review from a dam safety professional prior to implementation.

5.5 Professional Dam Safety Review

Construction or repair activities on an embankment dam should be reviewed by a dam safety professional prior to initiation. Due to the complexity of interaction among animal penetrations, the phreatic surface, slope stability, and other deficiencies, the impact of excavation activities on a dam can be unpredictable without thorough review by a qualified professional. This review should include the following elements at a minimum:

- Evaluation of the existing dam relative to the position of the phreatic surface and slope stability through review of pre-existing inspection reports, design drawings, design memoranda, and owner observations.
- Assessment of the impact of excavation given the phreatic surface position and physical characteristics of embankment materials (material type, density, plasticity, etc.).
- Evaluation of the restoration and preventive scheme proposed.

5.6 Sequenced Repair Program

Currently, dam safety inspections provide a comprehensive list of deficiencies observed at the time of the inspection. The list is generally separated into physical areas of the dam including the upstream slope, crest, downstream slope, emergency spillway, and principal spillway. However, in most cases, the list is not prioritized for the dam owner. Consequently, the dam owner is left with a long list of deficiencies with little guidance on immediate, near-term, and long-term repair items.

Considering that most dam owners do not have the financial means to address all deficiencies quickly, a prioritization methodology should be established for dam repair. The following sequence is one that provides the owner, regulator, and dam safety engineer with a reasonable opportunity to effectively evaluate the condition of an earthen dam (ASDSO, 2001). It must be noted that the following sequence is intended for general guidance only. Specific dam inspections may substantially deviate from the following sequence based on the needs and requirements of the individual dam.

- **Year 1.** (from date of last inspection) Repair animal penetrations that exhibit seepage, soil migration, or have caused slope instability in Zones 1, 4, or 5. Preventive measures should be installed where appropriate.
- **Year 2.** Repair penetrations in Zones 2 and 3. If deemed necessary, initiate investigation, analysis, and preliminary design of major repair activities.
- **Year 3.** Complete design and begin construction of major repair activities.
- **Year 4.** Complete construction of major repair activities and establish an operation and maintenance program that will manage animal intrusions and penetrations on a frequent and regular basis.

If dam failure is judged imminent or if dam safety or operation has greatly diminished, the above sequence may not be applicable. In these cases, a dam safety professional must be advised of the situation to develop a revised schedule.

5.7 Mitigation Through Design

5.7.1 Muskrat

Some of these design criteria are referred to as "overbuilding" however, they are generally effective at preventing serious muskrat burrow damages. The design measures are adapted from the following references: University of Nebraska, 1994; University of Missouri Extension, 1999; ASDSO, 2001; Connecticut DEP, 1999; USDA, 1991; and South Carolina DNR, 2003.

- Construct the upstream slope of the dam to a 3H to 1V slope. Muskrats favor steep slopes so gentle slopes will be less attractive (Figure 5-7).
- Construct the downstream slope of the dam at a 2H to 1V slope with a crest width of not less than 8 feet, preferably 10 to 12 feet.

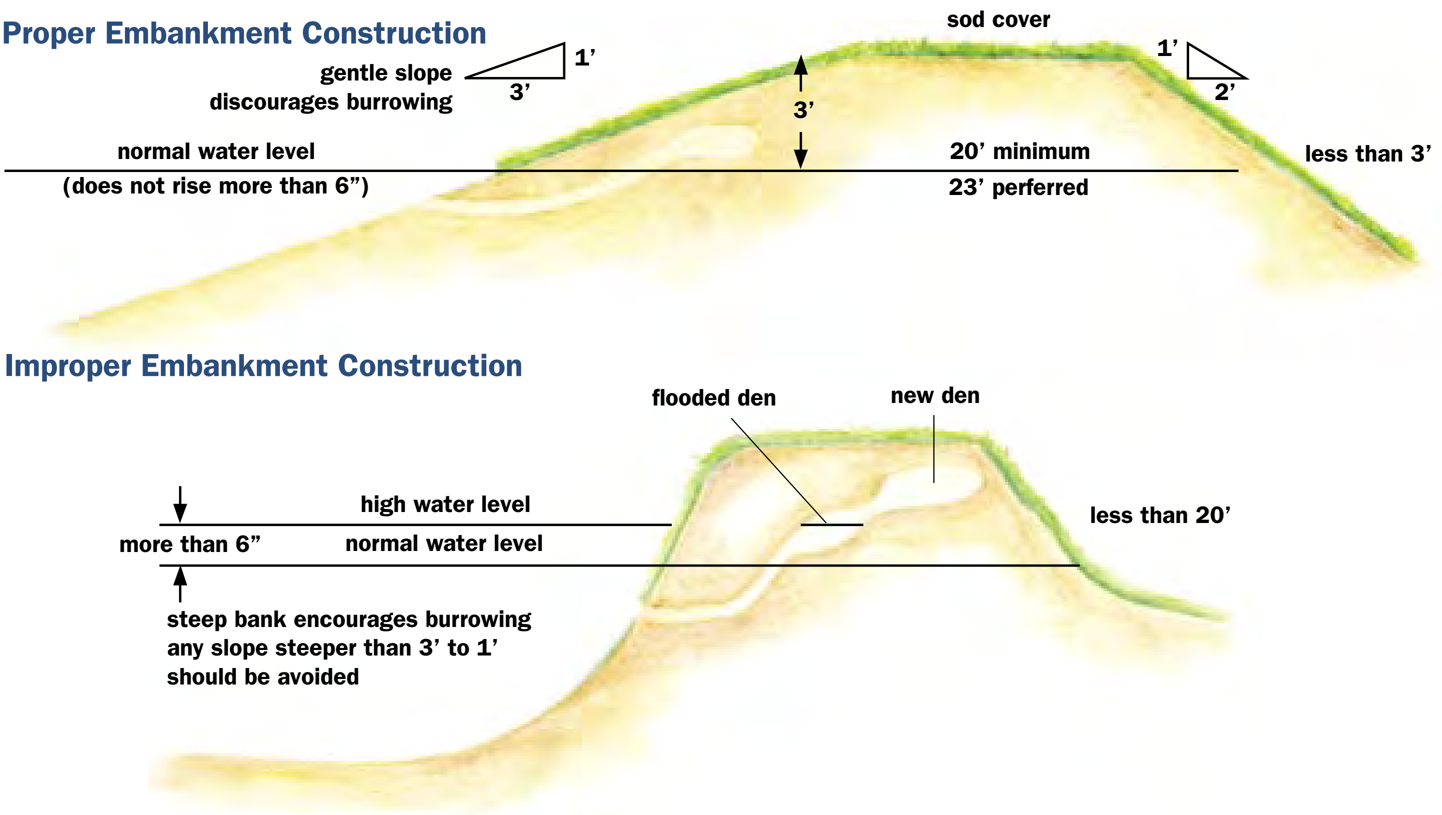

Figure 5-7. Proper dam construction can reduce muskrat damage.

- The normal water level in the pond should be at least 3 feet below the top of the dam and the spillway should be wide enough that relatively frequent storms (less than the 10 year storm event) will not increase the level of the water for any length of time.
- Design for a minimum width of 20 feet at normal water level.
- Bind soil adequately by sodding well.
- Protect the crest from muskrat by applying compacted dense-graded aggregate base course 4 to 6 inches thick.
- Construct a 10-foot-wide shelf projecting from the face of the dam into the reservoir at the water line. This shelf will act as a muskrat barrier and also reduce wave action erosion.
- Place stone rip-rap underlain by fine filter stone and geotextile (high strength, non-woven) extending from 3 to 4 feet below the water line to 1 foot above the water line. Riprap size and thickness will depend upon specific reservoir characteristics. The riprap will prevent muskrat from burrowing into the dam.
- Use an appropriate gabion wall system and/or enlarged reinforced concrete outlet works structures to act as exclusion systems at the toe of the downstream slope.
- Embed 1 to 2-inch welded wire or chain link fencing into the dam upstream face. Mesh wire should extend from 3 to 4 feet below the water line to 1 foot above the water line. Lay the wire flat against the banks and fasten it down every few feet to secure the wire. It is likely that portions of the mesh below the water surface will corrode over time and require replacement.
- Using a narrow trenching machine, cut a vertical trench extending the full length of the embankment in the centerline of the earth fill. The trench should extend from 3 to 4 feet below the water line to 1 foot above the water line. Fill the trench with concrete to create a core that will prevent muskrat from digging through the embankment.

The South Carolina Dam Safety Office indicates that using siphons and other "non-trickle" principal spillway systems may be effective against beaver, but their success is not documented.

- Design water control structures with a concrete apron to prevent muskrat burrows from damaging these facilities.

Several of the above design components indicate placement of the barrier 3 to 4 feet below the water line of the normal pool. It should be noted that if the barriers are not placed at least 3 feet (and preferably 4 feet) below the water line, then the muskrat will burrow underneath the barrier and penetrate the embankment; failure of the slope protection system and embankment damages will result.

5.7.2 Beaver

Structures or techniques to prevent beaver damage can often be included in initial engineering plans or added during dam upgrades and repairs. The following techniques have been adapted from the following references: University of Nebraska, 1994; North Carolina State University, 1994; Wilson, 2001; New York State DEC, 2002; Porter, 2003; Barnes, 1991; Virginia Cooperative Extension, 2000; and FEMA, 2000.

- Gently slope the embankment (3H to 1V or flatter) to discourage burrowing and minimize the probability of beaver dam construction.

- Install spillway risers so that they open upstream instead of toward the dam.

- Place riser structures far from the face of the dam in the deepest water possible.

- Protect large risers from clogging by installing mesh bars (at least 5 inches square) or hog pen panel (4 x 4 inches). This will prevent beaver from entering the trash rack.

- Protect intakes with a deep water cage or fence to prevent plugging.

- Replace the standard manhole cover on top of the riser tower with a "beehive" grate. This cast iron dome allows drainage during high water events, even if the lower orifices are blocked.

- Install a single strand, high-tensile electric wire across active beaver paths or around the shoreline just above the slope where beavers would exit the water. The electric wire should be staked about 3 to 4 inches above the soil surface and can be powered by a direct 110-volt charger or a rechargeable battery pack. After repeated shocks, the beaver will usually relocate to another area. Public safety issues and concerns must be addressed when considering this option.

- Install fencing around outlets to prevent plugging. Secure the fence to the reservoir bottom with metal posts. Fencing should be about 5 feet high, made of heavy-gauge woven wire with no larger than 6-inch openings. It should extend 10 to 20 feet out from the outlet. Before installing the fence, debris should be removed from the outlet (Figure 5-8).

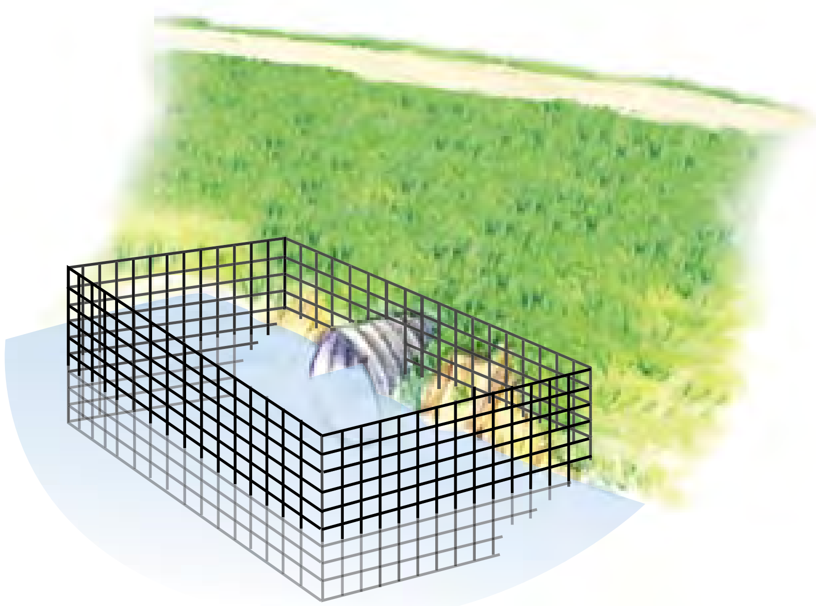

Figure 5-8. Install fencing around culverts and outlets to prevent beavers from blocking flow.

Avoid These Water Level Control Devices at Dams

Because these devices require partial obstruction of spillways or outlet pipes, their use at a dam should be strictly prohibited. Obstruction of spillways or outlets can cause reservoir levels to rise resulting in overtopping of the dam, erosion of earthen spillways and other detrimental impacts.

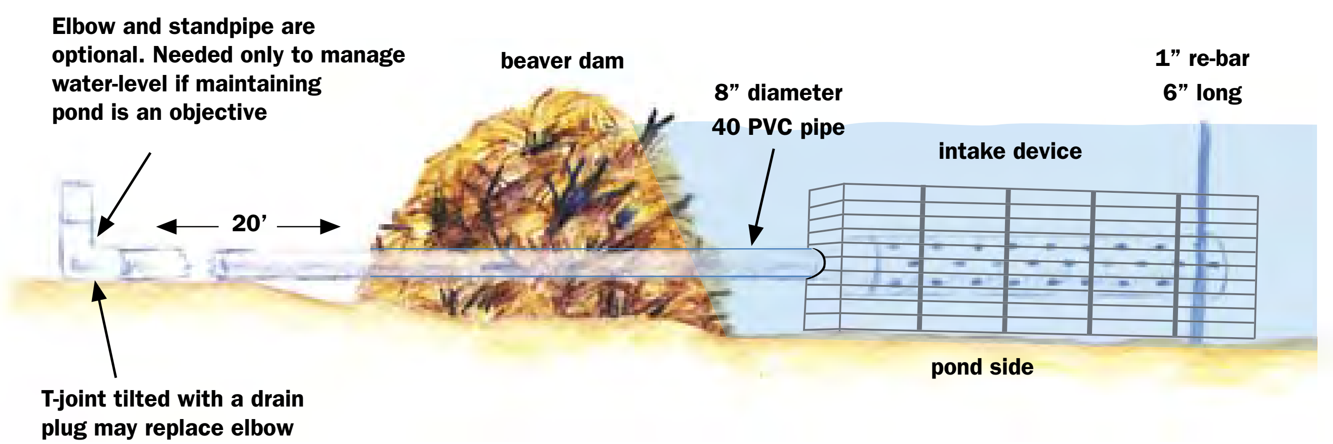

Figure 5-9. The Clemson Beaver Pond Leveler is a passive but effective means to control water levels through a beaver dam.

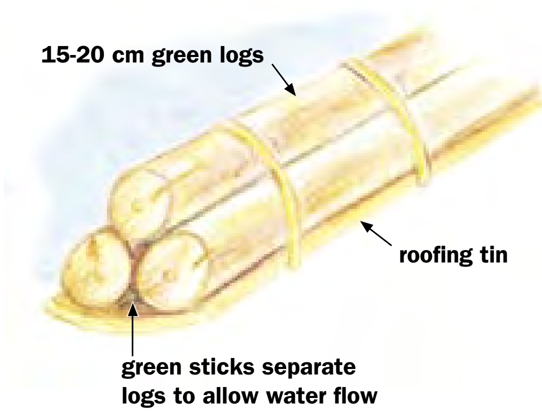

Figure 5-10. A 3-log drain manipulates water levels through a beaver dam.

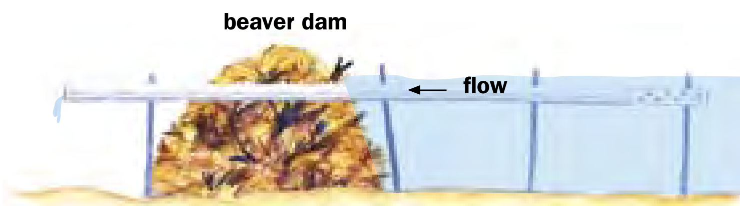

Figure 5-11. PVC Beaver Drain Pipe

Figure 5-12. Massachusetts Beaver Pond Leveler

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- Install a layer of riprap on the upstream side of the embankment to prevent burrowing. The riprap should extend from 4 feet below to 2 feet above normal water levels.

5.7.3 Mountain Beaver

It may be possible to exclude mountain beavers from a dam by installing a rabbit-proof fence (chain-link, chicken wire, etc.) around the embankment. The bottom of the fence must be tight against the ground or, for better protection, buried about 1 to 2 feet (Pehling, 2003).

5.7.4 Groundhog

It is possible to discourage groundhogs from burrowing in an earthen dam by armoring the structure with rock or other hard materials (Michigan State University Extension, 1998).

It is also possible to exclude groundhogs from an earthen dam by installing a fence around the area of concern. Groundhogs are good climbers so the fence should be at least 3 feet high and made of heavy poultry wire or 2-inch mesh woven wire. To prevent burrowing underneath the fence, it should be buried 10 to 12 inches into the ground or bent into an L-shaped angle (pointing away from the excluded area) buried 1 to 2 inches into the ground. For added protection, an electric wire placed 4 to 5 inches off the ground and 4 to 5 inches away from the fence may be installed (University of Nebraska, 1994). Public safety issues and concerns must be addressed when considering this option.

5.7.5 Pocket Gopher

Fencing is of limited use for protecting earthen dams from pocket gophers; the method is expensive and generally not practical because pocket gophers burrow so deeply underground. However, if fencing is used to exclude pocket gophers from the dam, it should be buried at least 20 inches into the ground and extend 6 to 8 inches above the ground (USDA, 1991).

5.7.6 North American Badger

Fencing may be used to exclude badgers from an earthen dam. The fence should be made of mesh wire and it should be buried to a depth of 12 to 18 inches to prevent badgers from burrowing underneath. This control method may not be practical for protecting large areas because installation can be costly and time consuming (University of Nebraska, 1994).

5.7.7 Nutria

There are several design measures that can be implemented to reduce nutria damage.

- Install fencing around the dam embankment. Fences should be about 4 feet high with at least 6 inches of fencing buried underground.
- Armor the embankment with riprap to discourage burrowing.
- Contour embankment slopes to an angle less than 45° to discourage burrowing.

5.7.8 Prairie Dog

The use of fencing to exclude prairie dogs from a dam is a potential management tool, although it is rarely practical because prairie dogs burrow so deeply underground. If fencing is chosen as a control method, a tight-mesh, heavy-gauge, galvanized wire fence should be used, with 2 feet buried in the ground and 3 feet remaining above ground (University of Nebraska, 1994).

Visual barriers may also discourage prairie dogs from inhabiting an area. Prairie dogs prefer areas of low vegetation to provide a clear view of their surroundings and to improve their ability to detect predators. Objects such as fences or hay bales that are strategically placed to block prairie dog views may reduce suitability of the habitat. High construction and maintenance costs generally reduce the viability of this option (University of Nebraska, 1994).

5.7.9 Ground Squirrel

Fencing is not usually a practical method of control for ground squirrels because they are able to climb over or burrow under most exclusion structures. Routine weed control and vegetative management may limit some damage, but the effectiveness of this method is usually limited as well (USDA, 1991).

5.7.10 Armadillo

It is possible to exclude armadillos from an earthen dam by installing a fence or barrier around areas of concern. Armadillos can both climb and burrow so the fence should be slanted outward at a 40° angle with a portion buried underground sufficient to maintain the fence's pitch.

5.7.11 Livestock

Fencing is a highly effective method of protecting earthen dams from domestic livestock and is moderately effective with free-ranging or wild grazing animals (USDA, 1991). Heavy wire fences, wooden post fences, or electric fences may be used (University of Nebraska, 1994).

5.7.12 Crayfish

No design techniques are effective at discouraging crayfish inhabitation.

5.7.13 Coyote

Fencing can be used to exclude coyotes from a dam. Both wire and electric fences will work, and a combination of the two will probably be most effective. Net wire fences should be about 5 feet high with barbed wire at ground level or a buried wire apron. Horizontal spacing of the mesh should be less than 6 inches and vertical spacing should be less than 4 inches. Electric fences usually consist of strands of smooth, high-tensile wire stretched to a tension of 200 to 300 pounds. Studies have shown that 13 strands of charged wire effectively protected pastures from coyote predation (University of Nebraska, 1994).

Studies have shown that 13 strands of charged wire effectively protected pastures from coyote predation.

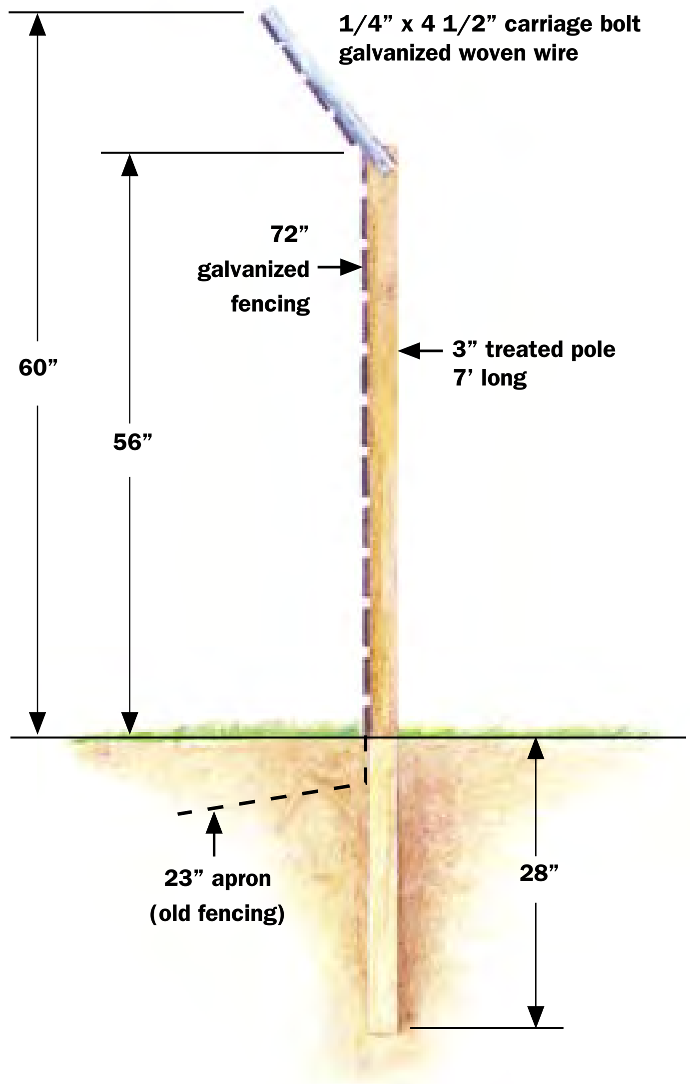

Figure 5-13. Installation of a net fence with wire overhang and buried apron is an effective coyote exclusion method.

5.7.14 Mole and Vole

Fencing may be useful for mole control in small dams. The fence should be made of rolled sheet metal or hardware cloth, with at least 12 inches buried underground and 12 inches extending aboveground. It is also possible to discourage moles from burrowing in an earthen dam by packing the soil with a roller to reduce soil moisture. This will reduce the habitat's attractiveness to moles (University of Nebraska, 1994).

Fencing of large-scale areas is generally not a cost-effective method of vole control (University of Nebraska, 1994).

5.7.15 River Otter

Fencing may be used to exclude river otters from an earthen dam. The fence should be constructed of mesh wire (3 x 3-inch or smaller) or hog-wire. Dam owners should regularly check the fence to ensure that it has not been spread apart or raised to allow otters to enter (University of Nebraska, 1994).

5.7.16 Gopher Tortoise

Fencing the dam embankment may be practical for protecting small areas from gopher tortoise damage (University of Nebraska, 1994).

5.7.17 Red and Gray Fox

Fencing can be used to exclude foxes from an area of concern. Both wire and electric fences will work, and a combination of the two will probably be most effective. Net wire fences should be constructed so that all openings are less than 3 inches. The bottom should be buried 1 to 2 feet into the ground with at least 1 foot above ground. For an effective electric fence, there should be at least three charged wires spaced 6 inches, 12 inches, and 18 inches above the ground (University of Nebraska, 1994).

5.7.18 Canada Goose

It is often possible to discourage Canada goose inhabitation by installing fencing, rock barriers, or vegetative barriers around shorelines. Fencing can be constructed out of a variety of materials including mylar tape, metal mesh, plastic or synthetic mesh, electric wires, or wood. Fences should be at least 25 inches tall and should not contain openings greater than 3 inches (Virginia Cooperative Extension, 2001b).

5.7.19 American Alligator

Fencing may be used to exclude alligators from earthen dams. The fence should be at least 5 feet high with the top edge angled outward (University of Nebraska, 1994).

5.7.20 Ants

There are no exclusion methods or design measures effective against ant inhabitation

5.8 Monitoring

Once a dam specialist identifies the burrow and the species creating or occupying it, the burrow(s) would be filled and a prevention technique implemented as appropriate. The next step to maintaining safe dam operation is to monitor the effectiveness of the remedial action (e.g., has the riprap effectively deterred muskrat activity?). In many cases, regular dam inspections and swift burrow mitigation (and preventive actions when needed) will adequately preserve safe dam operations. However, it is possible for a dam to become overrun by nuisance animals, or for several species to cumulatively compromise safe dam operations. In these cases, repair actions are only partial solutions. Monitoring can help the dam owner determine whether additional mitigation is necessary.

In general, it is recommended that the dam owner inspect the dam once every 3 months after first finding and repairing animal damage. The frequency is aimed at confirming the animal has not returned to the dam once the burrow is removed. Once burrows are identified, the owner should consider implementing a preventive action if a burrow occurred in one of the critical dam zones (see Chapter 5.4 for a discussion on animal burrows in critical dam zones). Understanding the potential fiscal limitations of dam owners, the most realistic approach is to use the fewest actions needed to ensure dam safety. As a guideline, if the dam owner finds new animal burrows in the dam on two consecutive inspections following repair and preventive actions, then implementing a wildlife control strategy is probably necessary to maintain safe dam operations (see Chapter 6.0 for a discussion on wildlife control).

6.0 Mitigating Damaging Wildlife

This chapter of the manual details methods for managing wildlife populations. General wildlife management information is provided first, followed by specific management information for the 23 species considered in this manual. The application of this data in the dam environment can be beneficial and at times necessary to protect human populations from the disastrous effects of dam failure. However, applied indiscriminately, these methods can adversely affect the dam environment, protected wildlife species, and even human populations. For this reason, nuisance wildlife management practices should be implemented only with coordination and input from state and federal wildlife agencies and the county agent responsible for toxicant and fumigant registration and application (Appendix A contains state wildlife contacts).

6.1 Compliance with State and Federal Regulations

6.1.1 Conformity to Federal Regulations

As the vast majority of surveyed states indicate, the dam owner is responsible for the identification and mitigation of nuisance wildlife at dams. Although the dam owner is empowered by the state dam safety official to manage a dam toward safe operation, the dam owner must abide by applicable federal and state regulations when implementing nuisance wildlife management measures. The Endangered Species Act of 1973 (ESA), the Migratory Bird Treaty Act of 1918 (MBTA), and the Federal Insecticide, Fungicide, and Rodenticide Act of 1996 (FIFRA) are three federal laws that must be complied with during application of wildlife management methods. The ESA protects species of plants and animals that are in danger of extinction. Under the ESA, it is illegal for anyone to "take" a species listed as threatened or endangered.

The ESA defines "take" as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct" (USFWS, 2002a). The MBTA was established to conserve migratory bird species in the United States and prohibits the hunting, trapping, possession, and transfer of listed species except under the terms of a valid permit or during authorized hunting seasons (USFWS, 2002b).

Species that are discussed in this manual and protected under the ESA and the MBTA include:

- Gopher Tortoise (*Gopherus polyphemus*). This species is listed as Threatened under the ESA throughout its range of Mississippi, Louisiana, and portions of Alabama, and is protected by state laws in Alabama, Georgia, Florida, and South Carolina.

- The American Alligator (*Alligator mississippiensis*). This species is listed as "Threatened by Similarity of Appearance to a Threatened Taxon" under the ESA throughout its range of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, and Texas. This designation means that the American Alligator is protected under the ESA because of its similarity in appearance to the American Crocodile (*Crocodylus acutus*). The American Crocodile is classified as Endangered under the ESA. The USFWS determined that in order to adequately protect the American Crocodile, which is often mistaken for the American Alligator, the USFWS must also protect the American Alligator. Therefore, though populations of the American Alligator are healthy throughout its range, it is afforded full protection under the ESA.

- Point Arena Mountain Beaver (*Aplodontia rufa nigra*). This subspecies is listed as Endangered throughout its range of California.

- Utah Prairie Dog (*Cynomys parvidens*). This species is listed as Threatened throughout its range of Utah.

- Northern Idaho Ground Squirrel (*Spermophilus brunneus brunneus*). This subspecies is listed as Threatened throughout its range of Idaho.

- Canada Goose (*Branta canadensis*). This species is protected under the MBTA throughout its range of the United States.

If dam owners suspect that one of these species is damaging the earthen dam, then the dam owner must contact the USFWS and the state wildlife agency to discuss management options. While it is often possible to relocate these animals with permits and guidance from the USFWS and the state wildlife agency, the permitting agency must be consulted prior to taking any action. It should be noted that the list of protected species can and does change, and regular contact with an agency is required to ensure that no protected species are adversely affected.

While difficult to predict each potential circumstance, there may be cases when management of a species not protected by the ESA or MBTA may result in the illegal taking of a protected species that is associated with the targeted nuisance species. For example, the endangered black-footed ferret (*Mustela nigripes*) depends on the burrows of prairie dog colonies for survival. Mitigation against the prairie dog may impact the ferret. Similarly, the eastern indigo snake (*Drymarchon corais couperi*) is afforded refuge by gopher tortoise burrows; thus, managing a dam for the tortoise could have secondary effects on the indigo snake. As some species show interdependencies on others, it is recommended that coordination with state and federal wildlife agencies be conducted before management of any species, protected or not, occurs.

Last, FIFRA divides pesticides, including toxicants and fumigants, into two categories: General Use Pesticides and Restricted Use Pesticides. General Use Pesticides will not ordinarily cause unreasonable adverse effects on the user or the environment when used as directed and as such, they are commercially available to the public. Restricted Use Pesticides, however, could cause adverse effects to the user or the environment even when used correctly. Restricted Use Pesticides can only be purchased by a certified pesticide applicator and applied by or under the supervision of a certified pesticide applicator, in accordance with FIFRA. Appropriate disposal of pesticide containers is also required.

6.1.2 Conformity to State Regulations

Certain wildlife species are protected by the state even though they are not listed as Federally threatened or endangered; each state determines its own regulations with regard to protected species. Furthermore, hunting and trapping regulations in regard to furbearer, game, and nongame species vary from state to state. For these reasons, it is recommended that a dam owner contact the appropriate state wildlife agency for information about mitigation of wildlife species, and hunting and trapping seasons, licenses, and permits before attempting to remove an animal from the dam environment or before any wildlife management actions are taken. As with federal laws, the list of protected species can change from year to year and regular contact with an agency is required to ensure that no protected species are adversely affected.

Finally, legal use of specific toxicants and fumigants varies from state to state; one state may allow a toxicant that is banned in another. As such, it is recommended that coordination with the state wildlife agency or county agent be conducted to determine which substances are allowed for use in each state. If toxicants or fumigants are selected as the management option, it is recommended that:

- The substance is used according to direction and precaution;
- The substance is stored securely in original containers away from children, animals, food, and feed;
- The substance is applied so as not to endanger humans, livestock, crops, beneficial wildlife, or water supply, or leave illegal residues;
- Excess substance is not dumped, and associated equipment is not cleaned near ponds, streams, or wells; and
- Substance containers are disposed of properly at an appropriate landfill facility.

6.2 Muskrat Management Methods

6.2.1 Muskrat Control Through Habitat Modification (South Carolina DNR, 2003; University of Nebraska, 1994; Michigan State University Extension, 1998; USDA, 1991)

Mow regularly to remove food supply. Specifically, remove cattails, arrowhead, and other plants that grow on the fringe of the reservoir.

Implement an aquatic vegetation control program to reduce aquatic vegetation preferred by the muskrat for food and cover. Muskrat populations can be effectively managed by eliminating food sources. The vegetation control program can be achieved through several management approaches:

- ***Herbicides*** are widely used to control aquatic vegetation. Out of the 200 herbicides registered with the U.S. Environmental Protection Agency, only 8 are available for aquatic uses, and only 6 of those 8 are widely used (2 herbicides are limited to use in 17 western States' irrigation systems under Bureau of Reclamation control). Coordination with the state agency responsible for aquatic plant management is required to ensure that the appropriate herbicide is selected based on management goals and that herbicides are lawfully applied.
- ***Hand Removal*** of preferred muskrat vegetation can be implemented; however this method is labor-intensive and needs to be repeated frequently to keep vegetation, especially perennial plants, under adequate control. Hand removal can be combined with herbicide application.
- ***Mechanical Removal*** utilizes small and large weed harvesters to remove vegetation around the shoreline. This method achieves immediate vegetation control in small dams and does not carry water-use restrictions after treatment, unlike herbicide application. However, weed harvesters cannot be used in all environments—for example, obstructions may preclude harvester use. This method is usually higher in cost, slower, and less efficient than other available methods.

Manipulate water levels in the reservoir to create an undesirable habitat for the muskrat. A 2-foot drawdown in the reservoir during the winter months can be an effective muskrat management tool. Drawdown allows a dam specialist to identify and repair muskrat holes in the upstream slope (refer to Chapter 5.3.1 for burrow repair discussion), and may drive away resident muskrats, which need adequate water levels. It is recommended that muskrats be trapped and removed during the drawdown; however, trapping and relocation should be coordinated with the appropriate state agency, since a permit may be required.

A secondary benefit of water level manipulation is the potential drying and freezing of aquatic plants—the muskrat's primary food supply—as the plants are exposed to air. It should be noted that some aquatic plants are tolerant of drawdown and may actually increase after a drawdown; therefore, drawdown as a primary aquatic plant management method is not recommended.

6.2.2 Muskrat Control Through Trapping (University of Nebraska, 1994; South Carolina DNR, 2003)

The most effective types of traps for muskrat include the Conibear® traps No. 110 and 120, and leghold traps like the long spring No. 1, 1½ or 2, and similar coil spring traps (Figure 6-1 and 6-2). The Conibear® traps are preferred because they are effective in shallow and deep water settings, easy to set up, and kill the muskrat quickly, preventing escapes. The Conibear® and leghold traps are most effective when set close to the den entrance in the "runs" or trails carved into the reservoir bottom by the muskrat's hind feet. Runs can be easily seen in clear water, or can be felt with

Field testing in a 100-acre rice field (36 Conibear® 110 traps were set) and a 60-acre minnow pond (24 1½ leghold traps were set) yielded an effective muskrat removal rate of 93.3% and 87.5% for the Conibear® and leghold traps, respectively. All tripped traps were 100% effective.

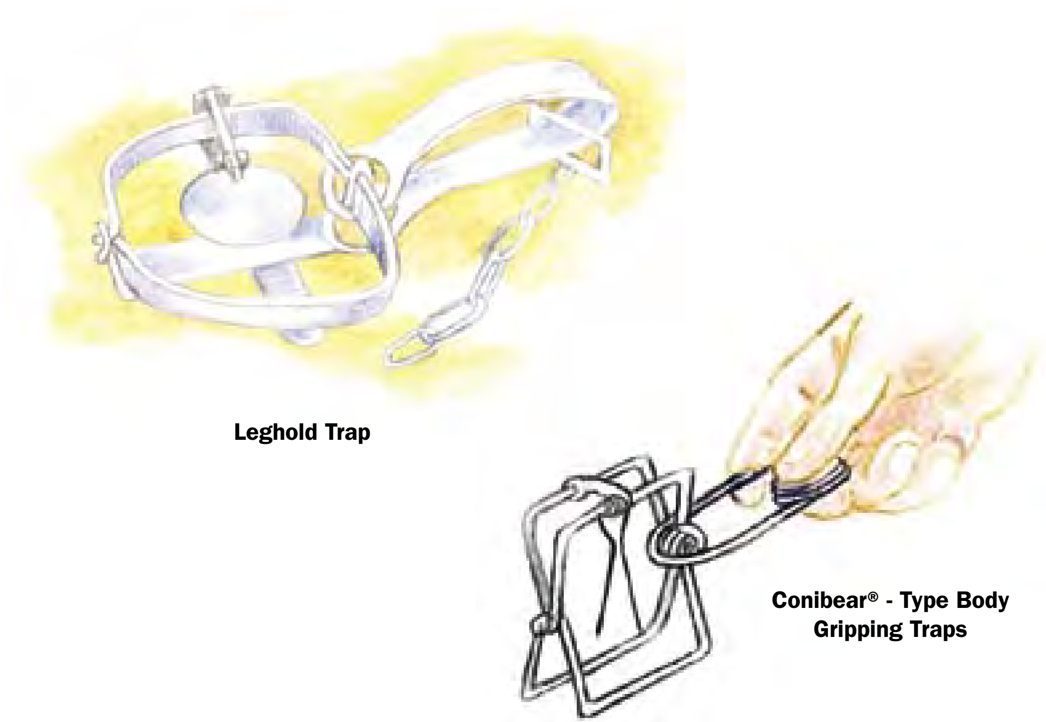

Figure 6-1. To capture muskrats, leghold traps should be set along runways, den openings, or natural resting areas. Conibear No. 110 traps should be set in the water.

Figure 6-2. Muskrat traps can be effectively set in four locations. Bait traps with carrots, potatoes, sweet potatoes, or apples.

the hands or feet in murky or deep water. Poles can be used to anchor the trap in front of the den (Figure 6-3).

Where legal, homemade stovepipe traps can also be effective. This type of trap is cheap, simple, and easy to make, but it requires more time and effort to set. A trap can be constructed by forming sheet metal into a 6 x 6-inch rectangular box, 30 to 36 inches long with heavy-gauge hardware cloth or welded wire doors. The doors should be hinged at the top to allow entry from either end, but no escape out of the box. The trap should be set right up against the primary den entrance to be most effective.

6.2.3 Muskrat Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for muskrat control.

6.2.4 Muskrat Control Through Toxicants (University of Nebraska, 1994)

Zinc phosphide (63% concentration) is the only toxicant Federally registered for muskrat control. To make a bait, vegetable oil is applied to cubes of apples, sweet potatoes, or carrots; the zinc phosphide is sprinkled on top; and the ingredients are mixed together thoroughly. The bait is then placed at the burrow entrance, on floating platforms (Figure 6-4), or on feeding houses. Zinc phosphide is a Restricted Use Pesticide and may therefore, only be purchased and applied by a certified pesticide applicator. Zinc phosphide should always be used as directed. Dam owners should contact the appropriate state wildlife agency regarding legality of toxicant use in their state.

Anticoagulants such as pivalyl, warfarin, diphacinone, and chlorophacinone have also been registered for muskrat control in some states. These anticoagulants come in the form of a "lollipop" made of grain, pesticide, and melted paraffin. As with zinc phosphide, anticoagulant baits can

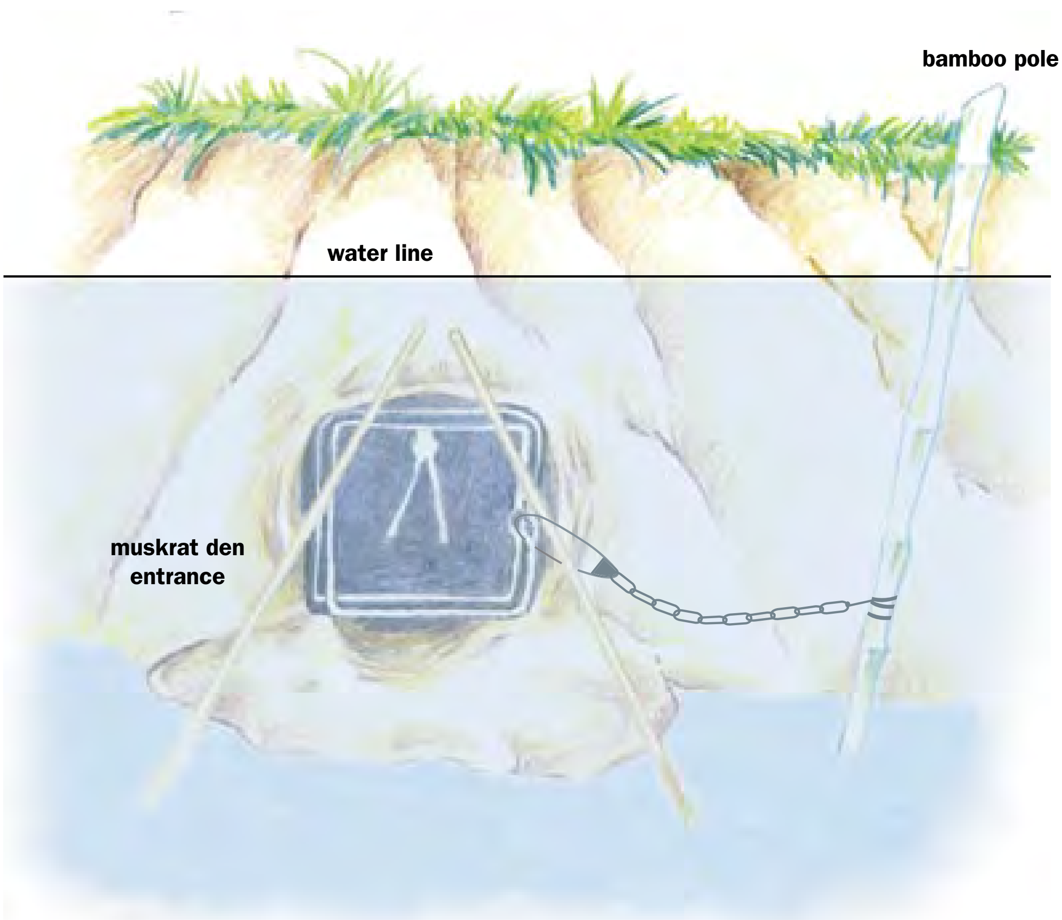

Figure 6-3. Pole set at muskrat den.

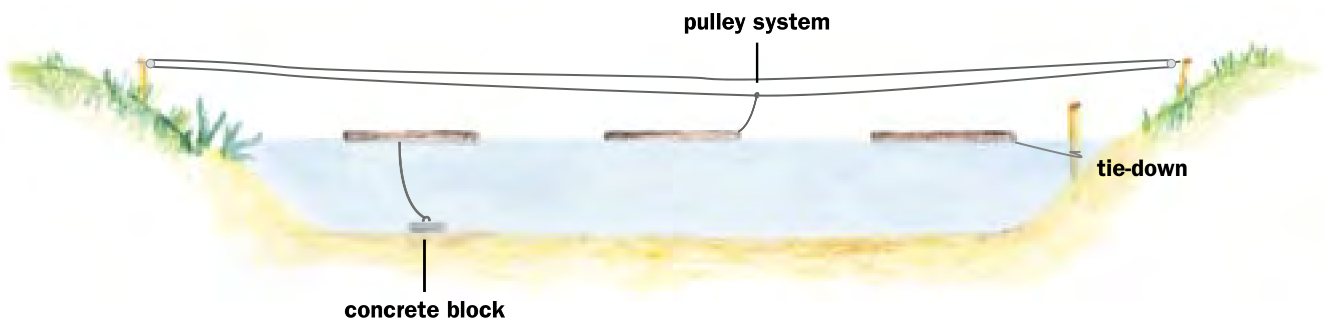

Figure 6-4. Toxicant bait platforms.

be placed at burrow entrances, on floating platforms, or on feeding houses. Dam owners should contact their state wildlife agency to see which, if any, anticoagulants are registered in their state.

6.2.5 Muskrat Control Though Frightening (University of Nebraska, 1994)

Frightening is not an effective method of muskrat control.

6.2.6 Muskrat Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for muskrat control.

6.2.7 Muskrat Control Through Shooting (University of Nebraska, 1994)

Shooting can be an effective method of eliminating a few individual muskrats. Hunting efforts are most successful at dawn and dusk. Dam owners should contact their state wildlife agency for information on hunting regulations and restrictions.

6.3 Beaver Management Methods

6.3.1 Beaver Control Through Habitat Modification (University of Nebraska, 1994; University of New Hampshire Cooperative Extension, 1997; USDA, 1994)

Clearing trees and shrubs near the reservoir will reduce potential food sources and habitat and may discourage beaver inhabitation of a dam. Daily destruction of existing dams and removal of dam construction material will sometimes cause existing beaver colonies or individuals to relocate.

Researchers in Louisiana found that deep water beaver dams could be removed more effectively than shallow water beaver dams, and that it was more effective to remove beaver dams in later summer rather than early or midsummer.

6.3.2 Beaver Control Through Trapping (University of Nebraska, 1994)

In most situations, trapping is the most effective and economical method of controlling beaver damage. Various types of traps can be used, but the Conibear® No. 330 is generally considered the most effective (refer to Figure 6-1 for trap types). It is designed primarily for water use, and works equally well in deep and shallow areas. Conibear®-type traps should be set on dry, solid ground to prevent injury to the person setting the trap. Once the trap is set, it can be

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moved to the water and anchored down with stakes. Traps can be effectively set in front of lodge entrances, in front of a hole in the beaver dam, or on underwater beaver trails.

Leghold traps (No. 3 double spring or larger) are also commonly used to capture beavers. This type of trap should be used with a drowning set attachment so that the captured beaver cannot escape. Proper placement is very important with leghold traps. They should be set just at the water's edge, slightly underwater, with the pan, jaws, and springs covered lightly with leaves or debris. There must be a cavity under the pan for the trap to properly trigger. Leghold traps are most effective when they are set slightly off-center on an underwater beaver trail.

Snares can also be used to capture beavers. The equipment costs less than trapping equipment, and snares can be set so that the beaver is caught alive and can then be relocated. Snares are frequently set under logs, near bank dens, and next to castor mounds.

Dam owners should contact their state wildlife agency regarding trapping regulations and seasons and regulations regarding live trapping and relocation.

6.3.3 Beaver Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for beaver control.

6.3.4 Beaver Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for beaver control.

6.3.5 Beaver Control Through Frightening (University of Nebraska, 1994)

Frightening is not an effective method of beaver control.

6.3.6 Beaver Control Through Repellents (University of Nebraska, 1994)

No repellents are Federally registered for beaver control.

6.3.7 Beaver Control Through Shooting

Shooting may also be used to remove small populations of beavers. If permitted by law, night shooting is most effective; however, hunting in the early evening and early morning hours can also be effective. Dam owners should contact their state wildlife agency for information on hunting regulations and restrictions.

6.4 Mountain Beaver Management Methods

The Point Arena mountain beaver is a Federally listed endangered subspecies and therefore subject to the provisions of the Endangered Species Act. This subspecies is found only in California. Dam owners in California who suspect that they have a mountain beaver problem should contact the USFWS and the California Department of Fish and Game for definitive species identification and management guidance.

6.4.1 Mountain Beaver Control Through Habitat Modification (University of Nebraska, 1994)

Removal of plants such as sword fern, bracken fern, or salal may reduce the attractiveness of a site to mountain beavers.

6.4.2 Mountain Beaver Control Through Trapping (University of Nebraska, 1994)

Trapping is an effective method of controlling mountain beavers. The Conibear® No. 110 is most commonly used (refer to Figure 6-1). The trap should be set in the main burrow entrance, anchored with three stakes. Trapping is most effective in warm months when mountain beaver are most active.

Live trapping is also possible using double-door wire mesh traps such as the Tomahawk. This method of trapping is recommended in areas where pets or livestock could accidentally be captured. The trap should be placed in the main burrow entrance with vegetation arranged along the inside and outside of the trap. The trap should be wrapped with black plastic and covered with soil to protect the captured mountain beavers from the weather. Captured animals should be placed in a dry burlap sack and euthanized or relocated to an appropriate location.

Dam owners should contact their state wildlife agency regarding trapping regulations and seasons and requirements for euthanasia or relocation.

6.4.3 Mountain Beaver Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for mountain beaver control.

6.4.4 Mountain Beaver Control Through Toxicants (University of Nebraska, 1994)

No toxicants are Federally registered for mountain beaver control. Some toxicants may be registered in certain states, though, so dam owners should contact their state wildlife agency regarding this option.

6.4.5 Mountain Beaver Control Through Frightening (University of Nebraska, 1994)

Frightening is not an effective method of controlling mountain beaver.

6.4.6 Mountain Beaver Control Through Repellents (University of Nebraska, 1994)

Repellents are effective for controlling mountain beaver that are causing damage to trees/seedlings, but this method is not practical for preventing damage to earthen dams.

6.4.7 Mountain Beaver Control Through Shooting (University of Nebraska, 1994)

Mountain beavers are nocturnal animals that spend most of their time below ground; therefore, shooting is not a practical method of mountain beaver control.

6.5 Groundhog Management Methods

6.5.1 Groundhog Control Through Habitat Modification (Michigan State University Extension, 1998)

It is possible to discourage groundhog inhabitation by mowing vegetated areas of the earthen dam to remove cover.

6.5.2 Groundhog Control Through Trapping (USDA, 1991; University of Nebraska, 1994)

Trapping is an effective method of controlling limited populations of groundhogs. Steel leghold traps (No. 2) (refer to Figure 6-1) and live traps are both commonly used. Traps should be set at the main burrow entrance or on major travel lanes. Live traps, which can be purchased commercially or home-built, require bait such as apple slices, carrots, or lettuce. Groundhogs captured in live traps should be euthanized or relocated to a suitable habitat where they will not cause further damage.

Conibear® traps (110, 160, or 220) may also be used in certain situations (refer to Figure 6-1). They should not be used where they could capture domestic animals or livestock. Conibear® traps should be set in major travelways or at the main entrance of a burrow system. No bait is necessary.

Dam owners should consult with their state wildlife agency regarding specific trapping regulations and requirements for euthanasia or relocation.

6.5.3 Groundhog Control Through Fumigants (University of Nebraska, 1994)

Use of the commercial gas cartridge is the most common method of groundhog control. The cartridge is ignited and placed in the burrow with all other entrances sealed. As the cartridge burns, it produces carbon monoxide and other gases lethal to the groundhog. Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. They should be used with caution and in accordance with the directions on the label.

Aluminum phosphide is a Restricted Use Pesticide that may be applied by a certified pesticide applicator to control groundhogs. The legal application of aluminum phosphide may vary from state to state, so dam owners should consult with their state wildlife agency or state pesticide registration board before implementing this control method. Aluminum phosphide comes in tablet form. Two to four tablets should be inserted into the main burrow and then all burrow entrances must be tightly sealed. Aluminum phosphide should always be used as directed on the label.

Dam owners should consult with their state wildlife agency for information on state and local regulations regarding the use of fumigants to control groundhogs.

6.5.4 Groundhog Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for groundhog control.

6.5.5 Groundhog Control Though Frightening (University of Nebraska, 1994)

Scarecrows or other effigies may be installed on or around the earthen dam to frighten groundhogs. This method of control works best if the scarecrows are moved regularly and if there is a high level of human activity around the dam.

6.5.6 Groundhog Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for groundhog control.

6.5.7 Groundhog Control Through Shooting (University of Nebraska, 1994)

Shooting is most effective if used as a follow-up to other control measures. Groundhogs are considered game animals in most states; therefore a hunting license may be required. Dam owners should consult with their state wildlife agency regarding specific hunting regulations and requirements.

6.6 Pocket Gopher Management Methods

6.6.1 Pocket Gopher Control Through Habitat Modification (Colorado State University Cooperative Extension, 2003)

Removal of forbs, through either chemical or mechanical treatment, may control some pocket gopher damage. This technique is generally effective only for individuals of the genera *Thomomys,* because they prefer the underground storage structure of forbs. Other species easily survive on grass and therefore will not likely be deterred by this technique.

6.6.2 Pocket Gopher Control Through Trapping (USDA, 1994; University of Nebraska, 1994)

Trapping can be extremely effective for pocket gopher control in small areas or when used in conjunction with toxicants. There are many types of traps available for pocket gopher control. The Macabee® gopher trap is the most popular, but other traps are also commonly used, including the Victor® Gopher Getter, the Death-Klutch 1 gopher and mole trap, and the Guardian gopher trap (Figures 6-5 through 6-8). Traps may be set in either the main tunnel or in one of the lateral tunnels (Figure 6-9). Trapping is most effective in the spring and fall, when gophers are pushing up new mounds, although it can be done year-round. Dam owners should consult with their state wildlife agency regarding specific trapping regulations.

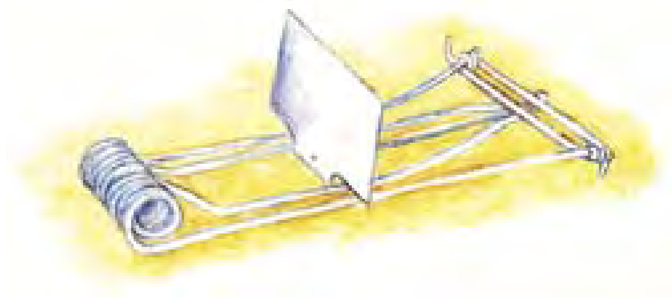

Figure 6-5. Macabee® gopher trap.

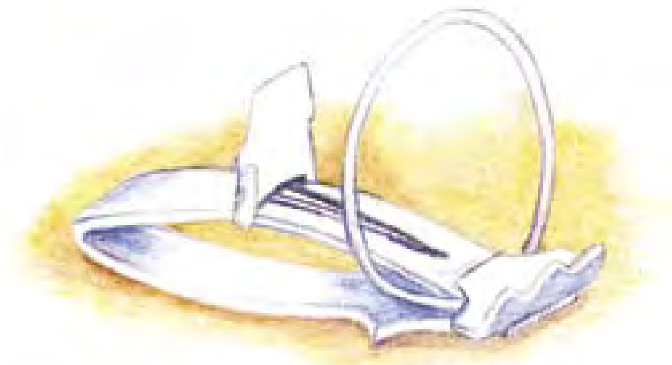

Figure 6-6. Victor® Gopher Getter.

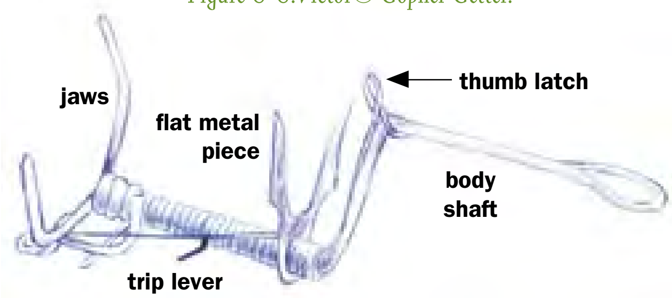

Figure 6-7. Death-Klutch 1 gopher and mole trap.

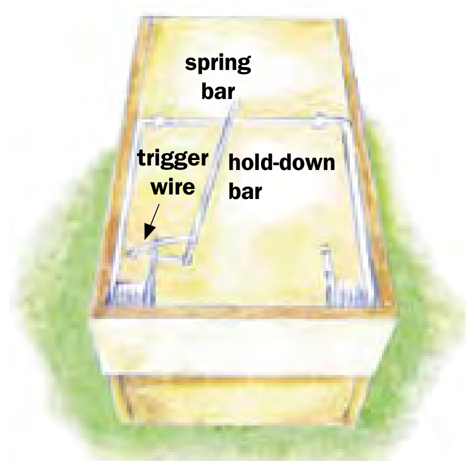

Figure 6-8. Guardian (California box-type) gopher trap.

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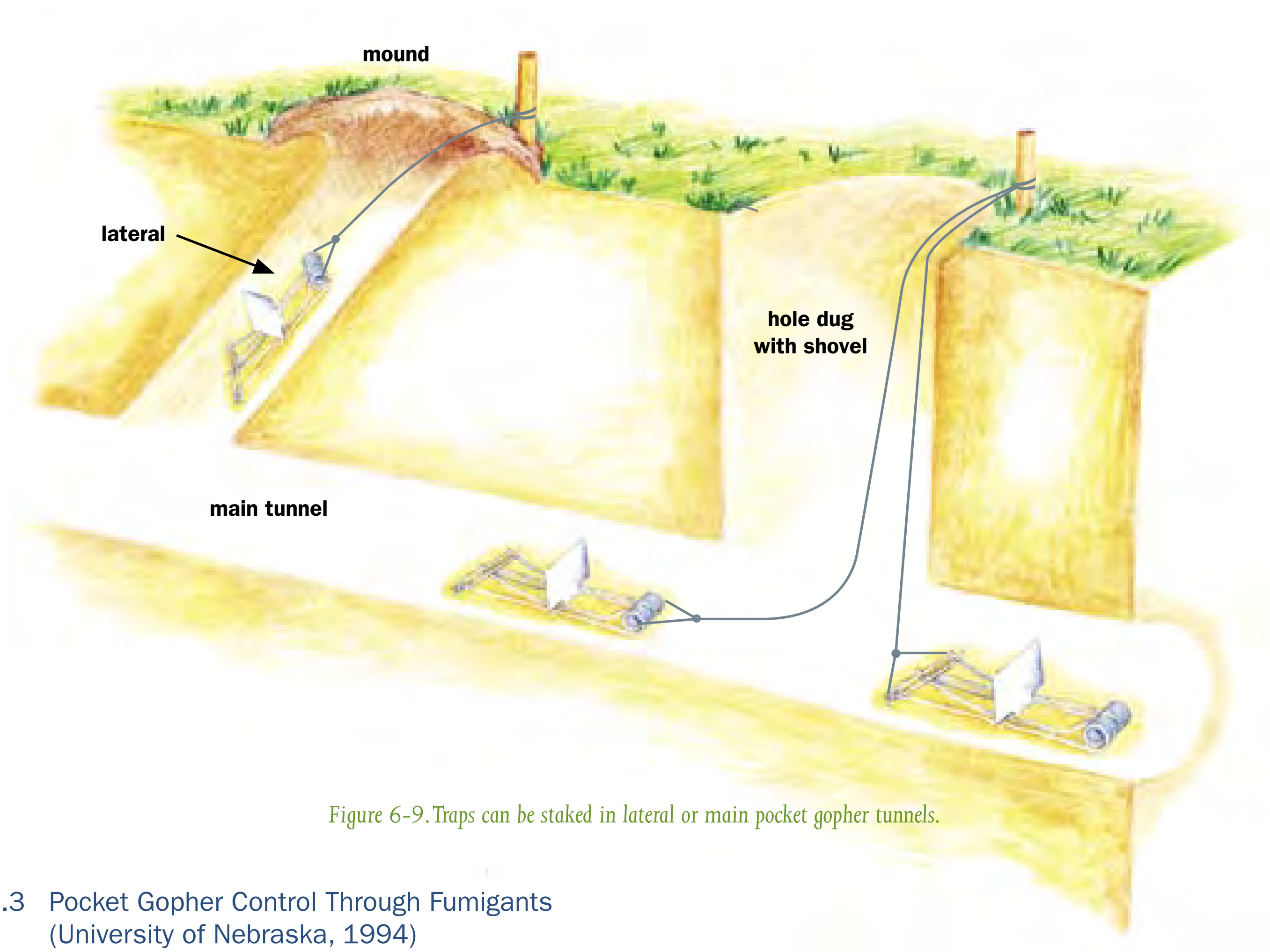

Figure 6-9. Traps can be staked in lateral or main pocket gopher tunnels.

6.6.3 Pocket Gopher Control Through Fumigants (University of Nebraska, 1994)

Aluminum phosphide and gas cartridges are both Federally registered for pocket gopher control. They are generally not effective though because the gas moves slowly through the tunnel system, allowing the fumigant to diffuse through the soil and escape to the surface. Carbon monoxide from automobile exhaust has proven more effective because of its greater volume and pressure. To implement this method of control, connect a hose or pipe to the engine exhaust and place it in a burrow opening near a fresh soil mound. Tightly pack soil around the hose or pipe and allow the engine to run for at least 3 minutes. This method is generally 90% effective and requires no federal registration. Dam owners should consult with their state wildlife agency for information on state and local regulations regarding fumigants.

6.6.4 Pocket Gopher Control Through Toxicants (University of Nebraska, 1994)

Several rodenticides are currently registered for pocket gopher control. Strychnine alkaloid (0.3 to 0.5% active ingredient) on grain baits is the most widely used. It is classified as a Restricted Use Pesticide and can only be sold to and used by a certified pesticide applicator. Applying 1 to 2 pounds per acre of 0.3 to 0.5% strychnine alkaloid grain with a burrow builder should provide an 85% to 95% reduction in the pocket gopher population. Zinc phosphide (2%) is also a registered toxicant for pocket gopher control, though it is less effective than strychnine. Additionally,

Carbon monoxide is generally 90% effective for pocket gopher control and requires no Federal registration.

two anticoagulants (chlorophacinine and diphacinone) are registered for pocket gopher control. Bait can be placed in a pocket gopher burrow system by hand, using a special hand-operated bait dispenser probe or with a mechanical burrow builder (Figures 6-10 and 6-11).

The first step to hand baiting with the bait dispenser is finding the main burrow, which is generally located 12 to 18 inches away from a plugged mound. Once the main burrow is located, place the probe over the burrow and push down until there is decreased resistance on the probe. Then push the button on the bait dispenser to release a metered dose of bait. For best results, each burrow should be baited in two or three locations.

Properly applied, strychnine alkaloid can provide an 85% to 95% reduction in a pocket gopher population.

Figure 6-10. Effective baiting with a bait dispenser requires accurately finding the pocket gopher burrow. Use the probe to detect the main burrow, which is usually on the plug-side of the mound, 8-18 inches away from the plug (USDA, 1994).

The burrow builder is a tractor-drawn device that mechanically delivers bait underground. As the burrow builder moves along, it makes an artificial burrow, dispenses the bait into the newly formed burrow, and then closes up the hole. Artificial burrows should be constructed at depths similar to those constructed by pocket gophers in the area.

All toxicant products should be used as directed on the label. Dam owners should consult with their state wildlife agency regarding legality of toxicant use in their state before implementing any control measures.

6.6.5 Pocket Gopher Control Through Frightening

No frightening methods are effective for pocket gopher control.

6.6.6 Pocket Gopher Control Through Repellents (University of Nebraska, 1994; Witmer et al., 1995)

Repellents may be used to discourage pocket gopher inhabitation, although the effectiveness of this method is still in question. Initial testing has shown that some predator odors, such as coyote or bobcat urine, may effectively repel

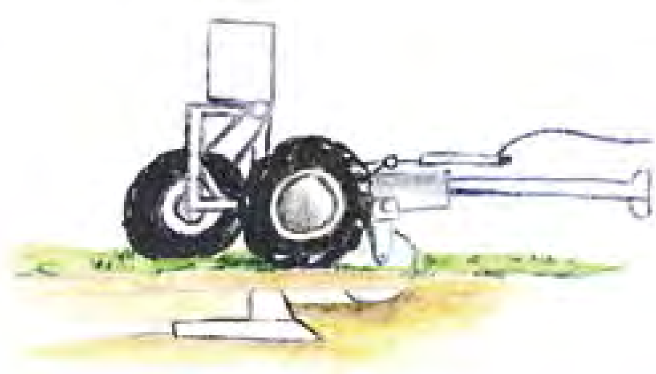

Figure 6-11. A burrow builder mechanically dispenses bait into constructed burrows. Adequate soil moisture is needed to form effective burrows. Adequate soil can be compressed in the hand and rolled gently without crumbling (USDA, 1994).

pocket gophers. Additionally, the mole plant (*Euphoriba lathyrus*), also known as the caper spurge or gopher purge, and the castor-oil plant (*Ricinus lathyrus*) have both been promoted as gopher repellents, although there is no scientific evidence to support this claim. Use of these plants is not recommended because they are poisonious to humans and pets, and can grow thickly, obscuring the dam.

6.6.7 Pocket Gopher Control Through Shooting (University of Nebraska, 1994)

Shooting pocket gophers is usually not a practical option because they spend most of their time below ground.

6.7 North American Badger Management Methods

6.7.1 North American Badger Control Through Habitat Modification (University of Nebraska, 1994; Texas Wildlife Damage Management Service, 1998)

Rodent control will alleviate most problems associated with badger damage. Badgers commonly prey on ground squirrels, pocket gophers, and prairie dogs. If this food source is eliminated, then damage from badger predation will be reduced and the badger will often move elsewhere in search of food. Dam owners should refer to sections of this manual pertaining to management of ground squirrels, pocket gophers, and prairie dogs for rodent control guidance.

6.7.2 North American Badger Control Through Trapping (University of Nebraska, 1994; Texas Wildlife Damage Management Service, 1998)

Badgers can often be removed from an area through the use of cage traps, leghold traps, or snares placed near the entrance of an active den. Cage traps require bait, such as a dead chicken or large rodent. After a badger is caught alive, it should be euthanized or relocated to an area where it will not cause further damage.

Leghold traps (No. 3 or 4) are most effective if attached to a drag such as a strong limb or fence post. If leghold traps are staked into the ground, it is likely that the badger will dig out the trap and escape.

Snaring involves setting a steel-cable loop in an animal's path to capture it by the neck, body, or leg. Snares are lightweight, compact, easy to set, low-cost, and they offer a high degree of human safety. Ready-made snares and snare components may be purchased from trapping suppliers. They must be attached to a solid object so the captured animal cannot escape. Snares should not be set where they could capture pets or livestock.

Dam owners should contact their state wildlife agency regarding trapping regulations.

6.7.3 North American Badger Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for badger control.

6.7.4 North American Badger Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for badger control.

6.7.5 North American Badger Control Through Frightening (University of Nebraska, 1994)

Badgers may be discouraged from inhabiting an area if high-intensity lights are installed and used at night.

6.7.6 North American Badger Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for badger control.

6.7.7 North American Badger Control Through Shooting (University of Nebraska, 1994)

Shooting can be an effective method of controlling small populations of badgers. Early morning, late evening, and after dark are the best times for hunting. Where legal, spotlights can be an effective tool for hunting at night. Dam owners should contact their state wildlife agency regarding hunting regulations and restrictions.

6.8 Nutria Management Methods

6.8.1 Nutria Control Through Habitat Modification (University of Nebraska, 1994; USDA, 1991)

Nutria can be discouraged from inhabiting an area by eliminating brush, trees, thickets, and weeds, which provide food and cover. Cleared vegetation should be burned or removed.

In certain situations, water level manipulation may be another damage control option. Dropping water levels in the summer and raising water levels in the winter will cause stress to nutria populations and may encourage them to relocate. The viability of this option is dependent upon reservoir useage (e.g., water spray, recreation, etc.) and owner willingness. In addition, lowering the water level has not yet been proven effective by researchers, but it is a tool to consider as part of a comprehensive nutria management strategy.

6.8.2 Nutria Control Through Trapping (University of Nebraska, 1994)

Trapping is a very effective method of controlling nutria. Leghold traps are most commonly used. Most trappers prefer double longspring traps (No. 11 or 2), but the No. 1 ½ coilspring, No. 3 double longspring, and soft-catch fox traps are also effective. Traps should be set just under the water where an active nutria trail enters the reservoir. The trap should be staked to the ground just off to the side of the trail and covered with leaves or other debris. To increase effectiveness, traps should be baited with chunks of apples, carrots, sweet potatoes, or watermelon rinds. In deep water, a drowning set should be used. If a nutria is captured alive in shallow water, then it should be disposed of humanely.

Single- or double-door live traps may be used to capture nutria. The cage should be at least 9 x 9 x 32 inches in size. Place the trap along active trails and bait with sweet potatoes or carrots. Captured nutria should be humanely destroyed.

Conibear® traps (No. 220-2, 160-2, and 330-2) are also commonly used to reduce nutria populations. These traps should be set on trails, at den entrances, in culverts, or in narrow waterways. They should not be used in areas frequented by children, domestic pets, or desirable wildlife species.

Snaring is another option for capturing nutria. Snaring involves setting a steel-cable loop in an animal's path to capture it by the neck, body, or leg. Snares constructed with 3/32-inch flexible stainless steel wire or galvanized aircraft cable are suitable for catching nutria. They should be set along trails, travel routes, feeding lanes, or bank slides.

Dam owners should contact their state wildlife agency regarding trapping regulations.

6.8.3 Nutria Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for nutria control.

6.8.4 Nutria Control Through Toxicants (University of Nebraska, 1994)

Zinc phosphide is the only toxicant registered for nutria control. It is a Restricted Use Pesticide that must be purchased and applied by a certified pesticide applicator. The zinc phosphide is mixed with bait, such as apples, carrots, or sweet potatoes, and then the bait is placed in waterways, ponds, and ditches where permanent standing water and recent signs of nutria activity are found. Do not place bait directly in the water, but rather on floating rafts (anchored to the bottom or tied to the shore as depicted on figure 6-4), small islands, floating logs, or exposed tree stumps. Ground baiting is not recommended because humans and nontarget animals may be exposed to the toxicant.

Prebaiting increases the effectiveness of this control method. Apply corn oil to chunks of apples, carrots, or sweet potatoes and place the prebait at the designated baiting station. The station should be prebaited for several nights. Observe the station to ensure that nutria, rather than nontarget animals, are taking the bait. Once the nutria are accustomed to eating the prebait, the zinc-phosphide treated bait can be applied. The toxic bait should be applied until no more bait is being taken. Dead nutria that have been exposed to zinc phosphide should be collected and disposed of by deep burial or burning to prevent zinc phosphide exposure to domestic and wild scavengers.

6.8.5 Nutria Control Through Frightening (University of Nebraska, 1994)

Harassment may temporarily deter nutria from inhabiting an area. Loud noises and high-pressure water sprays have worked in some cases. As a long-term control method, however, frightening is not an effective or practical option.

6.8.6 Nutria Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for nutria control.

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In certain areas, legal hunting with a shotgun or small caliber rifle has reduced nutria populations by 80%.

6.8.7 Nutria Control Through Shooting (University of Nebraska, 1994)

Shooting is an effective method of controlling nutria. This method is most effective at night with a spotlight, although it should be noted that this technique is not legal in all states. Shooting can be effective when carried out at bait stations, from boats, or from the bank. Dam owners should contact their state wildlife agency for information on hunting regulations and restrictions.

6.9 Prairie Dog Management Methods

Because other animals frequently inhabit prairie dog towns, including the Federally protected burrowing owl and black-footed ferret, dam owners need to be particularly cautious when taking action to control prairie dogs. In regions and habitats where burrowing owls and black-footed ferrets are known to live, dam owners should coordinate with their state wildlife agency and the USFWS to determine whether either of these species is present; field surveys by qualified biologists may be required. Burrows that have feathers or white droppings at the mouth probably contain burrowing owls. Black-footed ferrets are secretive animals, and since it can be very difficult to verify their existence in a particular burrow system, it is best to contact the USFWS and the state wildlife agency for guidance on completing a black-footed ferret survey (University of Nebraska, 1994). If either of these species is present, the dam owner must contact the USFWS and their state wildlife agency for management guidance.

It is also important to remember that the Utah prairie dog, one of the four prairie dog species found in the United States, is listed as a Federally threatened species and is therefore subject to the provisions of the Endangered Species Act. As the name implies, the Utah prairie dog is found only in Utah. Dam owners in Utah who suspect that they have a prairie dog problem should contact the USFWS and the Utah Division of Wildlife Resources for species identification and management guidance.

6.9.1 Prairie Dog Control Through Habitat Modification (University of Nebraska, 1994)

Installation of visual barriers may discourage prairie dogs from inhabiting an area. Prairie dogs prefer areas of low vegetation to provide a clear view of their surroundings and to improve their ability to detect predators. Objects such as fences or hay bales that are strategically placed to block prairie dog views may reduce suitability of the habitat.

6.9.2 Prairie Dog Control Through Trapping (USDA, 1991)

Trapping may be used to control prairie dogs, but it is quite labor intensive and therefore only practical for removing small populations. Cage traps for live capture, Conibear® traps (No. 110), and leg-hold traps are often used. Cage traps are most effective in early spring. They should be baited with oats flavored with corn or anise oil. Dam owners should consult with their state wildlife agency for guidance on releasing captured prairie dogs. Conibear® and leg-hold traps should be set in burrow entrances. They do not require bait. Dam owners should consult with their state wildlife agency regarding specific trapping regulations.

6.9.3 Prairie Dog Control Through Fumigants (University of Nebraska, 1994)

Fumigants can be used to control prairie dogs in some situations, however this method is often costly, time-consuming, and particularly hazardous to other wildlife. Fumigation is most effective as a follow-up to toxic baits. It should not be used in burrows where nontarget species are thought to be present.

Aluminum phosphide can reduce prairie dog populations by 85% to 95%.

Aluminum phosphide is a registered fumigant for control of burrowing rodents, including prairie dogs. It is a Restricted Use Pesticide and therefore must be purchased and applied by a certified pesticide applicator. Aluminum phosphide comes in tablet form. One tablet should be inserted into each burrow and then the burrow entrance should be tightly plugged with soil. When used correctly, aluminum phosphide typically provides an 85% to 95% reduction in prairie dog populations. The legal application of aluminum phosphide may vary from state to state so dam owners should consult with their state wildlife agency or state pesticide registration board before implementing this control method.

Gas cartridges may also be used to control prairie dogs. Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. When ignited, a gas cartridge will produce carbon monoxide, carbon dioxide, and other gases that are toxic to the prairie dog. The cartridge should be lit before it is placed in the burrow. Once it has been inserted, the burrow should be immediately plugged with soil. Gas cartridges should be used with caution and in accordance with the directions on the label. When used correctly, gas cartridges can provide a 95% reduction in prairie dog populations.

Gas cartridges can provide a 95% reduction in prairie dog populations.

Dam owners should consult with their state wildlife agency for information on state and local regulations regarding gas cartridges and the use of fumigants.

6.9.4 Prairie Dog Control Through Toxicants (University of Nebraska, 1994)

Baiting with a toxicant is generally the most economical and effective method of controlling prairie dogs. Zinc phosphide bait is currently the only registered and legal toxicant available for prairie dog control. It is available in 2% zinc phosphide-treated grain bait and pellet formulations. It is a Restricted Use Pesticide, which means that it is only available for sale to and use by certified pesticide applicators. Zinc phosphide baits can be applied from July 1 through January 31, though it is best to apply the baits in late summer and fall when prairie dogs are most active and there is no green forage available.

Zinc phosphide can be 75% to 85% successful in controlling prairie dogs when used correctly.

A prebait must be applied to the burrows before the toxic bait. The prairie dogs will become accustomed to eating the non-toxic grains, which will increase the effectiveness of the toxic bait. The prebait and the toxic bait may be applied by hand or by a mechanical bait dispenser attached to an all-terrain vehicle, motorcycle, or horse.

6.9.5 Prairie Dog Control Through Frightening (University of Nebraska, 1994)

Frightening is not an effective method of control for prairie dogs.

6.9.6 Prairie Dog Control Though Repellents (University of Nebraska, 1994)

No repellents are Federally registered for prairie dog control.

6.9.7 Prairie Dog Control Through Shooting (University of Nebraska, 1994)

Continuous shooting of prairie dogs can remove about 65% of the population annually, but it is generally not a practical or cost-effective method of control. Shooting is most effective in spring because it can disrupt breeding. Dam owners should consult with their state wildlife agency regarding specific hunting regulations and requirements.

6.10 Ground Squirrel Management Methods

The northern Idaho ground squirrel, one of 23 ground squirrel species in the United States, is Federally listed as a threatened species and is therefore subject to the provisions of the Endangered Species Act. The northern Idaho ground squirrel is found in limited distribution in the northwest. Dam owners in that region who experience problems with ground squirrels should contact the USFWS and their state wildlife agency for species identification and management guidance.

The New Mexico and Nebraska Dam Safety Offices have set up roosts in the dam environment to support raptors such as red-tailed hawks to provide predator control of small rodents.

6.10.1 Ground Squirrel Control Through Habitat Modification (USDA, 1991)

Routine weed control and vegetative management may limit some ground squirrel damage, but the effectiveness of this method is usually limited.

6.10.2 Ground Squirrel Control Through Trapping (University of Nebraska, 1994)

Trapping is a labor-intensive control method, and therefore it is generally only useful for removing small populations of ground squirrels. Jaw traps (No. 1 or No. 0), box or cage traps, and Conibear® traps (No. 110 or No. 110-2) may be used (refer to Figure 6-1). Generally, one trap is needed for every 10 to 15 squirrels present. Traps should be set on trails or near burrow entrances. Box or cage traps require bait, such as fruit, vegetables, peanut butter, or grain; baiting is not necessary with jaw traps or Conibear® traps. Dam owners should contact their state wildlife agency for information on state and local trapping regulations.

6.10.3 Ground Squirrel Control Through Fumigants (University of Nebraska, 1994)

Aluminum phosphide and gas cartridges are both registered fumigants for ground squirrel control. Fumigants work best for light squirrel infestations limited to a few acres. This method is most effective in the spring, when ground squirrels have just emerged from hibernation.

Aluminum phosphide is a Restricted Use Pesticide that comes in tablet form. This fumigant can only be purchased and applied by a certified pesticide applicator. One tablet should be placed in each burrow entrance and then the burrow should be plugged with soil to form an air-tight seal. The legal application of aluminum phosphide may vary from state to state so dam owners should consult with their state wildlife agency or state pesticide registration board before implementing this control method.

Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. When ignited, a gas cartridge will produce carbon monoxide, carbon dioxide, and other gases that are toxic to ground squirrels. The cartridge should be lit before it is placed in the burrow. Once it has been inserted, the burrow should be immediately plugged with soil. Gas cartridges should be used with caution and in accordance with the directions on the label. Dam owners should consult with their state wildlife agency for information on state and local regulations regarding gas cartridges and the use of fumigants.

6.10.4 Ground Squirrel Control Through Toxicants (University of Nebraska, 1994)

Zinc phosphide and two anticoagulants, chlorophacinone and diphacinone, are currently registered for ground squirrel control.

When used correctly, zinc phosphide can result in an 85% to 95% reduction in ground squirrel population.

Zinc phosphide is a Restricted Use Pesticide, which means that it can only be purchased and applied by a certified pesticide applicator. It is a single-dose toxicant delivered on oat baits. The ground squirrels should be exposed to an untreated prebait several days before using the toxic grain. Bait can be delivered by hand or mechanically dispensed.

Chlorophacinone and diphacinone are two anticoagulant baits that are registered in some states under various trade names. A continuous supply of bait must be applied for 4 to 9 days for the toxicant to be effective. The bait is usually delivered in a bait box, which can be made of rubber tires or metal, plastic, or wood containers. The commonly used PVC Inverted-T anticoagulant bait station consists of 4-inch sections of plastic irrigation pipe formed into an inverted "T" configuration (Figure 6-12). Dam owners should contact

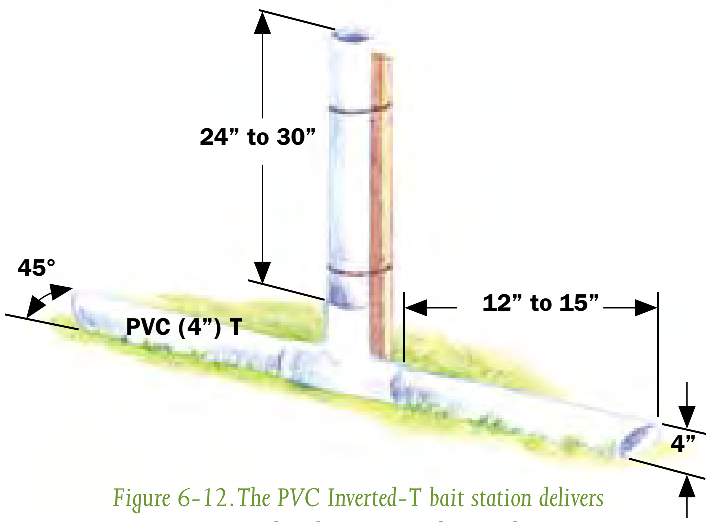


Figure 6-12. The PVC Inverted-T bait station delivers anticoagulant bait to ground squirrels.

their state wildlife agency for information on anticoagulants that may be available for use.

All products should be used as directed. Dam owners should consult with their state wildlife agency regarding legality of toxicant use in their state.

6.10.5 Ground Squirrel Control Through Frightening (University of Nebraska, 1994)

Frightening is not an effective method of control for ground squirrels.

6.10.6 Ground Squirrel Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for ground squirrel control.

6.10.7 Ground Squirrel Control Through Shooting (University of Nebraska, 1994)

Shooting may be used to remove small populations of ground squirrels, although it is an expensive and time-consuming method of control. Dam owners should consult with their state wildlife agency regarding specific hunting regulations and requirements

6.11 Armadillo Management Methods

6.11.1 Armadillo Control Through Habitat Modification (University of Nebraska, 1994)

It is possible to discourage armadillos from burrowing in an earthen dam by implementing the following habitat mitigation techniques:

- Remove brush or other cover to reduce the amount of suitable habitat.
- Apply soil insecticides to remove insects and other invertebrates that make up the majority of the armadillo’s diet.

6.11.2 Armadillo Control Through Trapping (University of Nebraska, 1994)

Trapping can be an effective method of managing armadillos. Live or box traps (10 x 12 x 32-inch), such as the Havahart or Tomahawk, work best. A trap’s effectiveness can be enhanced by adding “wings” (1 x 4-inch or 1 x 6-inch boards about 6 feet long) to funnel the animal into the trap (Figure 6-13). The best locations to set traps are along pathways to burrows and along fences or other barriers where armadillos may travel. Conibear® (No. 220) or leghold traps (No. 1 or 2) may also be used (refer to Figure 6-1). These types of traps should be placed at the entrance of a burrow.

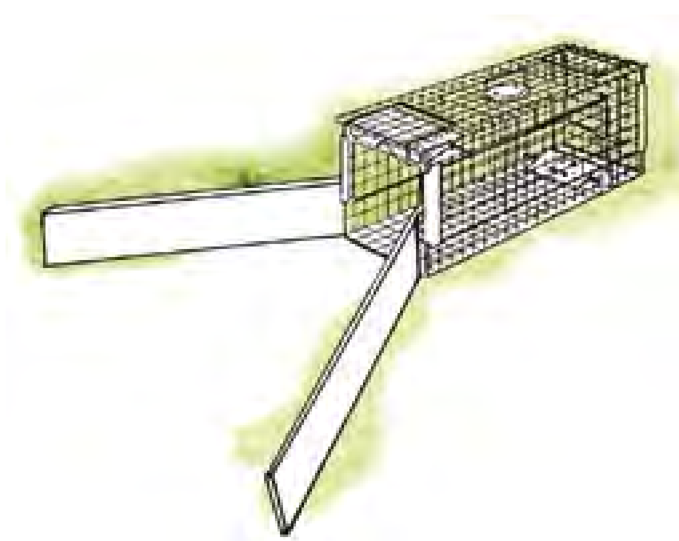


Figure 6-13. The effectiveness of cage traps can be enhanced by adding “wings” to funnel the armadillo into the trap.

6.11.3 Armadillo Control Through Fumigants (University of Nebraska, 1994)

No fumigants are Federally registered for armadillo control. However, there are some fumigants that are effective and that may be legal in certain states. Dam owners should consult their state wildlife agency regarding fumigants that may be legal in their area.

6.11.4 Armadillo Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for armadillo control.

6.11.5 Armadillo Control Through Frightening

Frightening is not an effective method of armadillo control.

6.11.6 Armadillo Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for armadillo control.

6.11.7 Armadillo Control Through Shooting (University of Nebraska, 1994)

Shooting is an effective method of controlling armadillos. The best time to shoot is during twilight hours or at night when armadillos are most active. Dam owners should consult with their state wildlife agency regarding specific hunting regulations and requirements.

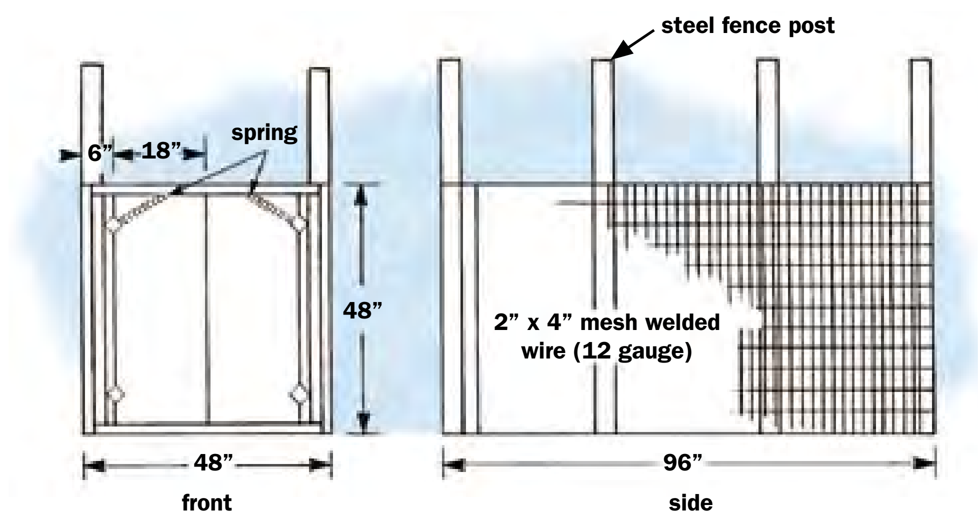
6.12 Livestock (Cow, Sheep, Horse, Pig, and Wild Pig) Management Methods

6.12.1 Livestock Control Through Habitat Modification (USDA, 1991)

Providing a water source away from the earthen dam may help reduce livestock damage near the dam, since livestock are often at the dam in search of drinking water.

6.12.2 Livestock Control Through Trapping (USDA, 1991; University of Nebraska, 1994)

Trapping is quite effective for wild pigs. Stationary corral-type traps and box traps are commonly used (Figure 6-14). They are most effective in summer when acorns and other



	2” x 4” x 24’ wood	8	6” steel fence posts
	36” x 48” x 3/4” plywood	4 lbs	16-penny nails
	36’ x 2” x 4” mesh welded wire	1 lbs	12-penny nails
4	6” strap hinges	2 lbs	1 1/2” staples
2	12” screen door springs	1	100 12-gauge wire

Figure 6-14. Stationary hog trap.

preferred natural foods are not available. Traps should be baited with grains, fruits, or vegetables. The traps may be placed anywhere that wild pigs concentrate.

6.12.3 Livestock Control Through Fumigants (USDA, 1991)

Fumigants are not suitable for livestock control.

6.12.4 Livestock Control Through Toxicants (USDA, 1991)

Toxicants are not suitable for livestock control.

6.12.5 Livestock Control Through Frightening (USDA, 1991)

Frightening devices such as animated scarecrows or firecrackers may temporarily deter livestock from inhabiting an area, but these techniques generally do not provide a long-term solution to livestock damage.

6.12.6 Livestock Control Through Repellents (USDA, 1991)

Repellents are not suitable for livestock control.

6.12.7 Livestock Control Through Shooting (USDA, 1991)

Shooting may be an effective method of removing a small population of nuisance livestock; however, hunting is generally only permitted for wild animals such as pigs. Dam owners should contact their state wildlife agency regarding hunting regulations and restrictions.

6.13 Crayfish Management Methods

6.13.1 Crayfish Control Through Habitat Modification (Virginia Cooperative Extension, 2001a).

Damage may be prevented by stocking the reservoir with natural enemies of crayfish, such as trout, bass, catfish, and large bluegills. These species will eat the crayfish, which will reduce the overall crayfish population and decrease the number of burrows.

6.13.2 Crayfish Control Through Trapping (University of Nebraska, 1994)

Wire cage traps baited with fish or meat can be used to catch crayfish.

6.13.3 Crayfish Control Through Fumigants (University of Nebraska, 1994)

No fumigants are Federally registered for crayfish control.

6.13.4 Crayfish Control Through Toxicants (University of Nebraska, 1994)

No toxicants are Federally registered for crayfish control. Some states, however, have regulations that allow application of certain insecticides for crayfish burrow treatment. Dam owners should consult with their state wildlife agency regarding the legality of toxicants in their state.

6.13.5 Crayfish Control Through Frightening

Frightening is not an effective method of controlling crayfish.

6.13.6 Crayfish Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for crayfish control.

6.13.7 Crayfish Control Through Shooting

Shooting is not a suitable method of controlling crayfish.

6.14 Coyote Management Methods

6.14.1 Coyote Control Through Habitat Modification (USDA, 1991)

Proper vegetative management (mowing and brush removal) and rodent control will often discourage coyotes from digging in earthen dams.

6.14.2 Coyote Control Through Trapping (University of Nebraska, 1994)

Steel leg-hold traps (No. 3 and 4) are often used for coyote removal. Effective use of these traps for coyote control generally requires a great deal of experience and training.

Dam owners should contact their state wildlife agency for guidance on trapping nuisance coyotes.

Snaring is another method of removing coyotes. Snaring involves setting a steel-cable loop in an animal's path to capture it by the neck, body, or leg. Snares are light-weight, compact, easy to set, low-cost, and they offer a high degree of human safety. In one study, they were proven to be more effective than leg-hold traps for coyote control. Snares are usually made of a 2.5- to 10-foot long piece of galvanized aircraft cable with a slide lock that forms a loop. Snares should be set along known coyote trails. They must be attached to a solid object so that the captured animal cannot escape. Snares should not be set where they could capture pets or livestock. Snares are not legal in all states so dam owners should consult with their state wildlife agency before choosing this control method. Once caught, coyotes should be humanely destroyed.

6.14.3 Coyote Control Through Fumigants (University of Nebraska, 1994)

Gas cartridges are the only registered fumigant for coyote control. Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. When ignited and placed in the den, a gas cartridge will produce carbon monoxide, carbon dioxide, and other gases that are toxic to the coyote. Gas cartridges should be used with caution and in accordance with the directions on the label. Dam owners should consult with their state wildlife agency regarding state and local regulations on gas cartridges and the use of fumigants.

6.14.4 Coyote Control Through Toxicants (University of Nebraska, 1994)

The only toxicant registered for coyote control is sodium cyanide used in an M-44 ejector device. The M-44 is a spring-activated device that expels a sodium cyanide capsule into the animal's mouth. The M-44 device should be set along the sides of trails or paths used by coyotes. This control method is most effective during cooler months. The M-44 sodium cyanide device is classified as a Restricted Use Pesticide and may only be used by USDA Animal Damage Control personnel and, in some states, certified pesticide applicators. The M-44 is not registered for use in all states so dam owners must consult their state wildlife agency before implementing this control measure.

6.14.5 Coyote Control Through Frightening (USDA, 1991)

Several types of frightening devices are available for coyote control, but these devices were designed for livestock protection and are not practical for protection of earthen dams.

6.14.6 Coyote Control Through Repellents (University of Nebraska, 1994)

No repellents have proven effective for coyote control.

6.14.7 Coyote Control Through Shooting (USDA, 1991)

Coyote hunting is often an effective method of control for livestock protection, but it is generally not practical for protecting earthen dams. If a dam owner decides to pursue this method of control, they must contact the state wildlife agency for information on hunting regulations.

6.15 Mole and Vole Management Methods

6.15.1 Mole and Vole Control Through Habitat Modification (University of Nebraska, 1994; USDA, 1991)

It is possible to discourage moles from burrowing in an earthen dam by implementing the following habitat modification techniques:

- Compact the soil with a roller to reduce soil moisture. This will reduce the habitat's attractiveness to moles.
- Apply insecticides to reduce food supply. Legal insecticides may vary by state so dam owners should contact their state wildlife agency for specific guidance.

6.15.2 Mole and Vole Control Through Trapping (University of Nebraska, 1994)

Trapping is the most effective method of reducing mole populations. Several traps are specifically designed for moles, including the Victor mole trap, Out O' Sight, and Nash (choker loop) mole trap. If used properly, any of these traps can be effective. Traps should be set in the surface runway where there is evidence of recent mole activity.

Trapping is generally not an effective method of reducing large vole populations because of prohibitive time and labor costs. Mouse snap traps may be used for control of a few individual voles. Traps should be set perpendicular to a runway with the trigger end in the runway. Voles are easiest to trap in the fall and late winter.

6.15.3 Mole and Vole Control Through Fumigants (University of Nebraska, 1994)

Both aluminum phosphide and gas cartridges are Federally registered for mole control. Aluminum phosphide is a Restricted Use Pesticide that comes in tablet form. One tablet should be placed in each burrow entrance and then the burrow should be plugged with soil to form an air-tight seal. The legal application of aluminum phosphide may vary from state to state so dam owners should consult with their state wildlife agency or state pesticide registration board before implementing this control method.

Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. When ignited, a gas cartridge will produce carbon monoxide, carbon dioxide, and other toxic gases. The cartridge should be lit before it is placed in the burrow. Once it has been inserted, the burrow should be immediately plugged with soil. Gas cartridges should be used with caution and in accordance with the directions on the label. Dam owners should consult with their state wildlife agency for information on state and local regulations regarding gas cartridges and the use of fumigants.

Fumigants are generally not effective for vole control. The vole burrow system is so complex and shallow that the fumigant easily escapes to the surface.

6.15.4 Mole and Vole Control Through Toxicants (University of Nebraska, 1994)

Strychnine alkaloid and chlorophacinone are both Federally registered for mole control. Strychnine alkaloid is a Restricted Use Pesticide that can only be purchased and applied by a certified pesticide applicator. However, since moles do not normally consume grain, strychnine alkaloid grain baits are seldom effective. Chlorophacinone is commercially available in pellet form under the name Orco Mole Bait. Researchers have found that this is a highly effective and easy to apply mole control technique. Dam owners should be aware, though, that two or more successive treatments are often required. If a dam owner chooses either of these methods of control, they should contact the state wildlife agency regarding the legality of toxicant use in their state.

Zinc phosphide is often used for vole control. Zinc phosphide is a single-dose toxicant available in pellet or grain bait formulas. Pellets or grain bait can be delivered to burrows by hand or mechanically dispensed. Zinc phosphide is a Restricted Use Pesticide, which must be purchased and applied by a certified pesticide applicator. Anticoagulant baits can also be used to reduce vole populations. Anticoagulants generally require several feedings and can take anywhere from 5 to 15 days to be effective. Bait can be delivered by hand, mechanically dispensed, or placed in various types of bait containers. Registration for anticoagulants varies by state.

All products should be used as directed. Dam owners should consult with their state wildlife agency regarding legality of toxicant use in their state.

6.15.5 Mole and Vole Control Through Frightening (University of Nebraska, 1994)

Frightening is not an effective method of control for moles or voles.

6.15.6 Mole and Vole Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for mole control.

Several repellents using thiram or capsaicin as the active ingredient are registered for vole control, but there is no evidence that these repellents are actually effective. Dam owners should contact their state wildlife agency or pesticide regulatory agency for information on available repellents in their state.

6.15.7 Mole and Vole Control Through Shooting (University of Nebraska, 1994)

Shooting is not an effective method of control for moles or voles.

6.16 River Otter Management Methods

6.16.1 River Otter Control Through Habitat Modification (University of Nebraska, 1994)

Habitat modification is generally not an effective method of control for river otters. Otters often share their environment with beavers, whose burrowing activity is detrimental to the earthen dam environment. Otters will often live in beaver burrows and dens and do not often dig their own dens. Before mitigating for the river otter, evaluate whether the damaging actions are caused by beaver so that the appropriate species is managed and proper preventive actions are implemented (as discussed in Chapters 4.0 and 5.0 of this manual).

6.16.2 River Otter Control Through Trapping (University of Nebraska, 1994)

Both Conibear (No. 220 and 330) and leghold (modified No. 1 ½ soft-catch and No. 11 double coilspring) traps have been successfully used to catch river otters. Traps should be placed underwater along river otter trails or on "pull-outs" where otters leave the water. Leghold traps can also be used out of the water along trails and peninsula crossings. River otter trapping is illegal in many states so dam owners should contact their state wildlife agency before initiating a trapping program.

6.16.3 River Otter Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for river otter control.

6.16.4 River Otter Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for river otter control.

6.16.5 River Otter Control Through Frightening (University of Nebraska, 1994)

Frightening has not proven to be an effective method of river otter control.

6.16.6 River Otter Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for river otter control.

6.16.7 River Otter Control Through Shooting (University of Nebraska, 1994)

Shooting is generally only effective for removing small populations of river otters. Dam owners should contact their state wildlife agency for information on hunting regulations and requirements.

6.17 Gopher Tortoise Management Methods

The gopher tortoise is a Federally listed threatened species and therefore subject to the provisions of the Endangered Species Act. The historic range of the gopher tortoise includes Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina. Dam owners in those states who suspect that they have a gopher tortoise problem should contact the USFWS and their state wildlife agency for management guidance.

6.17.1 Gopher Tortoise Control Through Habitat Modification (University of Nebraska, 1994)

Habitat modification is generally not an effective method of gopher tortoise control.

6.17.2 Gopher Tortoise Control Through Trapping

Since the gopher tortoise is Federally listed as a threatened species, dam owners should contact the USFWS or their state wildlife agency for management guidance.

6.17.3 Gopher Tortoise Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for gopher tortoise control.

6.17.4 Gopher Tortoise Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for gopher tortoise control.

6.17.5 Gopher Tortoise Control Through Frightening

Frightening has not proven to be an effective method of gopher tortoise control and would be prohibited under the Endangered Species Act.

6.17.6 Gopher Tortoise Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for gopher tortoise control.

6.17.7 Gopher Tortoise Control Through Shooting (University of Nebraska, 1994)

Gopher tortoises are protected under the Endangered Species Act and therefore, cannot be shot. Dam owners should contact the USFWS or their state wildlife agency for management guidance.

6.18 Red Fox and Gray Fox Management Methods

6.18.1 Red Fox and Gray Fox Control Through Habitat Modification

Proper vegetative management (mowing and brush removal) and rodent control will often discourage foxes from digging in earthen dams by reducing their primary food source.

6.18.2 Red Fox and Gray Fox Control Through Trapping (University of Nebraska, 1994)

Trapping is a very effective method of controlling foxes, however it requires a great deal of expertise and training. Steel leg-hold traps (No. 1 ½, 1 ¾, and 2 doublespring coil traps; and No. 2 and 3 double longspring trap) are suitable for both red and gray foxes. Cage traps may be used for juvenile red foxes. Traps set along trails, at entrances to fields, and near bait carcasses are most effective.

Snares may also be used to capture foxes. Snaring involves setting a steel-cable loop in an animal's path to capture it by the neck, body, or leg. Snares should be made from 1/16-inch, 5/64-inch or 3/32-inch cable to capture red or gray foxes. The snare should have a 6-inch loop that is placed 10 to 12 inches off the ground. Snares should be set on trails or in crawl holes that are frequented by foxes.

Traps and snares are not legal in all states. Dam owners should contact their state wildlife agency for specific information on trapping regulations.

6.18.3 Red Fox and Gray Fox Control Through Fumigants (University of Nebraska, 1994)

Gas cartridges are the only registered fumigant for red and gray fox control. Gas cartridges are General Use Pesticides that can usually be purchased at local farm supply stores or pesticide dealers. When ignited and place in the den, a gas cartridge will produce carbon monoxide, carbon dioxide, and other gases that are toxic to the fox. Gas cartridges should be used with caution and in accordance with the directions on the label. Dam owners should consult with their state wildlife agency for information on state and local regulations regarding gas cartridges and the use of fumigants.

6.18.4 Red Fox and Gray Fox Control Through Toxicants (University of Nebraska, 1994)

The only toxicant registered for red and gray fox control is sodium cyanide used in an M-44 ejector device. The M-44 is a spring-activated device that expels a sodium cyanide capsule into the animal's mouth. It should be set along trails and at crossings regularly used by foxes. This is a Restricted Use Pesticide and may only be used by USDA Animal Damage Control personnel and, in some states, certified pesticide applicators. The M-44 is not registered in all states so dam owners must consult their state wildlife agency before implementing this control measure.

6.18.5 Red Fox and Gray Fox Control Through Frightening (University of Nebraska, 1994)

Noise-making devices such as radios, amplifiers, or propane exploders may temporarily deter foxes from inhabiting an area, but they do not provide a long-term solution.

6.18.6 Red Fox and Gray Fox Control Through Repellents (University of Nebraska, 1994)

No repellants are registered for red or gray fox control.

6.18.7 Red Fox and Gray Fox Control Through Shooting

Shooting is another method of managing both red and gray foxes. Hunting regulations and seasons vary by state. Dam owners should contact their state wildlife agency for specific information on hunting foxes.

6.19 Canada Goose Management Methods

6.19.1 Canada Goose Control Through Habitat Modification (Virginia Cooperative Extension, 2001b; University of Nebraska, 1994)

The following habitat modification techniques can be implemented to reduce Canada goose damage:

- Minimize the amount of forage plants that exists near the water body by mowing or hand removal.
- Construct a wire grid of stainless steel spring wire or monofilament line above the surface of the water. This will prevent Canada geese and other waterfowl from using the water and discourage them from nesting in that

area. The individual lines should be staked to the ground about 12 inches above the water's surface.

6.19.2 Canada Goose Control Through Trapping (University of Nebraska, 1994; Virginia Cooperative Extension, 2001b)

Live trapping may be effective for small populations of Canada geese. Several types of traps are effective including walk-in funnel traps, rocket or cannon nets, and spring-powered nets. A federal permit is required before trapping may be initiated. In addition, all relevant state and federal agencies must agree on what will happen to the geese after capture. Dam owners should contact the USFWS and their state wildlife agency for guidance.

Walk-in funnel traps are most effective in late June or early July. These types of traps can be constructed using poultry wire, woven wire fencing, steel fence posts, and netting (Figure 6-15). The trap should be set immediately next to the affected waterbody and then the geese should be herded into the trap. The herders must surround the geese on three sides, forcing them into the trap. Once the geese are secured in the trap, they may be transported to a designated location.

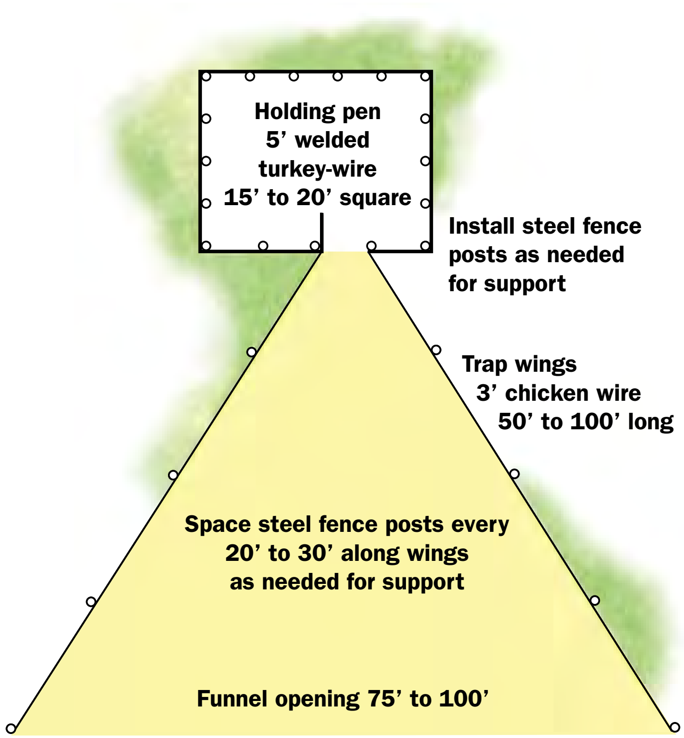


Figure 6-15. Canada goose funnel trap.

Net traps may also be used to capture Canada geese. Rocket or cannon nets with 2- to 2.5-inch mesh work well for large geese. The net should be placed at a location near the water and a second site should be repetitively baited with corn or other suitable bait until the bait is well accepted. Once the geese are trained to feed at the bait site, the area should be re-baited in preparation for capture. When the geese are concentrated at the site, the rocket or cannon net should be fired at the location so the birds are trapped underneath. The Canada geese can then be transported to a designated location. Spring-powered nets work in a similar fashion, though they are smaller than standard rocket or cannon nets. The net is triggered mechanically or electronically, and because it does not create as much noise as the rocket or cannon net, it may be more effective even though it is smaller.

A final method of capturing Canada geese is through the use of an immobilizing agent, Alpha-chloralose. Alpha-chloralose is a non-lethal chemical that is applied to bait and then fed to the geese. Approximately 20 to 90 minutes after ingestion, the geese will be unable to fly or escape and can be captured by hand. Alpha-chloralose may only be used by USDA Animal Damage Control (ADC) staff or biologists of other certified state or federal wildlife management agencies. Dam owners should contact USDA ADC staff, the USFWS, or their state wildlife agency for more information about this option

6.19.3 Canada Goose Control Through Fumigants

Fumigants are not a practical method of control for Canada geese.

6.19.4 Canada Goose Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for Canada goose control.

6.19.5 Canada Goose Control Through Frightening (Virginia Cooperative Extension, 2001b)

Auditory and visual scare devices may be used to deter Canada geese from inhabiting an area. Auditory scare devices make loud noises that will frighten geese away. Commonly used devices include propane cannons, pyrotechnics, and pre-recorded tapes of Canada goose distress calls. Visual scare devices installed on or around an earthen dam are also effective. They are usually inexpensive and easy to install, but they work best in conjunction with another deterrent.

Examples of visual scare devices include strobe lights, scarecrows, owl effigies, mylar reflective tape, flags, and balloons.

Harassment or hazing of Canada geese is generally more effective than visual or auditory deterrents, but it can be labor intensive and expensive. Examples of common hazing programs include use of radio-controlled toys (boats or airplanes), trained dogs, or high-power water spray devices. These deterrent activities must be persistent and repeated to remain effective.

6.19.6 Canada Goose Control Through Repellents (Virginia Cooperative Extension, 2001b)

Methyl anthranilate has been registered as a goose repellant under the name ReJeX-iT. This repellant is non-toxic and does not harm the geese. Re-JeX-iT is applied directly to the grass of an affected area. It may have to be reapplied frequently to remain effective. Repellents should always be used as directed.

6.19.7 Canada Goose Control Through Shooting (University of Nebraska, 1994)

Hunting is another effective method of reducing Canada goose populations. Since Canada geese are listed as migratory birds under the Migratory Bird Treaty Act, a federal permit is required. In many areas, state permits are also required for hunting Canada geese. Dam owners should contact the USFWS and their state wildlife agency for specific hunting regulations and requirements.

6.19.8 Other Methods of Canada Goose Control

It is also possible to reduce resident Canada goose populations by oiling, shaking, or puncturing their eggs. This requires a federal permit; dam owners should contact USFWS and their state wildlife agency for more information.

6.20 American Alligator Management Methods

The American Alligator is Federally listed as a threatened species "due to similarity of appearance" to the federally endangered American crocodile. This listing grants the American Alligator protection under the Endangered Species Act. Dam owners who experience problems with nuisance alligators should contact the USFWS and their state wildlife agency for management guidance.

6.20.1 American Alligator Control Through Habitat Modification (University of Nebraska, 1994)

Removal of emergent wetland vegetation may reduce alligator densities by reducing cover. There are strict laws however, regarding human modifications to wetlands so dam owners must consult with appropriate state environmental agencies before disturbing any wetland vegetation.

6.20.2 American Alligator Control Through Trapping (University of Nebraska, 1994)

Trapping is an effective method of eliminating alligators from an area. A baited hook is the simplest and most effective method. This involves rigging a large fish hook (12/0 forged) with bait (e.g., fish, beef, chicken, or nutria) and suspending it via rope from a tree or pole about 2 feet above the water. When the alligator swallows the bait, the hook is lodged in its stomach and the alligator is retrieved using the attached rope. This method almost always kills or injures the alligator.

Trip-snare traps and wire box traps may also be used. They are not quite as effective as the baited hook, but they do not kill or injure the alligator, which then must be relocated. Dam owners must contact the USFWS and their state wildlife agency for information on trapping regulations, the Endangered Species Act, and permit requirements.

6.20.3 American Alligator Control Through Fumigants (University of Nebraska, 1994)

No fumigants are registered for alligator control.

6.20.4 American Alligator Control Through Toxicants (University of Nebraska, 1994)

No toxicants are registered for alligator control.

6.20.5 American Alligator Control Through Frightening (University of Nebraska, 1994)

Under the Endangered Species Act, no actions to harass or frighten a protected species are allowed.

6.20.6 American Alligator Control Through Repellents (University of Nebraska, 1994)

No repellents are registered for alligator control.

6.20.7 American Alligator Control Through Shooting (University of Nebraska, 1994)

Shooting is an effective method of eliminating alligators. A sufficiently powerful rifle (.243 caliber or larger) should be used for a humane kill. Dam owners must contact the USFWS and their state wildlife agency for information on hunting regulations, compliance with the Endangered Species Act, and permit requirements.

6.21 Ant Management Methods

6.21.1 Ant Control Through Habitat Modification (University of Georgia Cooperative Extension Service, 2000)

It may be possible to reduce ant populations by physically destroying visible ant mounds. This can be accomplished by simply knocking down or disturbing mounds with a stick or shovel. Another option is to pour very hot (almost boiling) water directly on each mound.

Pouring very hot water on each ant mound will eliminate about 60% of mounds.

6.21.2 Ant Control Through Trapping

Ant traps are commercially available, but they are not effective for large, outdoor ant infestations.

6.21.3 Ant Control Through Fumigants (University of Georgia, 1993; University of Georgia Cooperative Extension Service, 2000)

Fumigants may help control some type of ant species. Earthfire® (vaporized resmethrin) and Brom-O-Gas (methyl bromide) are two examples of fumigants that have proven effective against fire ants. Both are Restricted Use Pesticides that must be purchased and applied by a certified pesticide applicator. These fumigants may not necessarily be effective for all ant species. Dam owners should contact a professional pest removal company for information on fumigants that may be effective for their particular ant infestation.

6.21.4 Ant Control Through Toxicants (University of Florida Cooperative Extension Service, 2002)

Ants can usually be controlled with baits or chemical treatments. Many of these products are available commercially at hardware stores, home and garden suppliers, and other retail outlets. These treatments come in various forms, including granules, liquids, gels, and ready-to-use tamper resistant containers. Treatment should be tailored to the type of ant species present and the extent of infestation. Dam owners should contact their local cooperative extension agency or a professional pest control company for assistance. Professional pest control companies may also be able to provide stronger treatment options if damage is significant and the use of commercially available products is not effective.

Insecticides can contaminate both ground and surface waters so dam owners need to be particularly cautious when applying baits or chemical treatments near a reservoir. Insecticide use must occur in accordance with Federal law (FIFRA of 1996).

6.21.5 Ant Control Through Frightening

Frightening is not an effective or practical method of ant control.

6.21.6 Ant Control Through Repellents

Large, outdoor ant infestations cannot be effectively controlled through the use of repellents.

6.21.7 Ant Control Through Shooting

Shooting is not a practical method of ant control.

7.0 Fiscal Considerations for Managing Animal Damage on Earthen Dams

"There is no free lunch. Either we make the investments required to keep our nation's dams safe, or we will pay the price in dam failures."

Martin McCann, consulting professor of civil and environmental engineering at Stanford University and director of the National Performance of Dams Program (NPDP).

Almost everyone in the dam community agrees that the funds spent preserving a dam's integrity and safe operation will almost always be less than those spent repairing an unsafe dam or worse, recovering from a dam failure. The economics behind this understanding are self-explanatory and probably need no quantitative explanation; yet across the nation, dams deteriorate from animal intrusion damages and dam owners struggle with the financial responsibility of repairing their unsafe dams, or removing them altogether when the repair costs become too great. Clearly then, the economic considerations related to appropriate dam management go beyond the economic efficiency and long-term benefit of such repairs; the considerations involve acknowledgement of animal damages as a problem, human motivation factors, and the availability of funding mechanisms at the federal and state level.

7.1 Fiscal Considerations for the Reluctant Dam Owner

As indicated in the FEMA/ASDSO workshops, inspectors, engineers, and regulators can find it difficult to convince dam owners that animal burrows and erosion can have serious detrimental effects on their dams. Even though dam failures are becoming all too common—partially a product of America's aging dams—some dam owners put too much confidence in the integrity of their dams, even when visible evidence of animal burrows and inappropriate vegetation are present on their dams. For these dam owners, animal damage management is not likely to become a budget line item until an understanding is developed of how adverse animal intrusion effects can cascade, resulting in extensive repair/replacement costs, as well as the associated liabilities, that follow a dam failure.

7.2 Fiscal Considerations of the Willing Dam Owner

Other dam owners are aware of the dangers inherent to animal damages at an earthen dam, but overlook routine owner actions that are relatively affordable and can save hundreds of thousands of dollars in the long-term, not to mention reduce the public safety hazard for those located downstream of the dam. Inspections and repair actions are indeed overlooked, as documented by the states in the 2003 surveys and in the 2002 workshop where "financial limitations by owners" is listed as the most common impediment to timely and adequate dam upkeep. Considering that over 50% of the dams in this country are privately owned (AS-

DSO, 2003), financial limitations to upkeep pose a daunting threat to public safety.

Still other dam owners know the inherent problems of animal damage, and vigilantly conduct inspections, mow twice annually, and fill burrows in a timely manner. However, some dams because of their size, location, and biological attractiveness continue to have animal damage problems despite owner vigilance. In these cases, the dam owner pays continuously to correct animal damages and routine owner actions become an expensive proposition in terms of both time and money.

7.3 Overcoming the Economic Hurdles

The current and persisting economic issues with regard to animal damage management at earthen dams is twofold: first, reluctant owners need to be educated on the dangers of animal damages and motivated by economic examples; and second, funding sources for all owners need to be identified to assist funding of needed repairs. To begin to address the first consideration, a simple estimate of routine dam maintenance as it relates to vegetation and animal management (one influences the other) is given below:

Table 7.1

Vegetation Management (mowing twice per year)	$500 to $1000 annually*
Owner Inspection (one to two times per year)	No cost for dam owner inspection; inspection once every 2 to 5 years by a Professional Engineer can cost between $3,500 and $7,500
Filling animal burrows (per burrow)	$100 to $300 depending upon burrow size and repair method (grout or excavate and replace)

*for most dams, as indicated in FEMA, 2002.
This estimate assumes the dam is in good condition and that the owner is providing upkeep of an already stable operation

As the table indicates, the cost of routinely maintaining a dam is estimated at greater than $500.00 dollars per year. For many private dam owners, such as businesses and citizens, the outlay of these funds, though relatively low, is prohibitive. Even those dam owners with substantial financial resources are often overwhelmed by the costs of dam maintenance and repairs (WaterWebster, 2003). In these cases, it is important for dam owners to consider that neglect will eventually lead to greater costs on many levels; in short, dam owners can't afford to save money when it comes to the upkeep of their dams. Economic impacts of a failed dam can include:

Liability Costs of Loss of Life and Property Damage. Liability may be imposed on a dam owner if maintenance, repair, or operations were conducted in an unsafe or improper manner. Liability could apply to the dam owner as well as the company who possesses the dam and the individual who or company which operates and maintains the dam. The dam owner must take actions to ensure the dam functions properly so that injuries to people or property are avoided. This applies to foreseeable conditions or circumstances that can be predicted with reasonable certainty. If an inspection identifies problems at the dam, then an owner should correct them (Pennsylvania DEP, 1995).

Clean-up Costs. The costs associated with clean-up from a dam failure can be tremendous, depending on the size of the reservoir and the amount of downstream development. Debris removal, sediment clean-up, and reconstruction of damaged infrastructure could be required.

Loss of Dam Infrastructure and Its Revenue. Over 30% of the dams in the United States are used primarily for recreation (ASDSO, 2003). The benefit of dams to recreational income to the community can be in the millions of dollars each year, depending on the reservoir size and recreational opportunities available.

Environmental Losses. Many reservoirs provide wildlife habitat and associated ecotourism revenue, which generates $59 billion annually in the United States. Communities often benefit from the "wilderness" which dams and their reservoirs provide.

Economic Effect on Community. A community that depends on the dam for several uses (e.g., flood control, irrigation, water supply) will have to locate other facilities to serve these purposes should the dam fail or be removed. Alternative sources could be costly or may not be available as quickly as needed, resulting in an adverse social and economic impact on the community.

In essence, a neglected dam can cause a cascade of adverse effects at the community level as well as result in liability issues for the dam owner. Attaching a reasonable dollar figure to each of the considerations above would illustrate that this considerable investment per year in maintenance is like paying an insurance premium that covers the dam owner and their community.

Lessons Learned:

- Maintenance of animal burrows is critical. Burrows should be backfilled and animals removed as soon as possible.
- Owners should inspect their dams in a regular and thorough manner.
- Pond levels should be monitored and safety precautions such as spillways and freeboard should be factored into design.

The second consideration presents the most current and widespread dilemma facing the entire dam community. Many dam owners conduct inspections and typical maintenance as required, but preventive measures and wildlife mitigation actions may also be required. It would seem that vigilant dam owners would ensure the required actions were forthcoming; however, this is not always the case. According to the workshop (FEMA, 2001) and the state surveys (FEMA, 2003), and as echoed in the document The Cost of Rehabilitating Our Nation's Dams (ASDSO, 2003), owners of dams in need of repair are often not able to finance the required actions due largely to a lack of funding mechanisms at the state and federal levels; dams become neglected and deteriorate to the point of being hazardous. Currently, there are only a handful of states that provide financial assistance in the form of loans or grants to repair unsafe dams, as presented in Table 7-2.

Animal Burrows Contribute to $5 Million Dam Breach

Wallula, Iowa

The Iowa Beef Processor's (IBP) Waste Pond was constructed in 1971 to store wastewater from the IBP Plant. When full, the pond had a surface area of 37 acres and a maximum storage capacity of 270 acre-feet. The pond was located on a natural drainage course and was impounded behind a 15-foot-high, 1000-foot-long earthen dam. State inspections in 1981 and 1985 discovered that the embankment was riddled with animal burrows. It was recommended that the burrows be filled and the animals removed from the site. Repairs were not made quickly enough, and the rapid melting of record snow pack coupled with higher than normal pond levels filled the waste pond and overtopped a portion of the west end of the dam (the dam had no emergency spillway). High pond levels allowed water to exit through animal burrows that were normally above the pond elevation. Uncontrolled leakage and seepage through the animal borrows exiting on the downstream face likely resulted in erosion that backcut rapidly toward the upstream face, eventually breaching the dam.

The estimated cost of the failure was $5 million, which included the cost of the five locomotives that were derailed downstream, environmental cleanup, and repair to the rail line. The cost to construct a new facility was several million more dollars.

Table 7-2 Summary of State Dam Funding Programs

State	Program Name and Type	Eligibility	Loan/Grant Amount
Arizona	Dam Repair (loan or grant)	State engineer determines dam to be dangerous to life, non-emergency	Loan – Cost of project
Maryland	Maryland Environmental Service (loan and planning assistance)	Counties, utilities, and private groups; must have established service district for water supply, resource reclamation, dredging or stormwater	
Massachusetts	No name given (grants)	Local communities for repair or removal	75% of the project; local share can be in-kind contributions
New Jersey	Dam Restoration and Clean Water Trust Fund (revolving loan fund; new grant fund for municipally-owned dams)	Local units of governments; private owners can be co-applicants	Loan – Cost of project Grants – Up to 100%
New York	Clean Water/Clean Air Bond Act (grants)	Municipalities for dam safety projects	75% of eligible project with 25% local match; $300,000 cap per project
Ohio	Ohio Water Development Authority (revolving loan fund)	Owner must be under mandate from ODNR **Dam Safety Loan Program** – Local units of government, state, districts **Dam Safety Linked Deposit Program** – private owners/organizations	Cost of project
Pennsylvania	Pennvest (revolving loan fund)	Projects associated with wastewater, water supply, or stormwater	Up to cost of project
Utah	Utah Board of Water Resources (loans or grants)	High hazard dam owners; mandated repairs	80-95% grant for irrigation or water supply dams; loans or grants for other owners
Wisconsin	DNR Municipal Dam Grant Program (grants)	Local units of government and lake districts	50-50 grants; $200,000 maximum

Similarly, the federal government extends dam rehabilitation assistance through only a few programs. The combination of existing state and federal assistance does not approach the estimated $36.2 billion needed nationwide to support needed dam repair and rehabilitation related to wildlife damages and other structural integrity issues.

Table 7-3. Summary of Potential Federal Programs for Dam Management

Agency	Program	Description
Natural Resources Conservation Service, Department of Agriculture	10.916 Watershed Rehabilitation Program	Provides grants to rehabilitate dams originally built with assistance from USDA Watershed Programs. Rehabilitation must extend the life of the dam and meet applicable performance and safety requirements. Priority is given to high hazard dams.
Natural Resources Conservation Service, Department of Agriculture	10.904 Watershed Protection and Flood Prevention	Provides grants and technical assistance to carry out watershed improvement projects that protect, develop, and utilize the land and water resources in small watersheds.
Bureau of Indian Affairs, Department of the Interior	15.065 Safety of Dams on Indian Lands	Provides direct payments to federally recognized Indian tribal governments and Native American organization to improve the structural integrity of dams on Indian lands.
Federal Emergency Management Agency, Department of Homeland Security	97.047 Pre-Disaster Mitigation (PDM)	Provides grants to states and communities for cost-effective hazard mitigation activities that are part of a comprehensive mitigation program, and that reduce injuries, loss of life, and damage and destruction of property. Dam repair and rehabilitation projects may be eligible for PDM funding if: • The project has a high benefit-cost ratio; • There is a high risk of dam failure or dam failure would result in significant damages; and • The project is consistent with State funding priorities.
Federal Emergency Management Agency, Department of Homeland Security	P.L. 107-310 National Dam Safety and Security Act of 2002	Funds are granted each year to state dam safety programs.
Federal Insurance and Mitigation Administration, Federal Emergency Management Agency	83.550 National Dam Safety Program (Dam Safety State Assistance Program)	Funds are distributed each year (in the form of project grants) to state dam safety programs.

In conclusion, the dam community is composed of owners in need of education and economic understanding of the consequences associated with neglected dams, as well as those owners who are diligent in dam upkeep, but perhaps unable to fund the necessary repair and preventive actions. Even if federal, state, and local agencies can educate the reluctant dam owners such that they become vigilant in the upkeep of their dams, our nation's dams will likely continue to degrade without adequate funding to implement the sometimes perpetual animal damage repair and management needed.

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Montgomery, Alabama 36130
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Arizona Game and Fish Department
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Little Rock, Arkansas 72205
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(916) 445-0411

Colorado Department of Natural Resources
Division of Wildlife
6060 Broadway
Denver, Colorado 80216
(303) 297-1192

Connecticut Department of Environmental Protection
Bureau of Natural Resources, Wildlife Division
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Division of Fish and Wildlife
89 Kings Highway
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Florida Fish and Wildlife Conservation Commission
620 South Meridian Street
Tallahassee, Florida 32399-1600
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Wildlife Resources Division
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Hawaii Department of Land and Natural Resources
Division of Forestry and Wildlife
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Indianapolis, Indiana 46204
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Des Moines, Iowa 50319-0034
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Kansas Department of Wildlife and Parks
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Lenexa, Kansas 66215
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Kentucky Department of Fish and Wildlife
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Frankfort, Kentucky 40601
(800) 858-1549

Louisiana Department of Wildlife and Fisheries
2000 Quail Drive
Baton Rouge, Louisiana.70808
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Maine Department of Inland Fisheries and Wildlife
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41 State House Station
Augusta, Maine 04333-0041
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Maryland Department of Natural Resources
Wildlife and Heritage Service
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Annapolis, Maryland 21401
(410) 260-8540

Massachusetts Department of Fisheries, Wildlife and
Environmental Law Enforcement
Division of Fisheries & Wildlife
251 Causeway Street, Suite 400
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(617) 626-1590

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Wildlife Division
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Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, Minnesota 55155-4040
(651) 296-6157

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Jackson, Mississippi 39211-6374
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Missouri Department of Conservation
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Nebraska Game and Parks Commission
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Nevada Department of Wildlife
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Reno, Nevada 89512
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Wildlife Division
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(603) 271-2461

New Jersey Department of Environmental Protection
Division of Fish and Wildlife
PO Box 400
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New Mexico Department of Game and Fish
PO Box 25112
Santa Fe, New Mexico 87507
(800) 862-9310

New York State Department of Environmental Conservation
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Albany, New York 12233-4750
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North Carolina Wildlife Resources Commission
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Raleigh, North Carolina 27604-1188
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Bismarck, North Dakota 58501-5095
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Ohio Department of Natural Resources
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Oklahoma Department of Wildlife Conservation
1801 N. Lincoln
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Oregon Department of Fish and Wildlife
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Salem, Oregon 97303-4924
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Pennsylvania Game Commission
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South Carolina Department of Natural Resources
Wildlife and Freshwater Fisheries Division
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Wildlife Division
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Texas Parks and Wildlife Department
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Appendix B
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Technical Manual for Dam Owners

Impacts of Plants on Earthen Dams

FEMA 534 / September 2005

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(DCR-VSWCB-034) (03/14)

TABLE OF CONTENTS

PREFACE

Damage to earthen dams and dam safety issues associated with tree and woody vegetation penetrations of earthen dams is all too often believed to be a routine maintenance situation by many dam owners, dam safety regulators, and engineers. Contrary to this belief, tree and woody vegetation penetrations of earthen dams and their appurtenances have been demonstrated to be causes of serious structural deterioration and distress that can result in failure of earthen dams. For the first time in the history of dam safety, a Research Needs Workshop on Plant and Animal Impacts on Earthen Dams (Workshop) was convened through the joint efforts of the Federal Emergency Management Agency (FEMA) and the Association of State Dam Safety Officials (ASDSO) in November 1999 to bring together technical resources of dam owners, engineers, state and federal regulators, wildlife managers, foresters, and members of academia with expertise in these areas. The Workshop highlighted the realization that damage to earthen dams resulting from plant and animal penetrations was indeed a significant dam safety issue in the United States. The purpose of this *Technical Manual for Dam Owners, Impacts of Plants on Earthen Dams* is to convey technology assembled through the Workshop by successful completion of four objectives. These objectives are as follows:

1. Advance awareness of the characteristics and seriousness of dam safety problems associated with tree and woody vegetation growth impacts on earthen dams;

2. Provide a higher level of understanding of dam safety issues associated with tree and woody vegetation growth impacts on earthen dams by reviewing current damage control policies;

3. Provide state-of-practice guidance for remediation design considerations associated with damages associated with tree and woody vegetation growth on earthen dams; and

4. Provide rationale and state-of-practice techniques and procedures for management of desirable and undesirable vegetation on earthen dams.

ACKNOWLEDGEMENTS

The editors of this *Technical Manual for Dam Owners, Impacts of Plants on Earthen Dams* wish to acknowledge the support of the dam safety organizations and agencies and many dedicated individuals that made significant contributions to the contents of this Manual.

Sincere appreciation is extended to past and present members of the Subcommittee on Dam Safety Research of the Interagency Committee on Dam Safety (ICODS), now the National Dam Safety Review Board Work Group on Dam Safety Research, for their support of the proposal to convene a Research Needs Workshop on Plant and Animal Impacts on Earthen Dams (Workshop), and to the members of ICODS for recommending funding for the Workshop through the Federal Emergency Management Agency (FEMA).

Appreciation and sincere gratitude are extended to the members, and especially to the full-time staff, of the Association of State Dam Safety Officials (ASDSO) for their support and coordination of the federally-funded project that culminated with convening of the Research Needs Workshop on Plant and Animal Impacts on Earthen Dams at the University of Tennessee in Knoxville, Tennessee, on November 30-December 2, 1999. The editors of this Manual are especially appreciative of the continued support, patience, and dedication of Susan Sorrell and Sarah Mayfield of the ASDSO staff.

The Steering Committee of the Workshop was comprised of the following individuals who contributed significantly and diligently to making the Workshop a truly historical dam safety technological event:

Dr. B. Dan Marks, P.E. (Chairman)
Dr. Bruce A. Tschantz, UT Knoxville
David K. Woodward, NCSU
Charles Clevenger, MS (Deceased)
William L. Bouley, USBR
Sarah M. Mayfield, ASDSO
Susan A. Sorrell, ASDSO (Project Coordinator)

Participants in the Workshop brought together diverse technologies, experiences, and scientific developments to create a significant contribution to dam safety in the United States. The editors of this Manual acknowledge the valuable contributions of the following Workshop participants:

Matthew A. Barner, Wright State Univ.
William L. Bouley, USBR
Charles Clevenger, MS (Deceased)
Dr. Kim D. Coder, Univ. of Georgia
Gary Drake, Reemay, Inc.
Edward Fiegle, GA Dam Safety
James K. Leumas, NC Dam Safety
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The contents of this Manual were significantly enhanced by editorial reviews and comments of the ASDSO Manual Overview Committee. The editors of the Manual are sincerely appreciative of contributions made by the following individuals:

Timothy G. Schaal, SD Water Rights Program
R. David Clark, MA Office of Dam Safety
Daniel M. Hill, Burgess & Niple, Ltd.
James K. Leumas, City of Raleigh, NC
Lori Spragens, ASDSO Executive Director (Project Coordinator)

Because of the efforts of the many individuals previously mentioned, the editors are confident that users of this Manual will develop a better understanding and gain a greater appreciation of the seriousness and magnitude of problems associated with the effects of tree and woody vegetation root penetrations on the safety of earthen dams and their appurtenances.

GLOSSARY

This glossary provides the definitions of some of the basic terms used in this ***Manual*** and is not intended to be a comprehensive glossary of terms associated with dam safety. A more extensive resource of dam safety terms and definitions is available through the many references provided at the end of each chapter of the ***Manual***.

Absorption - the process of being taken into a mass or body, as water being taken in by plant roots.

Abutments - the interface between the sides of a valley containing a dam and the dam embankment. Right and left abutments are referenced by viewing the dam while facing downstream.

Adsorption – the adhesion of an extremely thin layer of molecules to the surface of solid bodies or liquids with which they are in contact.

Appurtenances – structures associated with dams such as spillways, gates, outlet works, ramps, docks, etc. that are built to allow proper operation of dams.

Berm – a horizontal step or bench in the embankment slope of an earthen dam.

Biological Barrier – an herbicidal releasing system, device, or material designed to exclude root growth and/or penetration of plants into a protected underground zone (such as a dam embankment).

Boil – a typically circular feature created by the upward movement of soil particles by seepage flowing under a pressure slightly greater than the submerged unit weight of the soil through which seepage is occurring.

Breach – a break, gap, or opening in a dam that typically allows uncontrolled release of impounded water.

Capillary Rise – the rise of water in the voids of a soil mass as a result of the surface tension forces of water.

Clearing – the removal of trees and woody vegetation by cutting without removal of stumps, rootballs, and root systems.

Crest – the near horizontal top surface of an earthen dam, or the control elevation of a spillway system.

Diameter at Breast Height (dbh) – the diameter of a tree measured at about four feet (breast height of average person) above the ground surface.

Drainage System – graded and/or protected pervious aggregates in a dam designed to collect, filter, and discharge seepage through the embankment, abutments, or foundation.

Earthen Dam – a dam constructed of compacted natural soil fill materials selected to minimize embankment seepage while maximizing workability and performance.

Embankment – an earthen or rockfilled structure having sloping sides constructed of select compacted fill materials.

Failure – a (dam) incident that results in the uncontrolled release of water from the impoundment of a dam.

Freeboard – the vertical distance from the normal operating water level of an impoundment to the crest (top) of the dam.

Grubbing – the removal of stumps, rootballs, and lateral root system of trees and woody vegetation. A construction operation that is typically done following the clearing operation.

Herbicide – a chemical substance or mixture designed to kill or maintain undesirable Plants that may include herbaceous plants, vines, brush, and trees.

Hydraulic Height (of a Dam) – the vertical distance from the normal operating water level of the impoundment to the invert of the outlet works or downstream outlet channel.

Hydro-seeding – the technique of applying grass seeds, fertilizer, agricultural lime, and seedbed mulch to seeded area in a pressurized aqueous mixture.

Lateral Root System – roots of trees and woody plants that extend laterally from the tap root and/or rootball to provide lateral support and nutrient uptake for the plant.

Line of Saturation – the leading boundary of the progression of saturation of soil in an embankment exposed to an increasing head (source) of water (impoundment).

Line of Wetting – the leading boundary of the progression of wetting (partial saturation) of soil in an embankment exposed to an increasing head (source) of water (impoundment).

Maintenance – routine upkeep necessary for efficient inspection, and safe operation and performance of dam and their appurtenances. Labor and materials are required; however, maintenance should never be considered to comprise dam remediation.

Mowing – the cutting of grass, weeds, and small-diameter woody vegetation by mechanical devices such as mowers, bush hogs, and other vegetation cutting machinery.

Mulching – the application of protective material such as straw, fiber matting, and shredded paper to newly seeded areas.

Operation (of a dam) – activity by a dam owner for the necessary and safe use and performance of a dam, the appurtenances of a dam, and the impoundment.

Owner – any person or organization that owns, leases, controls, operates, maintains, or manages a dam and/or impoundment.

Phreatic Surface – the upper boundary (surface) of seepage (water flow) zone in an embankment.

Piping – the progressive downstream to upstream development of internal erosion of soil as a result of excessive seepage that is typically observed downstream as a hole, or boil, that discharges water containing soil particles.

Remediation – restoration of a dam to a safe and intended design condition.

Revegetation – restoration of desirable ground cover vegetation (i.e. grasses) to disturbed areas designed to prevent embankment surface erosion.

Rootball – the root and soil mass portion of a tree or woody plant that is located directly beneath the trunk or body of the tree that provides the primary vertical support for the tree or woody plant.

Root Penetration – intrusion of plant roots into a dam embankment so as to interfere with the safe hydraulic or structural operation of the dam.

Root System – roots contained in the rootball and the lateral root system collectively comprise the root system of trees and woody plans and provide both lateral and vertical support for the plant as well as providing water and nutrient uptake for the plant.

Seeding – application of a seeding mixture to a prepared seedbed or disturbed area.

Seepage – the flow of water from an impoundment through the embankment, abutments, or foundation of a dam.

Seepage Line – the uppermost boundary of a flow net, or the upper surface (boundary) of water flow through an embankment (see Phreatic Surface).

Slump – a portion of soil mass on an earthen dam that has or is moved downslope, sometimes suddenly, often characterized by a head scarp and tension cracks on the crest and embankment slope.

Spillway Systems – control structures over or through which flows are discharged from the impoundment. Spillway systems include Primary or Principal Spillways through which normal flows and small storm water flows are discharged and Auxiliary or Emergency Spillways through which storm water flows (floods) are discharged.

Stripping – the removal of topsoil, organic laden materials, and shallow root systems by excavating the ground surface (surficial soil stratum) after grubbing an area.

Structural Height (of a Dam) – the vertical distance from the crest (top) of the dam to the lowest point at the toe of the downstream embankment slope, or downstream toe outlet channel.

Stump – that portion of the trunk or body of a tree or woody plant left after removal by cutting during timber harvesting and/or clearing of trees and woody plants.

Stump Diameter – the diameter of a tree or woody plant at the ground surface.

Tap Root – the primary vertical root in the rootball that is the origin of development for the rootball and lateral root system growth.

Toe of Embankment – the point of intersection of the embankment slope of a dam with the natural ground surface.

Weeds – shallow-rooted, non-woody plants that grow sufficiently high as to hinder dam safety inspections and do not provide desirable embankment slope protection against surface runoff.

Woody Vegetation – plants that develop woody trunks, rootballs, and root systems that are not as large as trees but cause undesirable root penetration in dams.

Zone of Aeration – the partially saturated zone of a soil mass above the zone of saturation (above the height of capillary rise of water in a soil mass).

Zone of Saturation – the saturated zone of a soil mass above the phreatic surface defined by the height of capillary rise.

Chapter 1
Introduction

At the time Joyce Kilmer dedicated his famous poem "**Trees**" to Mrs. Henry Mills Alden, he was undoubtedly inspired by the beauty of a healthy living tree, and rightly so. For those that do not remember, the first verse of this famous poem is as follows: "***I think that I shall never see / A poem lovely as a tree.***" Most people are inspired and impressed by the splendor of trees; however, dam owners, operators, inspectors, dam safety regulators, engineers, and consultants might find the following verse more nearly appropriate. "***I think that I shall never see / A sight so wonderful as a tree / Removed from an earthen dam / Whose future safety we wish to see.***" This paraphrased verse is not intended to debase the great works of Joyce Kilmer; but rather, is intended to draw attention to the fact that trees and woody vegetation growth have no place on the embankment of an earthen dam.

Dam safety regulators and inspectors, engineers, and consultants are frequently confronted with grass roots resistance in the issue of removal of trees and woody vegetation from earthen dams. This resistance is often associated with sentimental, cultural, ecological, legal, and financial issues. A fundamental understanding and technical knowledge of potential detrimental impacts of trees and woody vegetation growth on the safety of earthen dams is necessary in order to address these issues.

Purpose

The purpose of this ***Manual*** is to provide the dam owner, operator, inspector, dam safety regulator, engineer, and consultant with the fundamental understanding and technical knowledge associated with the potential detrimental impacts of tree and woody vegetation growth on the safety of earthen dams. In addition to objectives related to raising the knowledge level of detrimental effects of trees and woody vegetation growth on the safety of earthen dams, the contents will provide the user of this ***Manual*** with an understanding of the methods, procedures, and benefits of maintaining a growth of desirable ground covering vegetation on the embankments of earthen dams.

Scope

The editors of this ***Manual*** have organized the contents in a sequential manner in order that the reader and user of this ***Manual*** can develop the desired fundamental understanding and gain the technical knowledge associated with the detrimental impacts of tree and woody vegetation growth on earthen dams. Chapter 2 deals with the problems associated with tree and woody vegetation growth on earthen dams. Chapter 3 presents some common misconceptions about tree growth and tree root development. These misconceptions are contrasted with factual data about tree growth and tree root development.

Chapter 4 presents a recommended earthen dam inspection protocol and procedures for determination of potential impacts of tree and woody vegetation growth on earthen dams. Chapter 5 begins the presentation of proper vegetation management on earthen dams. The user of this ***Manual*** is presented with methods and procedures for maintaining desirable vegetation growth, while also controlling tree and woody vegetation growth.

Chapter 6 presents a number of remediation design considerations associated with the removal of trees and woody vegetation from the embankments of earthen dams. This chapter also presents a recommended phased-remediation procedure for removal of undesirable vegetation (trees and woody vegetation) from earthen dam embankments. Chapter 7 is a succinct factual presentation of costs associated with either continual proper vegetative maintenance or long-term dam remediation construction after tree and woody vegetation removal. The contents of this chapter should make every dam owner cognizant of the need for proper operation and maintenance relative to vegetative growth on earthen dams.

Implementation

While this ***Manual*** may not be considered highly technical relative to the presentation of complex engineering calculations for the solution of potentially serious earthen dam safety problems, this ***Manual*** does present a combined sixty-five years of research and practice in dam safety engineering associated with tree and woody vegetation growth impacts on earthen dams. This ***Manual*** is presented in a manner to be beneficial to the entire dam safety community (dam owners, dam operators, dam safety inspectors, dam safety regulators, dam safety engineers and consultants). Dam safety engineers and consultants can utilize this ***Manual*** as a reference for recommendations for proper maintenance of desirable vegetation growth, control of undesirable vegetation growth, and remediation dam design associated with the removal and control of trees and woody vegetation growth on earthen dams. Dam safety regulators and dam safety inspectors can utilize this ***Manual*** as a guideline for the inspection of earthen dams relative to tree and vegetation growth dam safety issues and for the direction of dam owners and operators in the proper method and procedures for maintaining earthen dams without detrimental vegetative growth. Dam owners and operators can utilize this ***Manual*** to establish proper operation and maintenance programs to promote the growth of desirable vegetative growth on earthen dams and/or remove and control the undesirable tree and woody vegetation growth on earthen dams.

The last verse in the famous poem **Trees** by Joyce Kilmer is as follows: **“Poems are made by fools like me / But only God can make a tree.”** Again, the author will paraphrase this last verse, not to debase the great works of Joyce Kilmer, but to make a distinct point. **“Only God can make a tree / But not removing trees from dams / Is done by fools like me.”**

There is yet much research and study to be done relative to the growth of proper vegetative cover on earthen dams. However, there is no doubt that trees and woody vegetation have no place on the embankment slopes of an earthen dam. The authors of this ***Manual*** intend to continue technological development in the area of controlling tree and woody vegetation growth on earthen dams. The authors would appreciate documentation of unusual cases of tree and woody vegetation growth related to safety issues associated with earthen dams. Documentation of these issues can be communicated through ASDSO and/or directly to the authors of this ***Manual***.

Chapter 2
Problems with Tree and Woody Vegetation Growth

According to the 1998-99 National Inventory of Dams (NID) data, there are approximately 76,700 dams of significant size[1] and hazard category in the 50 states (USCOE, 1999). Most of these dams are regulated by the jurisdictional states, but many are not because of specific exemption clauses or different size or hazard restrictions. Because some states have lower size definitions for their dams than used for the NID count, the actual number of state-regulated dams is much higher (about 94,000). In Tennessee over 40 percent of the approximately 1000 inventoried dams ***not*** subject to regulation because of statutorily named county exclusions or agricultural use exemptions. Most of these unregulated dams and some of the regulated dams in Tennessee have troublesome trees and brush growing on their faces and crests. Some states estimate that as many as 95 percent of their regulated dams have trees. Figure 1 illustrates the general magnitude and range of the tree growth on regulated dams in 48 states where this information is reported (ASDSO, 2000). About half of the state-regulated dams are estimated to have excessive tree growth.

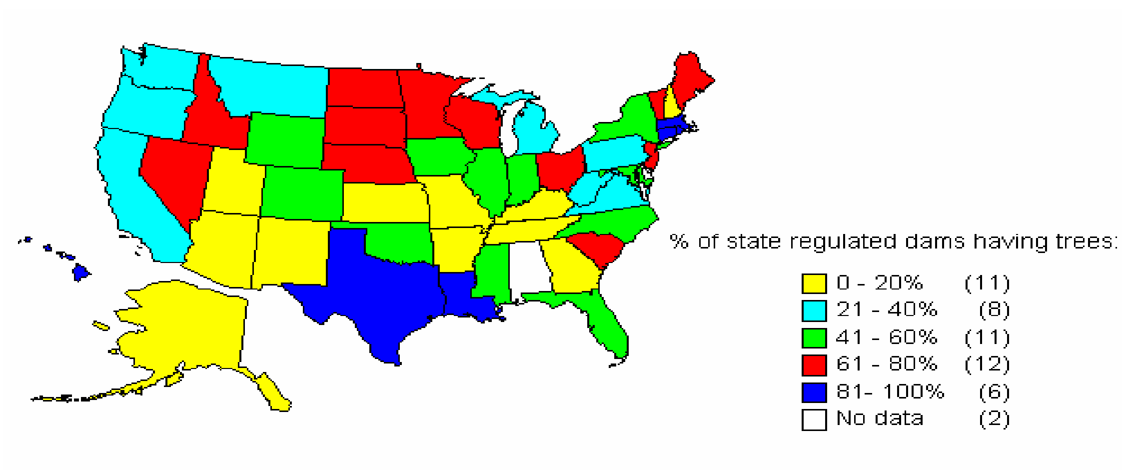

Figure 1. Estimated percentages of state-regulated dams having trees.

[1] Inclusion in the National Inventory has been defined under P.L. 99-662 and P.L. 92-367 to include dams that are at least 25 ft. high or 50 acre-feet of storage (excluding low hazard dams less than 6 ft. high or 15 acre feet of storage) and dams that due to location may pose a significant threat to human life or property in event of failure.

Most dam safety engineers, including state and federal officials, consultants, and other experts involved with dam safety, agree that when trees and woody plants are allowed to grow on earthen dams, they can hinder safety inspections, can interfere with safe operation, or can even cause dam failure. In the past, engineers and dam safety experts have not always been in agreement about the best way to prevent or control tree growth, remove trees, or repair safety-related damages caused by trees and woody vegetation. However, all dam engineers agree that a healthy, dense stand of low-growing grass on earthen dams is a desirable condition and should be encouraged.

From November 30 - December 2, 1999, a joint ASDSO/FEMA-sponsored workshop was held in Knoxville, Tennessee, for the purpose of inviting a panel of experts to discuss various problems, policies, and practices associated with plant and animal penetrations of earthen dams. Much of this manual follows up the work and recommendations produced by the workshop participants for engineers and owners to use in managing problems associated with both plant and animal intrusions. This chapter will discuss the consensus of current attitudes, issues, and policies involving woody vegetation penetrations of earthen dams, by state and federal officials, researchers, and practitioners active in dam safety.

Attitudes Toward Woody Plant Growth on Dams

The Association of State Dam Safety Officials (ASDSO) sent out survey questionnaires to dam safety officials in all 50 states and to federal representatives to the Interagency Committee on Dam Safety (ICODS) to determine state and federal agency attitudes about the effects of trees and woody plant growth on dams under their jurisdiction (ASDSO, 1999).

In this survey the state and federal agency representatives were asked (1) if they considered vegetative growth to be a problem on dams, (2) if they had specific policies or operating procedures for removing unwanted vegetation and trees on dams and if they didn’t, how did they handle such problems, (3) what legal, financial, environmental or other constraints did they have in dealing with unwanted vegetation problems, (4) to provide documented evidence and examples where vegetation has negatively affected the safe operation or has contributed to the failure of dams, (5) to provide references to current or past research regarding the effects of plants and trees on dam safety, and (6) to provide example cost and other information related to rehabilitation and remediation of dams having problem woody plant growth. This chapter summarizes the collective state and federal attitude, and practice toward woody plant growth on dams.

Problems Caused by Trees and Woody Plants

Of the 48 states that responded to the above seven questions (Alabama and Delaware did not reply), all state dam safety officials indicated that they consider trees and plant growth on dams to be a safety problem. One eastern state dam safety engineer goes so far to say that trees are probably the major problem that he has to deal with. He notes further that most of the trouble occurs because owners (and some engineers) do not recognize trees as problems and become complacent as trees slowly grow into serious problems. Both state and federal officials agree that trees have no place on dams. Federal agencies like the Corps of Engineers, U. S. Bureau of Reclamation, and TVA, which own, operate and maintain their own dams, do not allow trees to grow on their structures. Figure 2 shows a problem dam in Nebraska where tree roots have been reported to penetrate the chimney drain and thus affect the operation of the dam.

Figure 2. Example dam with problematic trees in Nebraska.

Figure 3. Example dam with inspection-hindering trees in Tennessee.

The problem most commonly noted by state officials is that trees, woody vegetation, briars, and vines interfere with effective safety inspections. Figure 3 illustrates this problem for a dam located in Tennessee.

Figure 4 gives a breakdown of the percentage ranges of regulated dams where the 48 reporting state dam safety officials shown in Figure 1 estimate that trees and brush hinder safety inspections in their respective states (ASDSO, 1999). While half the states report having only 20 percent or fewer dams with significant trees and woody vegetation that hinder inspections, vegetation on an estimated 30,000 or nearly a third of the collective state-regulated dams, is reported to obstruct effective dam safety inspections.

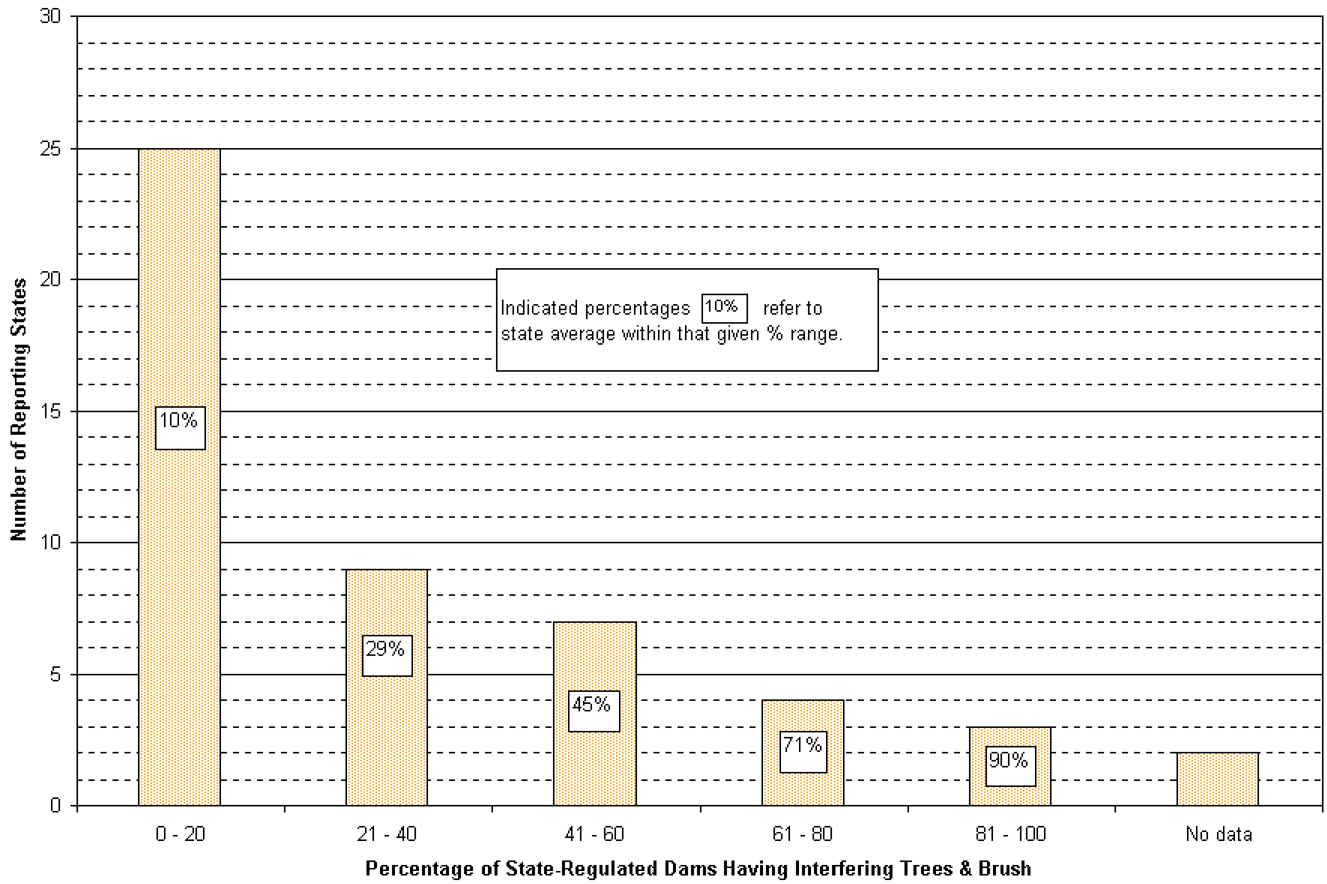

Figure 4. Estimated percentages of state-regulated dams where trees and brush are considered a deterrent to effective safety inspections.

Other dam safety problems caused by woody vegetation growth are:

- Uprooted trees that produce large voids and reduced freeboard; and/or reduced x-section for maintaining stability as shown in Figure 5.
- Decaying roots that create seepage paths and internal erosion problems.
- Interfering with effective dam safety monitoring, inspection and maintenance for seepage, cracking, sinkholes, slumping, settlement, deflection, and other signs of stress

Figure 5. Serious damage by uprooted tree to embankment stability at a dam in Oregon.

- Hindering desirable vegetative cover and causing embankment erosion
- Obstructing emergency spillway capacity
- Falling trees causing possible damage to spillways and outlet facilities
- Clogging embankment underdrain systems
- Cracking, uplifting or displacing concrete structures and other facilities
- Inducing local turbulence and scouring around trees in emergency spillways and during overtopping as shown in Figure 6.

Figure 6. Tree root induced scouring on crest and downstream face of Coffey dam in Kansas.

- Providing cover for burrowing animals
- Loosening compacted soil
- Allowing roots to wedge into open joints and cracks in foundation rock along abutment groins and toe of embankment, thus increasing piping and leakage potential.
- Root penetration of conduit joints and joints in concrete structures

Current Policies and Procedures

Twenty-four of the 48 responding states noted that they had formal policies and/or operating procedures for addressing tree and woody plant growth issues. These policies usually include one, or some combination, of the following:

- Trees are not allowed to grow on dams or near toe and abutment
- All trees and stumps must be removed, but roots may be left
- All trees, stumps, and roots must be removed
- All trees must be removed, but root systems of "small" trees may be left; root systems of "large" trees must be removed
- Dams are treated on a case-by-case basis -- usually under the direction of a qualified professional engineer.

For those states that choose to distinguish between "small" and "large" trees, the definition basis ranges from two to eight inches in diameter; most use a size of four or six inches in carrying out their policies.

Of the remaining 24 states indicating that they have no formal policies or procedures, the range of recommended procedures to dam owners varies widely. Some states evaluate dams on a case-by-case basis, while other states require owners either to maintain their dams, to remove vegetation for inspection, or to use other means for dealing with plant problems such as requiring a qualified engineer to be retained, depending on the dam hazard classification.

In summary, states follow several schools of thought and considerations in dealing with trees and vegetation on existing and new dams:

Existing Dams:

- Distinguish between "small" trees and "large" trees
- Remove all trees, stumps, and roots from dam embankment
- Cut trees to ground level, but leave stumps and roots
- Cut trees, remove stumps, but leave roots
- Consider case-by-case basis
- Breach, remove, or decommission dam
- Require retention of a qualified engineer by owner
- Do nothing.

Chapter 4: Dam Remediation Design Considerations presents recommended procedures for removal of trees and dealing with tree and woody vegetation related problems.

Figure 6. Trees cut prior to removing stumps and roots from dam.

Figure 7. Completed remediation job after removing stumps, seeding, fertilizing & mulching.

Figures 6 and 7 illustrate extensive efforts necessary to restore a heavily wooded earthen dam to a desirable vegetated and maintained condition.

New Dams:

- Establish effective ground cover and hope for the best in continual maintenance
- Use vegetative barriers such as bio-barriers, or use silvicides/herbicides/chemical treatment.

Constraints to Removing Trees and Plants

Several state and federal dam safety officials reported constraints to removing and/or controlling unwanted trees and other vegetation. Constraint categories explicitly cited by state dam safety officials (number of states in parentheses) are given below:

- Financial limitations by owners (13 states)
- Environmental regulations and/or permits (10 states)
- Legal issues (6 states)
- Aesthetics (5 states)
- Threatened/endangered species issues (2 states)
- Media (1 state)
- Sentimental reasons (several).

States indicated that the greatest constraint to removing unwanted trees and plants and repairing a structure infested with roots is limited financial capability by the owner. States such as Kentucky try to work with the owner to minimize the financial burden without threatening public safety. Ohio has recently established two low-cost loan programs to assist qualified public and private dam owners in funding safety-related improvements to their dams, including repairs mandated by the state dam safety program.

Environmental constraints range from limitation of the use of certain herbicides or chemicals for controlling vegetation and for treating stumps and/or roots near water bodies; to prohibition of, or air quality concern for, burning cleared vegetation. Unless exempted, vegetation removal and maintenance around dams may conflict with wetland protection regulations. In Washington, environmental issues can pose a major hurdle to removing trees, but ultimately, public safety takes precedence over environmental concerns. In Arizona, problems with time-consuming environmental permit requirements for larger plant removal projects are sometimes encountered.

Some states have limited legal power to force owners to remove trees and vegetation from dams. This lack of authority may cause delays and expensive and time-consuming litigation to obtain an order. Other states, like Maine, do not have specific laws that force owners to remove vegetation from their dams, and removal orders have yet to be tested. One state, South Carolina, notes that if the owner will not voluntarily cut or remove unwanted vegetation, the only course is to start legal action against the owner. Because legal help is limited, such help is normally requested for the "most extreme cases." This means that only a few owners can be forced to do something about their vegetation. In New Hampshire, legal assistance is sometimes necessary to perform enforcement functions. In Oregon, if there is a problem with a recalcitrant owner, a Proposed Order can be initiated by the Oregon Dam Safety Program to correct the situation if it is determined to be an immediate threat to the integrity of the structure. However, this process can be rather lengthy and expensive when staff time, materials, and attorney fees are included in the costs of preparing for a contested case hearing. In the end, most dam owners have the right to contest state directives to remove trees and other plants through administrative and legal processes and judicial appeals.

In some states, concerns have arisen when dams are located in parks or environmentally sensitive areas, especially when endangered or threatened species habitat is involved, in turn creating legal constraints.

Aesthetics and sentimental reasons are often used by dam owners and their neighbors to resist removing trees and undesirable vegetation. This is particularly true if owners have intentionally planted ornamental trees and shrubs on their dams to provide shade or fruit, or to improve looks. Some owners believe that the more woody vegetation on a structure, the better -- thus making it very difficult for state dam safety officials to request its removal.

The power of the press has had major influence on tree removal programs in some cases, especially where the target dam is owned by a poor or downtrodden citizen or insolvent municipality. Heated controversy between public safety interests and private owners or interest groups was generated through various newspaper stories and letters to the editor in 1990 over the removal of 500 mature cottonwood trees on two dams owned by an 85-year-old widowed rancher who at the time was suffering from serious illness. The news stories, which cast the owner as being targeted because she was vulnerable, influenced the owner's neighbors to encourage her to take a stand against further removal of 500 remaining trees because they felt that enforcement of the state dam safety act "would cause more harm than good."

While these constraints affect the ability of many states to enforce their regulations, some states such as Arkansas, Georgia, Colorado, Iowa, Maryland, Montana, New Jersey, North Carolina, and Tennessee report no major constraints to enforcement and consider the safety of dams to be of primary importance.

Federal agencies appear to have fewer constraints than states relative to mandating the upkeep and maintenance of jurisdictional dams. However, some federal agencies noted that they must make sure that they comply with the National Environmental Policy Act and the Endangered Species Act prior to initiating tree and plant control and management. Isolated constraints at the National Park Service involving funding priorities, historic preservation, and disruption of visitor services may override safe operation and maintenance needs at some dams. Local watershed districts that are often poorly funded are responsible for the operation and maintenance of many of the USDA/NRCS flood control dam projects.

Vegetation-Caused Problems and Failures

Twenty-nine states indicated documented evidence where vegetation on dams has either caused dam failure or negatively affected their safe operation. Sixteen states had no documented evidence and five states had no response. Several states provided photos (Figure 8) and information on tree caused failures or dam

Figure 8. Exposed tree roots in overtopped dam.

safety problems. The most recent documented dam failure due to tree root penetration occurred in May 1999 at an unnamed Air Force Academy dam near Colorado Springs. Here, an approximately 13-ft. high dam with a pond capacity of less than 5 acre-feet of horse stable waste water failed, releasing its contents and injuring a horse in a stable located about 100 yards downstream. The failure occurred after more than 7 inches of rain had fallen in the previous 72 hours. The dam had several pine trees on its crest and faces, and the breach opening exposed an extensive, deep root system. Roots up to 4 inches in diameter were found in the breach area. Figure 9 shows an example of a large root exposed in the bottom of the channel at the breach. The dam had not overtopped, and the failure was attributed to internal erosion of the decomposed granite embankment material along the roots. A tree had been located directly over the breach.

Figure 9. Large pine tree root located in the channel of the breach opening of a failed Air Force Academy waste lagoon pond dam (David Eyre, Senior Civil Engineer, Air Force Academy, Colorado, 1999).

At the Federal level, USDA/NRCS referred to documented cases where dam failure has been determined to be caused solely by trees, and noted that trees have also masked other more serious seepage problems, which went undetected.

Past and Current Research

Other than a few references to the University of Tennessee Tree Growth Report (Tschantz, 1988), only one or two other citations for tree or woody plant-related research were identified by the state dam safety officials (USDA/SCS, 1981). The surveyed Federal agencies had relatively little to offer in the way of references to current or past research regarding the effects of tree and plant growth on dam safety. The Corps of Engineers referred to geotechnical and other related program research conducted at the Waterways Experiment Station, published as a technical report series, Repair- Evaluation-Maintenance-Rehabilitation (REMR). One recent study for the St. Paul District showed that a hole formed by a blown-down tree in the downstream toe area can produce a potentially dangerous increase in hydraulic seepage gradient and internal erosion or piping problems in dikes (Duncan, 1999). The USDA/NRCS referred to the 1950's research work done at the ARS Hydraulics Laboratory in Stillwater, Oklahoma, on Flow in Vegetative Channels, which could have application to some emergency spillways.

A recent literature review, sponsored by ASDSO/FEMA and conducted for the Steering Committee on Plant and Animal Penetration of Earthen Dams, researched available material on the effects of woody plants on dam safety (Tschantz et al, 1999). All types of sources and searches were inventoried, including ASDSO conference and workshop proceedings, ASCE technical journals and articles, USCOLD, direct e-mail and telephone contacts of selected federal and state agency officials, universities, research laboratories and other data bases accessible through the National Technical Information Service (NTIS) and National Performance of Dams Program (NPDP). While only a few references were found on recent or current research of tree and plant effects on dam safety, several references on federal and state practices, policies, and procedures for dealing with trees and vegetation were cited in such topical areas as:

- woody plant physiology
- documented examples of woody plant-caused dam failures, operation, and maintenance problems
- case histories related to tree-caused dam failures
- current and past federal, international, and other research activities
- federal, state, international, and other organizations' policies, procedures and practices for preventing and remediating woody plant problems, and
- federal, state or private cost documentation for removing or controlling trees and woody plants.

Costs of Removing Trees and Tree Related Remediation

Limited cost information for removing trees and brush or for repairing damages caused by vegetation at dams was available from the states or federal agencies. Most state dam safety officials indicated either that they did not have the data or that the owner or his consultant would have that information. Virginia reported that, while costs can be nominal, in extensive tree growth situations where grubbing is required, $10,000 to $20,000 per dam is common and that at one dam; the tree-clearing cost was about $40,000. Missouri reported that such costs could range from $1,000 to $10,000 depending on how badly the dam is overgrown with trees. A prominent North Carolina geotechnical engineering firm stated that ten different contractors, working in North Carolina, South Carolina, and Georgia, reported recent bid prices ranging from about $1500 to $3000 per acre for cutting trees at ground level, removing stumps and root balls, and grubbing the area to remove perimeter roots. Contractors were advised that clearing and grubbing would be done on embankment slopes ranging from 1.5:1 (Horizontal to Vertical) to 4:1 (Horizontal to Vertical), within possible wet areas in the lower 1/3 to 1/2 of the downstream slopes, and on earthen dams ranging in height from 25 to 50 feet. Table 1 compares cost experiences reported by state dam safety officials in different regions of the country for clearing and grubbing trees from dams.

Reporting State	Number of Dams	*Cost per acre	Survey Comments
Georgia	More than 25	$1,000 to $5,000	Based on consultants' feedback; cost varies depending on dam face conditions such as slope steepness, degree of wetness and tree density.
Oklahoma	1 1	$900 $1,150	2 acres of d/s slope over 2-1/2 day period 3-1/2 acres, current proposal estimate.
South Dakota	Several	$100 to $200/Acre	Usually 10 - 20 trees per dam
Nevada	1	$532	Based on 3 hourly laborers working for 2 weeks on 3.25 acres of willow & mesquite removal on d/s dam face (~1995)
Michigan	General DNR construction cost experience	$3,500 $6,000 $12,000	Light clear/grub (diam.<6") Medium clear/grub (diam.<12") Heavy clear/grub (diam<24")
Tennessee	7	$1,540 (Ave.) (approx. range = $1030 to $3290)	Total clearing, grubbing & reseeding cost for 7 dams = $16,705 @ ~1.5 acres per dam. Jobs included range of tree sizes & heavy brush. (1995-98)
Texas	1	$5,500	Part of overall site clearing and grubbing contract for new dam in East Texas (1995)
Ohio	1	$10,000	Cost included clearing, grubbing, mulching and seeding. Heavily wooded; hundreds of trees removed from d/s slope (1999)
Minnesota	Current estimates from Minnesota consultant Small Projects	$1350 $2800 $4475 $4225 $6775 $960	Clearing brush with brush saw - no grubbing Clearing brush by hand - no grubbing Clear and grub brush, incl. stumps Cut & chip up to 6" trees; grub/remove stumps Cut & chip up to 12" trees; grub/remove stumps 16 m-hrs @ $60/hr to clear and grub small trees (diam. < 6") for less than one acre projects

*Reported costs not indexed

Table 1. Cost Comparisons for Clearing, Grubbing and Removing Trees from Dams.

While the range of remedial costs varies widely, depending on several factors, it appears that about $1,000 - $5,000/acre may be a reasonable baseline to use for rough estimating purposes, with the lower figure applicable to small and low-density tree growth and the larger figure appropriate to mature, very dense tree stands.

A typical 25-foot high by 750-foot long earthen dam having 3:1 (Horizontal to Vertical) embankment slopes, a 15-foot crest width, and a freeboard of 10 feet above normal pool has approximately two acres of exposed crest and face area for potential tree growth. Total costs for clearing and grubbing trees for such a dam would be in the range of $2000 to $10,000 depending upon the local site conditions.

Several site-specific factors can influence tree removal costs. These include size and type of trees, growth density, total job size (number of acres), location of growth (crest and/or both faces), embankment slope steepness, slope condition (such as degree of wetness or surface texture), degree and type of required surface treatment (backfilling, use of herbicides or bio-barriers, mulching, seeding, fertilizing, etc.), and regional labor and construction indices.

The U. S. Bureau of Reclamation reported detailed cost data using three herbicidal application methods (aerial, cut-stump, and ground-based foliar-application) in its 1987-93 program to control salt cedar along waterways in seven states of the Upper Colorado Region. Application costs ranged from about $60/acre for aerial spraying to about $1000/acre for cut-stump and spray methods (Sisneros, 1994). The National Park Service indicated that it has done tree removal with the assistance of the U. S. Bureau of Reclamation, but cost information is not readily available.

Summary

Trees appear to be a major dam safety issue for many states. Based on recent survey responses from 48 states, it is estimated that about one half of the state-regulated dams have trees growing on them. The same reporting states estimate that an average of nearly a third of the dams that they regulate have sufficient trees, brush and other growth to hinder effective safety inspections.

Current state and federal policies, procedures, and practices relating to tree and woody plant removal, control, and management for dam safety are generally fragmented and inconsistent among state and federal dam safety agencies**.** ***However, all state and federal agency dam safety officials and experts agree that trees have no place on dams and need to be managed and controlled on both existing and new dams for at least three important reasons:*** (1) trees and dense vegetation hinder effective dam inspections; (2) tree roots can cause serious structural instability or hydraulic problems, which could lead to dam failure and possible loss of life; and (3) trees and brush attract burrowing animals, which can in turn cause serious structural or hydraulic problems.

The fragmentation among state and federal agencies applies only to procedures about ***how*** and ***to what extent*** the trees and their roots should be removed and resulting cavities remediated to ensure a hydraulically and structurally safe dam. Other chapters in this ***Manual*** present methods and practices for controlling trees and woody plants and for remediating damage caused by trees and other woody plants.

While limited information is available, a sampling of state dam safety officials and other experts report that the cost of removing trees and brush from the face of a dam can broadly range from about $1,000 to $10,000 per acre, depending on several factors. Typically, the cost of clearing and grubbing trees from dams falls into the $1,000 - $5,000 per acre range. The broad range of costs is not surprising as most dam safety engineers agree that tree removal costs are very much site specific. Controlling vegetation annually is relatively inexpensive, but removing trees on and repairing damage to neglected dams may cost owners several thousand dollars.

Most dam safety experts agree that research needs to be done on determining the relationship of plant and tree species to root penetration of artificial environments such as embankment dams; the interaction between root systems and the phreatic zone and surface; and development and understanding of various types of physical, biological, and chemical treatment and barriers for controlling root growth. Because many existing dams exhibit dense growths of trees and woody vegetation with deep-penetrating root systems, engineering methods need to be developed for understanding, predicting, and stabilizing the effects of these root penetrations to minimize internal erosion and failure. Dam safety experts agree that both technical and non-technical pamphlets and brochures, practice manuals, web-based documents, workshops, and guidance materials need to be developed for educating dam owners about the problems caused by trees and woody vegetation. Engineers, dam safety officials and inspectors, developers, and contractors must be provided technical training and information relative to the control and/or safe removal of trees and other undesirable woody vegetation from earthen dams.

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Chapter 3
Tree Growth and Tree Root Development Requirements

The purpose of this chapter is to provide the reader and user of this ***Manual*** with a basic understanding of plant physiology related to fundamental processes of tree growth and tree root development. It is not the intent of this chapter to delve into a detailed biological study of trees and woody vegetation, but to provide the reader with a fundamental understanding of the requirements for tree growth and tree root development while attempting to dispel some of the misconceptions and myths associated with tree and woody vegetation growth, particularly as related to tree root development.

Common Myths and Misconceptions

There are many misconceptions and common myths relating to trees and woody vegetation that have been accepted by many people without a scientific basis. Many of these common myths and misconceptions relative to plant physiology have originated from uneducated interpretations of observations associated with tree growth and tree root development. Some of these myths and misconceptions associated with trees and woody vegetation affect correct interpretation and understanding of the impact of such growth on the safety of earthen dams. The more common myths and misconceptions must be dispelled so that a new level of understanding about the impacts of trees and woody vegetation on earthen dams can be properly developed. Trees and woody vegetation, like all living things, must have oxygen, nutrients, and water (moisture) to survive. Without these requirements, tree roots cannot continue development and tree growth cannot continue. The root system of trees and woody vegetation is in simplified terms comprised of two major components that are the root ball, typically directly below the trunk of the tree, and the lateral or perimeter transport root system that typically extends beyond the 'drip line' or vertical projection of the canopy of the tree.

Tree Tap Roots are thought by many to be the primary root system for all ages and types of trees and woody vegetation. In fact, the taproot is the first root to develop from the seed or reproductive source. This central root is an extension of the stem and differs from the stem only in that the root contains nodes for development of additional roots. Once the taproot has stabilized the young plant (tree), the root ball begins to develop and the taproot becomes less important than other roots that grow laterally from the taproot. The developing root ball provides vertical support for the tree as well as providing nutrients and water (moisture) to the tree. Roots extending laterally from the root ball increase the stability of the tree while functioning to collect and store nutrients, oxygen, and water for the tree. While it is true that some trees have more clearly defined taproots, taproots of most trees do not extend significantly far below the massive root ball of healthy trees. However, taproots are more predominant in locations where trees grow in deep deposits of loose dry soils.

Tree Root Soil Stabilization is likely the most common misconception associated with tree growth and tree root development. How many times has the reader heard, or perhaps mistakenly said, **"If it were not for those trees and tree roots this slope would really be eroded or unstable – those tree roots are really 'holding' that soil slope"**. Many otherwise knowledgeable and educated individuals believe the myth that tree roots actually stabilize soil masses by 'holding' the soil together. This misconception leads many people to believe that heavy tree and woody vegetation growth is actually beneficial for steep embankment slopes. Tree root development that is necessary to provide nutrients for tree growth and stabilize the tree actually loosens the soil mass. Laterally extending tree roots could be thought of as being nature's original application of the geotechnical engineering design concept of soil nailing. ***Root penetration stabilizes the tree and loosens the soil mass within which the tree roots are developing; the converse is a myth and certainly not true.***

Groundwater Penetration by tree root systems is another common myth and misconception believed by many otherwise knowledgeable individuals. Although Cypress, Tulip Poplar, some Willow and Water Birch tree species appear to have root systems that are submerged, nutrient root systems of trees cannot survive beneath the water table or the phreatic surface (seepage line) in an earthen dam. Trees and woody vegetation depend upon their transport root systems to provide the major portion of the oxygen demand for continual tree growth and tree root development. Most species of trees and woody vegetation quickly die of suffocation once the lateral transport root system and root ball are inundated. This phenomenon can be visually observed in many areas of Arkansas, Mississippi, and Louisiana where large tracts of timber have been artificially flooded for duck hunting. If these flooded tracts of timber are not drained seasonally, the timber (trees) die as a result of suffocation. Similarly, beaver activity causes significant losses in the timber industry every year as a result of inundation of harvestable timber. Tree roots do not penetrate the water table or the zone of saturation where oxygen demands of the tree cannot be met. If the zone of saturation or water table is raised above the level of tree roots for an extended period, the tree will die as a result of suffocation. Tree root development and tree growth cannot occur when moisture contents in the soil mass are greater than about forty percent.

Soil Moisture Uptake of many species of trees far exceeds that which most individuals would estimate as a normal requirement of water for continual tree growth and tree root development. It is not uncommon for most species of healthy mature trees to absorb 200 to 300 gallons of water per day if this amount of water is available to the lateral transport root system. Reduced availability of soil moisture will curtail continual tree root development until such time that the soil mass is replenished with sufficient moisture to allow resumption of tree root development. Tree root development and tree growth cannot occur in soil masses having moisture contents less than about twelve percent for extended periods.

Woody Vegetation Control Versus Dam Performance is an issue that is clearly misunderstood by many dam owners, operators, inspectors, dam safety regulators, engineers, and consultants. Tree and woody vegetation root penetration is not a beneficial effect on the performance of earthen dams. As indicated previously, tree root penetration does not stabilize a soil mass, particularly an embankment slope. Quite the contrary, tree root penetration loosens the soil of an embankment slope and creates a condition more conducive to surface water penetration and slope failure. Earthen dams are not unlike other engineered structures in that they must be properly maintained in order to perform as perceived in the original design of the structure.

When does routine vegetation maintenance and control become a dam safety and/or dam performance issue? The author is of the opinion that vegetation maintenance and control on an earthen dam ends, and the need for an ***engineered*** earthen dam rehabilitation plan begins, when effects of an improper vegetation maintenance and control program create conditions that are ***detrimental to the structural integrity*** of the earthen dam. For example, an earthen dam that exhibits a dense growth of grasses and weeds that are waist high, but is free of significant woody vegetation growth, is an earthen dam that is in need of proper vegetation maintenance and control to allow proper inspection of the dam. However, waist-high grasses and weeds would not typically affect the structural integrity of the earthen dam. Conversely, an earthen dam that supports a dense growth of four to eight inch diameter trees that preclude proper access for inspection is a dam safety and performance issue. Dense growths of trees and woody vegetation not only present a hindrance to proper dam safety inspection, but also are detrimental to the structural integrity of the earthen dam. Proper removal of trees and woody vegetation from earthen dams is a dam safety and performance issue that must be conducted in accordance with properly designed dam remediation plans and specifications.

Tree Root Characteristics and Requirements

As previously indicated, root systems of trees and woody vegetation consist of two primary components that are the root ball and the lateral transport root system. While all tree and woody vegetation roots have a primary function of providing oxygen, nutrients, and water to the plant, they also provide stability for the plant. The root ball that is typically directly below the trunk of the tree provides vertical support while the lateral transport roots provide lateral support for the tree. Root systems of trees and woody vegetation growing on dam embankment slopes will typically be asymmetrical as a result of the need for the tree to be stabilized in the sloping embankment soil mass. The lateral transport roots will typically be better developed on the uphill side of the tree than on the downhill side of the tree. Dr. Kim D. Coder at the University of Georgia has conducted extensive studies and research on tree growth and tree root development requirements and characteristics. He has developed data from these studies and research programs that relate tree trunk size to root ball diameter and lateral transport root system diameter. These data are presented in Table 1 below.

Table 1: Typical Rootball and Root System Sizes for Various Tree Sizes

Tree Diameter, inches	Rootball Diameter, feet	Root System Diameter, feet
4 to 5	6	10 to 12
6 to 7	8	16 to 18
8 to 9	10	20 to22
10 to 11	12	26 to 28
12 to 14	14	30 to 32
15 to 18	16	38 to 46
19 to 23	18	48 to 58
24 to 36	20	60 to 90
37 to 45	22	92 to 112

During the presentation of common myths and misconceptions about tree growth and tree root development, requirements of trees and woody vegetation for continual growth and root development were discussed. Based upon research and studies conducted by Dr. Kim Coder, requirements for tree and woody vegetation growth and root development are tabulated in Table 2.

Table 2: Root Growth Resource Requirements

Requirement	Minimum Value	Maximum Value
Soil Oxygen Content	**2.5%**	**21.0%**
Soil Air Voids	**12.0%**	**N/A**
Soil Bulk Density (Clays)	**N/A**	**87 pcf**
Soil Bulk Density (Sands)	**N/A**	**112 pcf**
Water Content of Soil	**12.0%**	**40.0%**
Limiting Soil Temperatures	**40ºF**	**94ºF**
Soil pH Values	**3.5**	**8.2**

Soil air void content is one of the most critical factors for continual tree root development. This factor is critical since both soil density and soil oxygen content are dependent upon the amount of air voids present in a soil mass. Because of the importance of soil air void content, Dr. Coder conducted extensive research to determine limiting air void contents for various soil types required for continual tree root growth (See Table 3).

Table 3: Limiting Soil Air Voids for Root Growth in Various Soil Types/Textures

Soil Type/Texture	Air Voids, %
Sand	**24**
Fine Sand	**21**
Sandy Loam	**19**
Fine Sandy Loam	**15**
Loam	**14**
Silt Loam	**17**
Clay Loam	**11**
Clay	**13**

Utilizing weight-volume relationships for various soil types and textures, Dr. Coder was able to determine the limiting (maximum) dry density of soil that would allow continual tree root development. Results of these correlations between minimum soil air void content and maximum soil dry densities required for continual tree root development are presented in Table 4 below.

Table 4: Limiting Soil Dry Density for Root Growth in Various Soil Types/Textures

Soil Type/Texture	Dry Density, pcf
Sand	112.3
Fine Sand	109.2
Sandy Loam	106.1
Fine Sandy Loam	103.0
Loam	96.7
Silt Loam	90.5
Clay Loam	93.6
Clay	87.4

In an attempt to relate the research data developed by Dr. Coder to geotechnical engineering data developed from over 200 earthen dam projects, the author has compiled a comparative list of soil properties for various soils that have been found in earthen dam embankments. The ranges given in the data presented in Table 5 below are associated with soil in a loose condition and soil in a compacted state that might be required in the construction or remediation of an earthen dam. ***The user of this Manual must be aware that these soil parameters are typical values and should not be relied upon for design of new earthen dams or design of remediation plans for existing dams.***

Table 5: Summary of Typical Soil Parameters

Soil Type	Specific Gravity	Void Ratio	Porosity, %	Dry Density, pcf	Permeability, cm/sec
Sand	**2.62 to 2.66**	**0.40 to 0.90**	**30 to 45**	**90 to 115**	**0.01 to 0.0001**
Silt	**2.60 to 2.68**	**0.50 to 1.20**	**35 to 55**	**75 to 110**	**0.001 to 0.00001**
Clay	**2.66 to 2.72**	**0.60 to 1.40**	**40 to 60**	**70 to 105**	**0.0001 to 0.0000001**

As one can see from the tabulated summary of typical soil parameters, continual tree root development cannot occur in soils that are well compacted. One of the best methods of controlling tree and woody vegetation growth on new earthen dams and existing earthen dams where remediation requires placement of additional embankment fill soil is to compact the embankment fill soils to a high degree of compaction. Increased compaction of embankment fill soils reduces the air void content and limits the amount of surface water that can infiltrate into the embankment slope. However, a good ground cover of grasses can be established in well-compacted soils since the depth of grass root penetration is minimal and the surficial soils will typically sustain the shallow grass root penetration.

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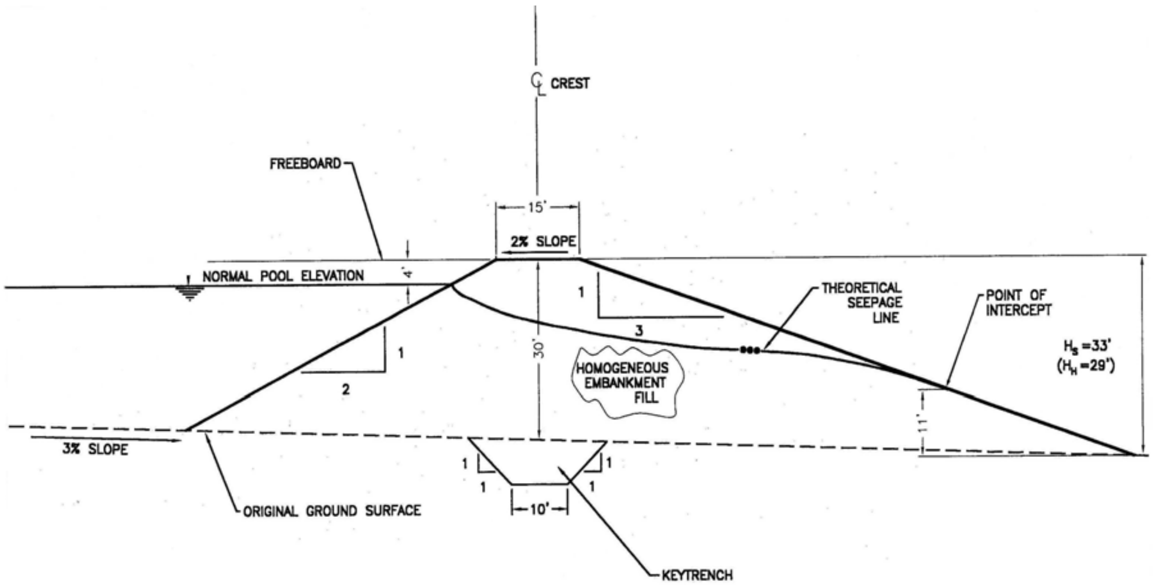
Chapter 4
Earthen Dam Safety Inspection and Evaluation Methodology

The purpose of this chapter is to illustrate dam behavior during the initial years of design life and to present a suggested inspection and evaluation methodology. An example earthen dam configuration will be presented in order to illustrate earthen dam behavior and to develop the suggested inspection methodology.

Example Earthen Dam Configuration

The example earthen dam is assumed to be a high-hazard dam having a structural height of about 33 feet and impounding a lake area of about three acres at normal pool elevation. The contributing watershed of the lake is about 320 acres (0.5 square mile) with a base flow of about one-half (0.5) cubic feet per second (cfs).

The configuration of the example earthen dam consists of an upstream slope of 2:1 (horizontal to vertical), a crest width of fifteen feet, and a 3:1 (horizontal to vertical) downstream slope. The dam has a freeboard of four feet making the hydraulic height of the dam about 29 feet. The dam is founded on relatively impervious (compared to the embankment fill soil) material with a down gradient slope of about three percent. The example earthen dam section has a key trench directly below the centerline of the dam crest that has a bottom width of ten feet and side slopes of 1:1 (horizontal to vertical). The dam crest has a two-percent slope toward the impounded lake and the upstream slope has no protection system against tree and woody vegetation growth or wave erosion. The embankment of the example earthen dam is assumed to be homogeneous. Figure 1 is a representation of the example earthen dam configuration with the theoretical seepage line intercepting the downstream slope at about one-third the hydraulic height of the dam. **Rule-of-Thumb:** ***The phreatic surface intercepts the downstream slope of a homogeneous earthen dam at a vertical distance of about one-third the hydraulic height above the toe of the downstream slope, provided there is no internal drainage system in the dam embankment.***



TYPICAL EMBANKMENT SECTION
WITHOUT TOE DRAIN SYSTEM

Figure 1

Based upon data provided for the example earthen dam, this dam would be listed on the National Inventory of Dams (NID). In addition, the example earthen dam would be classified as a small-size, high-hazard dam by most state dam safety regulations**.**

Figure 2 illustrates the example earthen dam with an embankment subdrain system located within the downstream embankment slope. The subdrain or embankment drain system is located at about the point of interception of the seepage line with the downstream slope if there was no embankment toe drain system within the downstream slope. As a result of the presence of the embankment subdrain system, the seepage line through the dam embankment has been modified (lowered) from the location of the theoretical seepage line for a homogeneous earthen dam embankment. The seepage line within an earthen dam is often mistakenly considered to have a permanent location.

However, the location of the seepage line is continually changing as a result of many influential factors. Fluctuations in the pool elevation, seasonal and long-term climatological conditions, and the growth of trees and woody vegetation in close proximity to the seepage line are some of the factors that influence changes in the location of the phreatic surface within an earthen dam embankment.

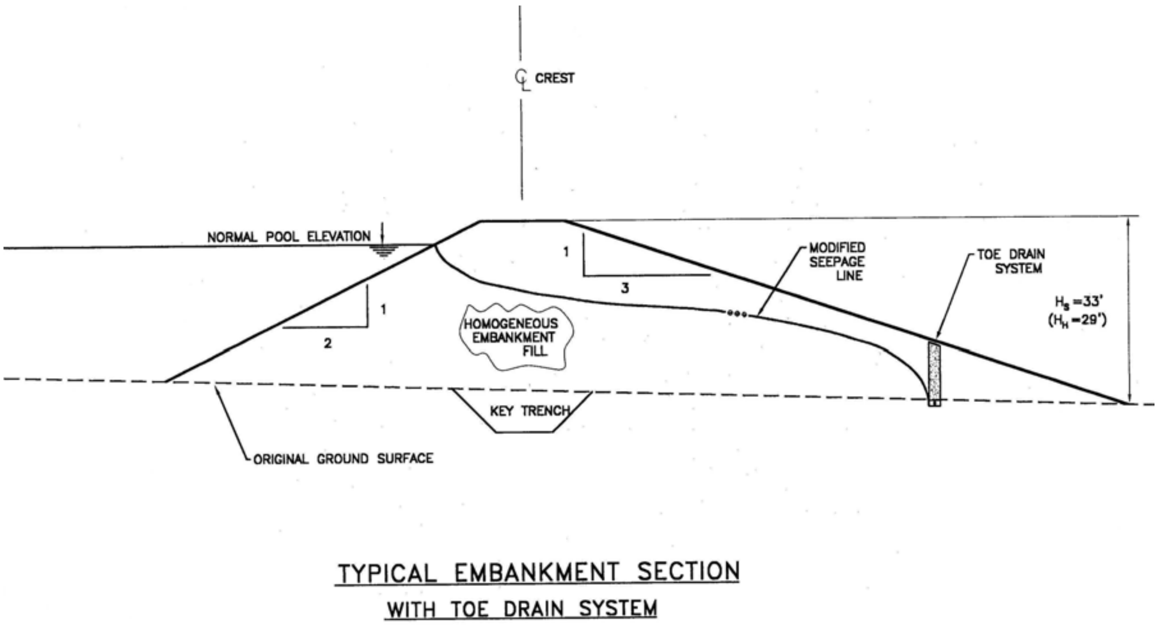


Figure 2

Important moisture regimes other than the steady-state seepage line (phreatic surface) are often not given proper consideration in the evaluation of the performance of earthen dams. The ***zone of saturation*** is located immediately above the phreatic surface or seepage line where embankment fill soils have become saturated as a result of capillary rise caused by capillary forces in the soil voids. Figure 3 illustrates the presence of zones of saturation associated with that of a theoretical seepage line location without an embankment subdrain system as well as that of a modified seepage line location with an embankment toe drain system. The height of capillary rise (thickness of the zone of saturation) is directly dependent upon the effective mean diameter of soil voids within the earthen dam embankment. The effective mean diameter of compacted soil is dependent upon the ***effective particle size*** (De) of the compacted embankment fill soil. Soil within the zone of saturation is completely saturated; however, there is no flow or gravity induced movement of water unless some external force disturbs the soil. This phenomenon is often observable during the inspection of downstream slopes of earthen

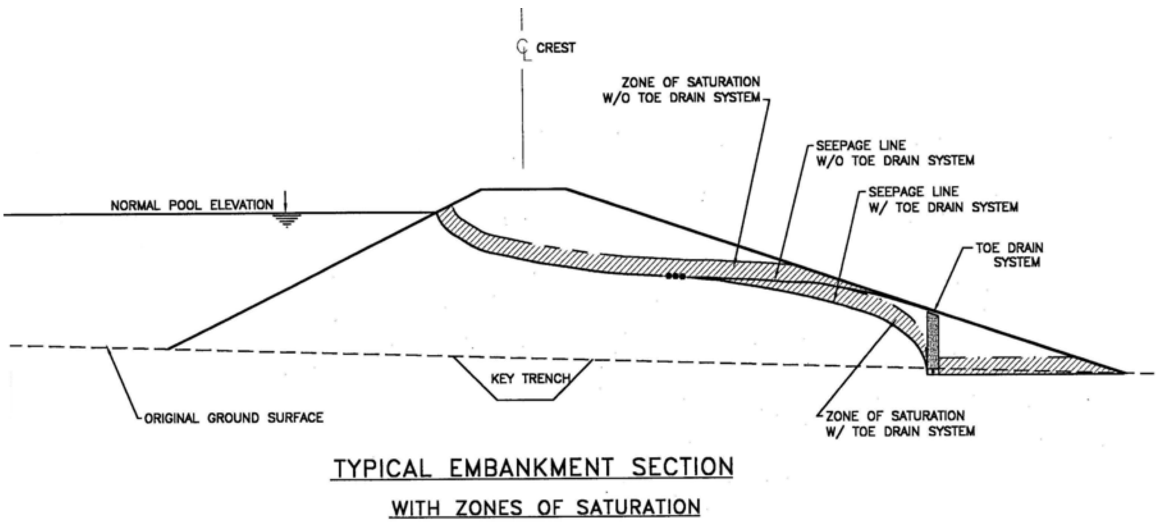


Figure 3

dams. Seepage and free flowing water can be seen on the downstream slope of an older dam below the point of interception of the seepage line if no embankment subdrain is present. Above the point of interception of the seepage line with the downstream slope, the soil is saturated and the Zone of Saturation can be observed for a significant distance above the seepage line intercept in some cases. In the Zone of Saturation, pore water may be observed to fill tracks made in the water-softened embankment soil. However, once the tracks are filled by pore water released from the disturbed soil there will be no continued flow or seepage from the embankment. This condition is often confused with the presence of embankment seepage. Installation of a subdrain location in this situation may lower the phreatic surface relatively quickly; however, months or even years may be required to drain the zone of saturation because of tensile forces or negative pore pressures in the embankment fill soils.

Embankment Wetting, Saturation, and Seepage

Prior to presentation of the behavior and performance of an earthen dam embankment during the initial years of the design life, one must have an understanding of relationships between various velocities of moisture movement and water flow through compacted embankment soils. First, consider the relationship between the optimum compaction moisture content of an embankment soil and other moisture content properties.

Rule-of-Thumb: ***The optimum compaction moisture content as determined by ASTM D-698 (standard Proctor compaction test) is approximately two to four percent below the Plastic Limit (PL) of most soils and about three to five percent below the saturation moisture content of the same soils.***

Compacted soils will typically increase in moisture content from the compaction moisture content to about the PL of the soil relatively quickly after construction of an earthen embankment. The rate of wetting is much greater in soils compacted dry of optimum moisture content than in soils compacted wet of optimum moisture content. Although compacted soils may undergo wetting or increase in moisture content relatively quickly when exposed to a source of water, the rate of saturation is much slower because air trapped in discontinuous soil voids must be dissolved in soil pore water during the saturation process. Embankment wetting and saturation are not associated with seepage or the flow of water through a homogeneous earthen dam; however, relative velocities of wetting and saturation can be related to values of steady-state seepage velocity, permeability, or hydraulic conductivity of compacted embankment soils.

Figure 4 is an illustration of the example earthen dam with relationships between various soil water flow velocities and permeabilities. First, consider the relationship between the vertical and horizontal permeability of a compacted homogeneous embankment soil.

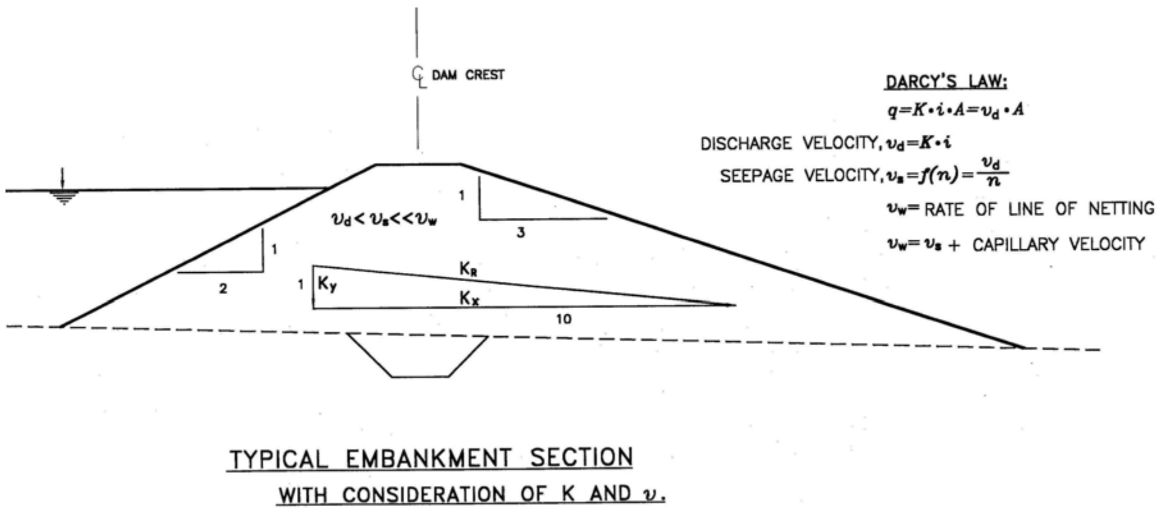


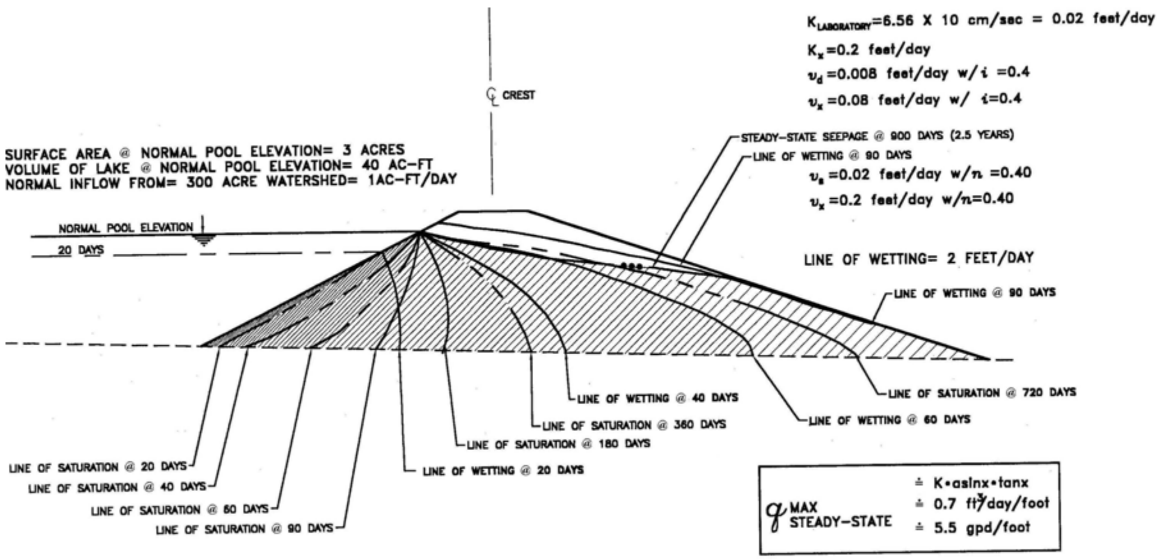
Figure 4

Rule-of-Thumb: ***The horizontal permeability of a compacted homogeneous embankment soils are typically about nine times to ten times (one order of magnitude) greater than the vertical permeability.***

Variation between the horizontal permeability and vertical permeability is the result of the internal structure of compacted soils. This variation does not account for poorly compacted lifts since the embankment is assumed to be homogeneous. Consequently, if laboratory permeability tests indicate that a compacted embankment soil exhibits a hydraulic conductivity value of about 0.000004 centimeters per second (cm/sec) then the horizontal permeability of this compacted embankment soil will be about 0.000036 to 0.00004 cm/sec. Second, consider Darcy's Law that is the basis for all theories and analyses associated with the flow of water through soil masses. Darcy did not account for soil voids relative to soil solids in derivation of his equation. As a result, the area of discharge is the total cross-sectional area through which flow is occurring. If one assumes that the hydraulic gradient producing flow through a soil mass is equal to one (unity), then the ***discharge velocity*** (Darcy's flow velocity) is equal to the permeability value of the soil. The actual flow velocity in the voids of the soil is often identified as the ***seepage velocity*** and is approximately equal to the discharge velocity divided by the porosity value (expressed as a decimal) of the soil. Assuming that the compacted embankment soil in the example earthen dam has a porosity of forty (40) percent (0.40), the seepage velocity of the soil would be about 2.5 times greater than the discharge velocity. Third, consider the wetting velocity or the velocity of the ***line of wetting***. The wetting velocity is the rate at which soil increases in moisture content up to about the PL when exposed to a free water source. The line of wetting can often be observed as it progresses through soil masses, particularly soils that are dry of optimum moisture content. The wetting velocity is the sum of the seepage velocity and the capillary velocity or the velocity of wetting attributable to capillary forces in the soil.

Rule-of-Thumb: ***The wetting velocity or the velocity of the line of wetting through compacted soil is about one order of magnitude (ten times) greater than the seepage velocity.***

Applying this factor to the previous comparison between seepage velocity and discharge velocity, one finds that the wetting velocity is about 25 times greater than the discharge velocity. Based upon the foregoing discussion of earthen dam embankment wetting, saturation, and steady-state seepage velocities, consider the illustration in Figure 5. This figure illustrates embankment wetting, saturation, and steady-state seepage during the early years of the design life of an earthen dam. Assume that laboratory testing indicates that embankment soils of the example dam embankment have a permeability or hydraulic conductivity value of 0.02 foot per day. The discharge velocity would be about 0.008 foot per day with a hydraulic gradient of about 0.4 resulting in a horizontal discharge velocity of about 0.08 foot per day. The associated seepage velocity would be about 0.02 foot per day with a soil porosity of about 40 percent and the horizontal seepage velocity would be about 0.2 foot per day. The velocity of the line of wetting or the wetting velocity would be about 2.0 feet per day.



PROGRESSION OF EMBANKMENT WETTING & SATURATION
WITHOUT CONSIDERATION OF VEGETATION

Figure 5

Based upon the estimated normal inflow from the contributing watershed, the lake retained by the example dam should reach about fifty percent volume in approximately twenty days and reach normal pool elevation in about forty days. Solid lines in Figure 5 illustrate the location of the line of wetting at various time intervals. The line of wetting should reach the downstream slope in about ninety days. ***Note: The compacted embankment soils remain partially saturated after passage of the line of wetting.*** Dashed lines in Figure 5 illustrate the line of saturation at various time intervals. The line of saturation moves at the seepage velocity that is about one-tenth the value of the wetting velocity. When the line of wetting has reached the downstream slope in about ninety days, the line of saturation is still at about the vertical from the intercept of the normal pool with the upstream slope. Based upon this rate of progression, the line of saturation will not reach the surface of the downstream slope and steady-state seepage will not be initiated for about 900 days (about 2.5 years), ***provided that no external influences affect the rate of wetting and saturation***.

The estimated maximum steady-state seepage rate for the example dam will be about 5.5 gallons per day per foot of dam. Before leaving Figure 5, imagine that the example dam contains an embankment subdrain system as indicated in Figures 2 and 3. The rate of progression of the line of wetting and the line of saturation will both be affected by the presence of the subdrain system.

Even without the presence of an embankment subdrain system, the time required for the line of wetting could encompass an entire growing season depending upon the time of year that the dam was completed. More importantly, the time that is required for the line of saturation to intercept the downstream slope might encompass two or three entire growing seasons. Tree and woody vegetation growth can become quite dense and relatively large within the initial two to three growing seasons if not properly controlled.

The initiation of tree and woody vegetation growth on the downstream slope begins the soil moisture uptake cycle so that the line of saturation and the seepage line may never completely develop and intercept the downstream slope. The condition represented by Figure 6 might initially be considered to be beneficial to the stability of the dam embankment. However, one must understand that as the tree and woody vegetation growth continues compacted soils of the dam embankment are continually loosened by the penetration of major tree and woody vegetation root systems. Furthermore, trees that might appear healthy to an untrained inspector may be an unhealthy specimen and have a premature death leaving penetrating root systems to rot inside the dam embankment. Additionally, soil nutrients in the compacted soil embankment of an earthen dam may not be sufficient for development of growth beyond which the tree cannot be properly sustained without premature death. Regardless of the cause, trees and woody vegetation do die and cease to uptake soil moisture that they previously used. This change in soil moisture uptake will affect the zone of aeration, zone of saturation, and the location of the seepage line in the vicinity of the unhealthy or dead trees and woody vegetation.

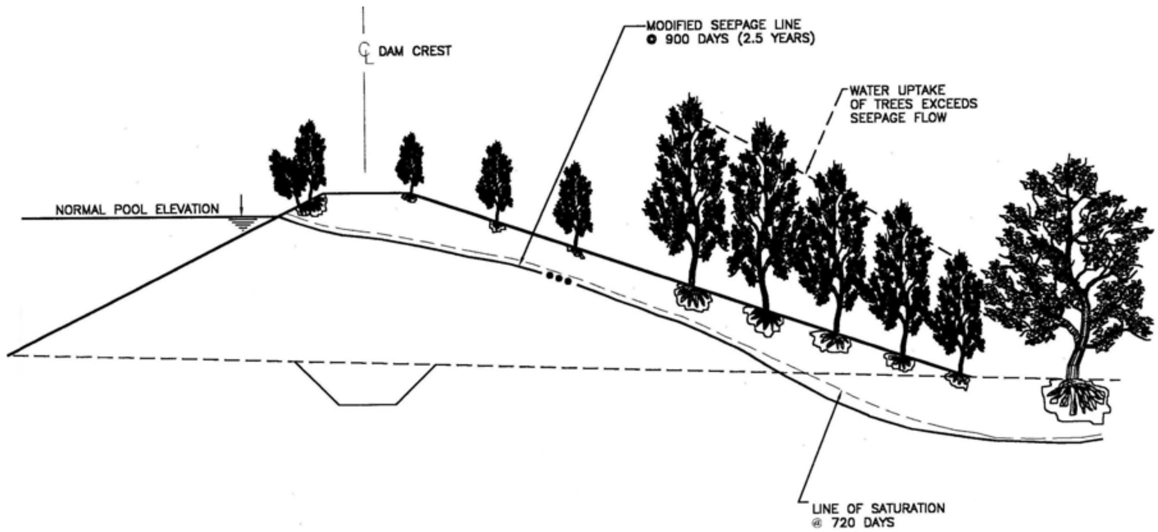


Figure 6

The Mid-Life Crisis of an Aging Earthen Dam

Once an earthen dam embankment has become impregnated with numerous trees and woody vegetation penetrations, routine and even major maintenance activities will likely not be sufficient to regain the original design life of the dam. At this time in the life of an earthen dam, previously identifiable maintenance problems have become serious dam performance and dam safety issues. Restoration through an ***engineered*** dam remediation design and remediation construction is typically required to bring the dam to acceptable standards relative to dam safety requirements.

Figure 7 illustrates some of the problems and dam safety issues that can be created by uncontrolled or non-maintained tree and woody vegetation growth in what has been termed by the author as the ***'Mid-Life Crisis'*** of an earthen dam. Seepage flow may be emerging from rootball cavities of blowdowns (uprooted trees) because they are no longer using soil moisture and the seepage line has adjusted upward toward the surface of

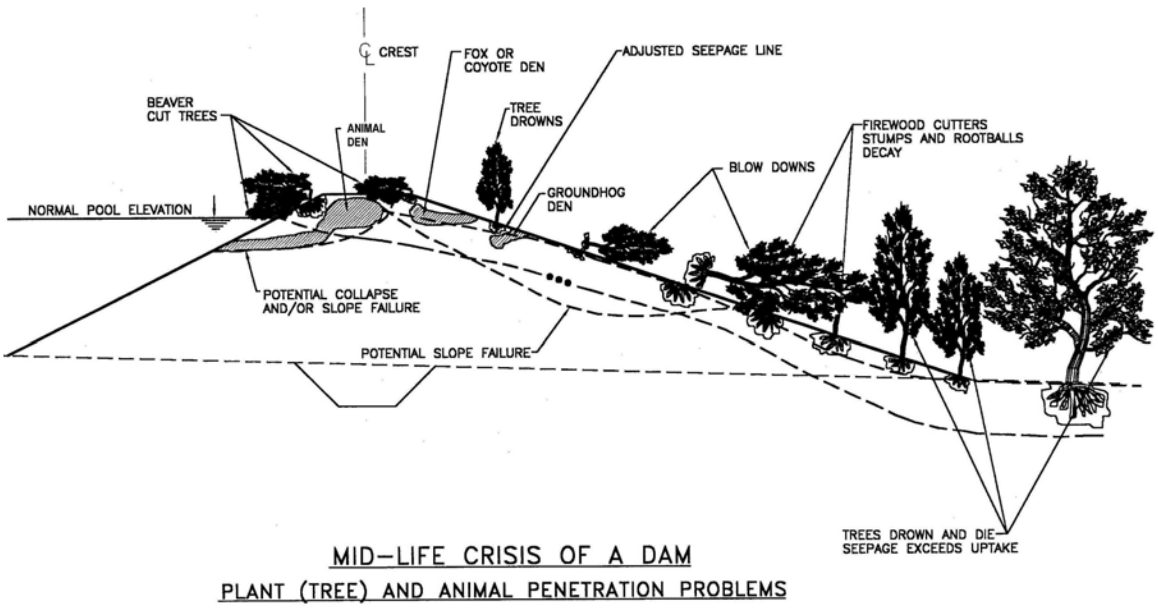


Figure 7

the slope. Removal of mature trees by woodcutters deletes the soil moisture uptake of the removed trees thus further modifying the location of the seepage line closer to the surface of the downstream slope. Rootballs and root systems of otherwise healthy trees located at and beyond the toe of the downstream embankment slope become inundated by the adjusted seepage line. Since trees cannot live through prolonged submergence of their major root systems, these trees will become unhealthy and die leaving decaying rootballs and root systems as serious penetrations in the earthen dam. Rootball cavities remaining from blowdowns (uprooted trees) and their relationship to the seepage line create conditions susceptible to potential slope failure of the downstream embankment slope. Restoration of the example earthen dam illustrated in Figure 7 to a safe condition cannot be brought about through routine maintenance activities. An ***engineered*** dam remediation design and remediation construction will be required to restore this dam to a safe condition and original design life.

Inspection and Evaluation Methodology

The effectiveness, economics, and constructability of dam remediation designs for earthen dams begin and end with proper evaluations of the characteristics and seriousness of deficiencies as related to dam safety issues. ***<u>All</u> tree and woody vegetation growth on earthen dams is undesirable and has some level of detrimental impact upon operation, performance, and safety of an earthen dam***. However, not all tree and woody vegetation growth on earthen dams imposes the same level of impact on operation, performance, and dam safety. Dam owners, regulators, inspectors, and engineers must develop an understanding of the impact of tree and woody vegetation growth relative to location on the dam configuration. Proper evaluation of the seriousness of dam safety issues related to tree and woody vegetation growth on earthen dams is typically associated with the location of the undesirable plant growth on the dam embankment.

A few examples of the variability of seriousness of plant penetrations are presented herein to begin the learning process. The presence of a twelve-inch diameter tree on the downstream side of the crest of an earthen dam typically does not pose the same degree of impact on potential dam safety as a twelve-inch diameter tree located in the lower portion of the downstream slope. Conversely, a twelve-inch diameter tree in the upper portion of the downstream slope does not typically create the same level of seriousness as an unhealthy twelve-inch diameter tree on the upstream slope or front crest of a dam having a narrow crest width. Ornamental shrubs having shallow root systems along a wide roadway crossing the crest of an earthen dam will not impose the same level of seriousness as similar shallow rooted woody vegetation growing on the lower portion of the downstream slope.

The purpose of developing a well-defined inspection and evaluation methodology is to allow the establishment of dam remediation design priorities. Most anyone having a basic understanding of the seriousness of tree and woody vegetation growth to the safety of earthen dams can inspect an earthen dam and recommend removal of all trees, stumps, and root systems. However, inspectors and dam engineers must develop a definitive inspection and evaluation methodology in order to prioritize the seriousness of various locations of tree and woody vegetation growth on earthen dams.

Many individual dam owners do not have economic resources to undertake extensive dam remediation projects to bring an earthen dam into safe operation and performance conditions if the dam exists in a severely deteriorated condition. These owners often have to budget dam remediation projects over a scheduled maintenance and remediation construction period. Dam safety regulators, inspectors, and engineers that have developed and utilized a well-defined dam safety inspection and evaluation methodology can communicate priorities to dam owners so that the needed dam remediation design components can be completed in a prioritized manner. All too often dam safety regulators and engineers overwhelm dam owners with dam deficiencies without consideration of prioritization of deficiencies on dam safety, performance, and operation.

Dam Safety Inspection and Evaluation Zones

Five dam safety inspection and evaluation zones have been identified within the geometric configuration of a typical earthen dam. The delineated zones, illustrated in Figure 8, are not numbered in any implied order of seriousness relative to the impact of tree and woody vegetation growth, but have simply been numbered from upstream to downstream. The seriousness and potential impacts of tree and woody vegetation growth within each inspection and evaluation zone will be discussed during the description and identification of the delineated dam safety inspection and evaluation zones.

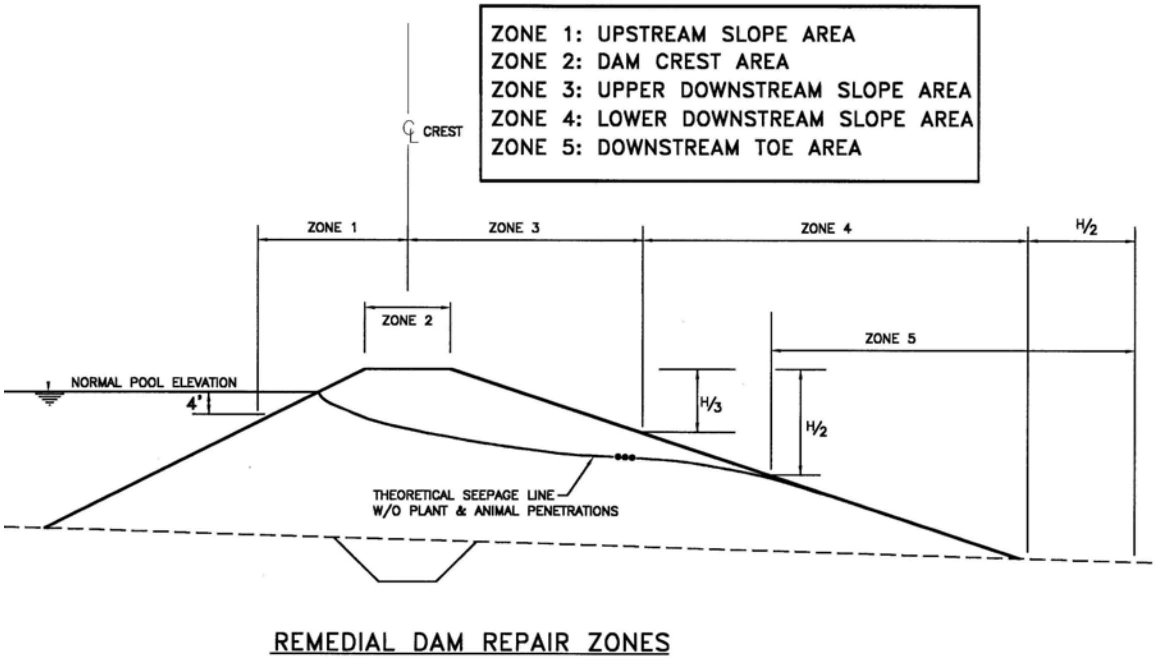


Figure 8

Inspection and Evaluation Zone 1 begins on the upstream slope of the earthen dam embankment at about four feet below normal pool elevation. Zone 1 extends laterally to the centerline of the crest of the dam. Tree and woody vegetation growth in Zone 1 is more critical relative to dam safety in the case of dams having a narrow crest width than those having a wide crest width. Zone 1 also includes the area subject to damage resulting from wave erosion and frequently recurring rapid drawdown events.

Inspection and Evaluation Zone 2 includes the entire width of the crest of the dam. Zone 2 overlaps Zone 1 by one-half the crest width. Overlapping a portion of Zone 1 with a portion of Zone 2 was done to emphasize the critical portions of both zones. Zone 2 is typically considered to be one of the least critical zones relative to dam safety issues associated with tree and woody vegetation growth. However, careful inspection of Zone 2 often reveals evidence of serious dam safety issues such as tension cracks, slope failure scarps, and erosion features that may or may not be related to tree and woody vegetation growth originating in other dam safety inspection and evaluation zones.

Inspection and Evaluation Zone 3 extends from the centerline of the crest of the dam to a point on the downstream embankment slope that is about one-third of the structural height below the crest of the dam. Zone 3 overlaps Zone 2 by one-half the crest width and is typically considered the least critical zone relative to dam safety issues associated with tree and woody vegetation growth. The seepage line and zone of saturation in this portion of an earthen dam embankment are typically sufficiently far below the surface to allow excavation of tree rootballs on the downstream slope of the dam without installation of a drain or filter system. A portion of Zone 2 has been overlapped by Zone 3 to draw attention to the most critical portion of Zone 3 that is the downstream portion of the crest of an earthen dam.

Inspection and Evaluation Zone 4 extends from a point on the downstream embankment slope that is about one-third the structural height of the embankment to the toe of the downstream embankment slope. Zone 4 is one of the two most critical zones relative to dam safety issues associated with tree and woody vegetation growth as well as other potential dam safety issues. This zone typically contains the interceptions of both the zone of saturation and the seepage line with the downstream slope. The close proximity of the zone of saturation and seepage line to the surface of the downstream embankment slope in this zone is a critical factor relative to dam safety issues associated with tree and woody vegetation growth. ***Tree and woody vegetation growth in this Zone 4 must be of major concern to everyone associated with the safety of an earthen dam and must be evaluated carefully relative to prioritization of dam remediation requirements.***

Inspection and Evaluation Zone 5 extends from the mid-height of the downstream embankment slope to a distance of one-half the structural height beyond the toe of the downstream embankment slope. This zone typically contains the interception of the seepage line with the downstream embankment slope and potential boiling (soil piping) action beyond the toe of the downstream embankment slope. As such, this zone is critical relative to long-term, steady-state seepage stability considerations for an earthen dam. Tree and woody vegetation growth in this zone rapidly develops into serious conditions that directly affect the safety of an earthen dam. Zone 5 overlaps Zone 4 to draw attention to the more critical portions of both Zone 4 and Zone 5. As in the case of Zone 4, Zone 5 is typically considered to be one of the two most critical zones relative to dam safety issues associated with tree and woody vegetation growth. Tree and woody vegetation growth in Zone 5 must be a concern to all involved in the safety of an earthen dam. ***Maintenance and/or engineered dam remediation must be undertaken immediately in the event that tree and woody vegetation growth is significant within Zone 5.*** Control of tree and woody vegetation growth well beyond the toe of the downstream embankment slope cannot be over-emphasized. This area of an earthen dam is critical to overall stability and potential dam safety issues associated with embankment and foundation seepage.

The dam safety inspection and evaluation methodology set forth herein can be easily modified and/or extended to meet the needs of specific dam owners, dam safety regulators and inspectors, and engineers. This proposed methodology for dam safety inspections and evaluations should provide a basic plan that will allow the reader to customize and/or improve existing dam safety inspection and evaluation programs.

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Chapter 5
Controlling Trees and Woody Vegetation on Earthen Dams

The establishment and control of proper vegetation on an earthen dam are essential to maintaining a *safe* dam. Effective, shallow-rooted, vegetative cover is necessary to reduce and prevent embankment slope erosion. Trees and other undesirable deep-rooted vegetation should be prevented from being established for the following reasons:

- Permit effective inspection and monitoring of embankment crest and faces
- Allow for adequate access to dam for normal and emergency operation
- Prevent structural damage from embankment piping and internal erosion, unstable slopes from toppled trees, concrete wall/slab joint cracking/displacement, and other problems
- Reduce possibility of root-blocked drains
- Prevent blockage of spillway channel
- Discourage rodent and other animal activity by eliminating food source and habitat
- Eliminate expensive tree and brush removal and remediation costs
- Reduce impression of owner neglect

Consequently, dam owners should observe these four important rules:

1. Existing trees should be removed and not be allowed to mature on earthen dams, abutment groins, or around water conveyance structures
2. Trees or shrubbery should never be planted on or around new or existing dams
3. Existing trees should be watched closely until they are removed
4. Grasses and shallow-rooted native vegetation are the most desirable surface covering for an earthen dam.

Dam owners should be especially aware of dangerous or potentially hazardous tree conditions such as decaying or dead branches; lightening-caused splits; stripping or breakage; leaning, uprooted or blown-down trees; and seepage around exposed tree roots located along embankment slopes, especially in vulnerable downstream toe or abutment areas. Outward leaning trees may result from a slumping embankment condition that can be an indicator of slope instability. Any of these conditions warrants immediate attention by the owner and a qualified engineer.

Woody vegetation and tree growth creating undesirable root penetrations in earthen dams can be controlled or prevented by proper management of root growth into new dams and dams that have previously been cleared of trees by proper removal procedures. In this manual, some of the characteristics of woody vegetation and tree growth are presented relative to the aging of an earthen dam. Remedial dam repair design procedures and construction techniques are presented for proper removal of trees of various sizes in various areas of the geometric configuration of an earthen dam. Proper management and control of woody vegetation on new and previously repaired dams (tree removal projects) are based upon an understanding of soil conditions that limit root growth, factors that affect or promote root growth, and various procedures and techniques that can be used to stop, redirect, and/or reduce the rate of root elongation.

The purpose of this chapter is to provide a basic understanding of requirements for healthy root elongation, and to provide an introduction to some techniques and procedures that can be utilized to manage and control undesirable woody vegetation and tree growth on earthen dams. Development of a basic level of tree-literacy combines basic understanding of soil properties and characteristics with basic understanding of requirements and characteristics of healthy tree root elongation and tree growth into a single conceptual understanding of management and control.

Healthy Tree Growth Requirements

The primary requirement for healthy tree growth is an environment for continual elongation of tree roots. Continual elongation of tree roots is essential to healthy tree growth for the following reasons: 1) respiration that requires a continual flow of oxygen to root tissue through soil pores; 2) soil moisture uptake that requires continual availability of soil pore water that can be captured by root tissue; 3) nutrition that requires root systems to make continuously renewed soil/root surface contact to provide needed elements and nutrients for healthy tree growth; and 4) support and stabilization that requires soil-to-root surface contact to resist externally applied loads.

Managed tree root growth control is required to prevent or minimize dangerous impacts on dams. To constrain root growth, identification of soil attributes and it's supporting environment that promote or limit growth is required. By understanding what soil conditions limit growth, various tools and techniques can be used to stop, redirect, or inhibit tree root growth and elongation. The following discussion on root growth requirements, limitations and mechanics is based on a series of publications authored and furnished by Dr. Kim Coder of the University of Georgia Cooperative Extension Services (Coder, FOR98-9, -10, -11, & -13, 1998). The reader is referred to these well-referenced publications for further and more detailed information.

Trees are not much different from all living organisms, relative to biological needs. Trees must have (1) oxygen gained through respiration, (2) water gained through adsorption and absorption, and (3) nutrition gained through adsorption and absorption, and (4) a stable foundation to withstand external forces. General root growth resource requirements are summarized in Table 1. Roots utilize soil spaces for access to water and essential element resources, and soil mass to provide structural support. Soil minerals surround the water-filled and air-filled voids or pores. These pores are continually filling and draining with water and air, depending upon the availability of water, water uptake, and atmospheric air. Root growth follows pathways of interconnected soil voids. Such voids result because of space between soil particles, between soil structural units (i.e., blocks, plates, aggregated soil, etc.); along soil fracture lines, lenses, joints, and various interstitial interfaces; and through paths of biological origins such as decayed or shrunken roots, animal burrows, etc. Better means of controlling growth can be developed by understanding resource levels that encourage and limit root growth (Coder, FOR98-9, 1998).

Root Resource	Requirements	
	Minimal	Maximum
Oxygen in soil atmosphere	2.5%	21%
Air pore space in soil (for root growth)	12%	-
Soil bulk density restricting root growth	- -	1.4 g/cc (clay) (note: 1 g/cc = 62.4 pcf) 1.8 g/cc (sand)
Penetration strength (water content dependent)	0.01 kPa (note: 1 kPa = 1kN/m^2 = 10 mbar = 0.145 psi)	3 MPa
Water content in soil	12%	21%
Root initiation (O_2% in soil atmosphere)	12%	21%
Root growth (O_2% in soil atmosphere)	5%	21%
Progressive loss of element absorption in roots (O_2% in soil atmosphere)	15%	21%
Temperature limits for root growth	40°F/4°C	94°F/34°C
PH of soil (wet test)	pH 3.5 (acidic soils)	pH 8.2 (alk. soils)

Table 1. General list of tree root growth resource requirements (After Coder, FOR98-9, 1998).

Roots survive and proliferate where adequate water is available, temperatures are warm, oxygen is present and other essential resources are concentrated. They generally tend to be shallow, limited by available oxygen and water saturation in deeper soil. However, near the base of the tree, deep-growing roots can be found, but are aerated by soil fissures and cracks and around roots where mechanical forces exerted by wind loads on the tree loosen the soil.

The ability of primary root tips to enter soil pores, open soil pores and elongate through pores is dependent upon the force generated by the root and the soil penetration resistance. As the diameter and length of an expanding root increase, its strength to resist structural failure and its expansive force it can generate both increase. The chance for structural failure increases with longer and smaller diameter roots, while short and thick roots generate significant force but minimize structural failure. Radial expansion of the root structure immediately behind the tip also helps to fracture or reduce penetration resistance in the soil ahead of the elongating root tip.

Roots use the mass of the tissues behind the tip, including root hairs, lateral root formation, and microbial entanglements to minimize the length over which root elongation force (or pressure) is expressed, thus reducing structural failure potential. As the root elongates, only root tissue within about six root diameters behind the tip is involved with force generation. Root tissue further back will act as an anchor and support base against the soil. Root tip pressure can be enormous and can range up to 9-15 MPa (9,000-15,000 mbars, 130-215 psi, or 18,700 – 31,000 psf)), with 1MPa or about 15 psi being most cited. Thus a typical root tip diameter of one millimeter is capable of generating up to about a 0.25-pound force. While tree roots cannot produce enough pressure to penetrate concrete, pipes, and most plastics or metals, they do take advantage of cracks, holes, joints and faults already in materials and exacerbate cracks and faults by growing root mass within, beneath, or around materials. When water supply is short, or when temperatures increase, diameter of roots are sacrificed to facilitate more elongation. Roots can lose more than one-third of their diameter under dry conditions, leaving roots thinner and elongating at a slower rate. Such conditions can generate passageways and set up the possibility for piping and internal erosion conditions in an earthen dam. Additionally, the loss of root contact with the soil and potential for mechanical failure of the elongating root system can lead to poor tree support, thus making a tree vulnerable to wind forces and possible upending. Tree roots are opportunistic in the colonization and control of resource space. The attributes that make a root an ideal resource gatherer for the tree conspire to make roots soil matrix explorers and fault exploiters. To prevent, control or eliminate roots from the soil infrastructure, dam owners and dam design engineers need an understanding of environmental conditions that limit and promote root growth. The foregoing discussion is summarized in terms of the four main requirements and conditions for tree growth and tree root development as follows:

Trees need to breathe. Oxygen is required for healthy tree growth through continual root elongation. In order for proper root respiration to occur, oxygen must continually move through soil pore spaces to the root tissue. Tree roots are not the only living things in the soil pore system that is competing for oxygen. As oxygen flows toward an otherwise healthy root system, enormous numbers of aerobic organisms can utilize portions, and perhaps all, of the available soil pore space oxygen before it can be utilized by root systems. If all of the oxygen is used before reaching the root system, changes must occur in the characteristics and growth rate of the root system. Trees have the ability to generate energy for short periods using carbohydrates in low or non-oxygen environments. However, this process is taxing on tree growth, and is approximately twenty times more inefficient than under normal oxygen availability and respiration conditions (Rendig & Taylor, 1989; Coder, FOR98-10,1998). Air-filled voids in soil must be of sufficient size and continuity to allow carbon dioxide to move away from the root system and oxygen to move to the root system in order to sustain healthy root elongation and tree growth. Water-filled voids resulting from saturated soils around roots inhibit this process at a rate 10,000 times less than air-filled voids (Rendig & Taylor, 1989; Coder, FOR98-10, 1998). When oxygen drops below two to five percent of atmospheric content, root growth and the root's ability to generate elongation force significantly declines (Souty & Stepniewshi, 1988). Table 2 summarizes air void content requirements of various soil texture and types that limit root elongation. The table data shows that, for most embankment soils, trees need at least 10-25% air-filled voids in order to promote healthy growth. In summary, ***Roots that cannot breath die, resulting in unhealthy, unstable, and/or dead trees.***

Soil Texture	Root-limiting % pores normally filled with air
Sand	24%
Fine sand	21
Sandy loam	19
Fine sandy loam	15
Loam	14
Silt loam	17
Clay loam	11
Clay	13

Table 2. Root growth limiting air-pore space values by soil texture (After Coder, FOR98-10, 1998)

Trees need to drink. Second behind the need for oxygen is a tree's requirement for water. Water uptake of trees occurs both by adsorption and absorption. In the same manner as that described for oxygen supply, tree root systems depend upon the flow of soil pore water to the root system to continually uptake sufficient water to sustain healthy root elongation and tree growth. Soil voids that are sufficiently small to prevent continual flow of pore water can limit the amount of water that elongating roots can use within the soil matrix. Often, the moisture uptake is typically lower than that required for root elongation and healthy tree growth. As noted in Table 1, root elongation and healthy tree growth cannot be sustained where average soil moisture contents are less than about 12 percent nor greater than about 40 percent. ***Soils that restrict free moisture movement preclude healthy root elongation (penetration) and healthy tree growth. Compacted soils limit pore space and therefore tend to limit supplies of both oxygen and usable water to trees.***

Trees need nourishment. Third, roots systems must provide nutrition for healthy root elongation and tree growth. Root elongation is required to encounter needed minerals, nutrients, and companion microorganisms in the soil mass. Root elongation must be continuous since replenishment of nutrients in soil is a long-term process that will not meet the requirements of stationary root systems and trees. Elongating or growing root systems continually encounter soil pores of various sizes. Soil pores that are larger than root tips create little resistance to root elongation; however, as soil pore sizes approach the size of root tips and/or become smaller than root tips resistance to root elongation increases significantly. Soil pores that are much smaller than root tips may be deformed in weak or soft soils; however, these small soil voids will reject root penetration in dense or strong soil masses. Roots cannot 'squeeze' into small, rigid soil pores within soil masses where soil strength and density preclude soil deformation and, therefore, growth is inhibited. ***High strength, dense soil masses containing limited required nutrients for healthy root elongation will not sustain healthy tree growth.***

Trees need foundation support. Tree stabilization and support is provided by both components of the tree root system. The root plate (root ball) provides vertical support for the weight of the tree much the same as a shallow foundation system provides support for a building column. However, tree root systems must also resist laterally applied external loads (i.e., wind loads). Lateral root systems provide required lateral support capacity against horizontal forces through development of soil-to-root frictional forces (nature's own application of "soil nailing"). Inadequate root elongation results in reduction of base and lateral support, resulting in an unstable tree that becomes unhealthy and/or subject to failure under laterally applied loads. ***Dense, compacted soil masses preclude proper lateral root elongation thus creating unstable, unhealthy trees that are subject to premature failure.***

In summary, whether in design of new dams or in maintenance of older existing dams, engineers and dam owners need to appreciate the forces, conditions and resources that control and affect the health and stability of trees so as to prevent or discourage trees from growing on new or re-constructed dams or to understand why/how trees respond to given and changing conditions on existing earthen dams.

Tree Root Elongation Management and Control

There are at least eight well-documented methods and tools available to control and limit tree (root) growth through the application of tree root elongation processes, resource availabilities, and soil preparation characteristics. These methods take advantage of depriving the tree roots of ideal resource needs for healthy growth discussed above. While these methods have been primarily used in urban or agricultural applications and settings, some methods are directly applicable to use on earthen dams and include the following methods described by Coder (FOR98-11):

1. **Intelligent designs** and applications that include techniques and materials based upon knowledge of tree growth and root development requirements. Here, minimizing available soil material faults or interfaces and tree root spaces are the preferred means for controlling and discouraging tree growth with the philosophy 'Build it correctly and they will <u>not</u> come!'

2. **Root kill zones** utilizing cultivation methods, sawing and cutting, trenching, vibratory plows, and chemicals to control, discourage, and remove root structure. However, these methods often result in damaging or killing the tree that, perhaps, should have been removed in the first place.

3. **Root exclusion zones** utilizing soil structure changes, soil compaction, water/aeration, stress, anaerobic conditions, soil injections and slurries, soil additives, and chemicals to prevent roots from colonizing the soil structure areas due to applied physical or chemical changes to the soil. Changing the soil structure, pore space volume or drainage/aeration matrices can generate a soil environment that roots cannot effectively grow and sustain. A variety of physical- or chemical-based soil altering materials (i.e., soil injected clay slurry or cement solutions) can be effective, at least over the short term if adequate soil volume is treated. Compacting soils appear to be a very good way to prevent root colonization. High density soils increase the resisting strength of these soils to root penetration and deprive the roots from needed oxygen and available water. Certain types of clay soils, freeze-thaw cycles, biological activity, and poor soil compaction can, over time, produce root-accessible pore space. Soil or infrastructure building material additives that neutralize or sterilize the available minerals and nutrients such as nitrogen gas, sulphur, sodium, zinc, borate, salts, or herbicides may produce serious environmental consequences, short-lived results, and non-targeted damage potential. Other methods or additives may be cost-prohibitive. See Figure 6 at end of chapter for root clearance zones.

4. **Air gap systems** designed to provide temporary and permanent air spaces for root pruning and lack of root support by use of large cobble stone barriers and drain systems. One of the more effective means of controlling tree root growth is providing stone matrices that dry quickly, create large air gaps, have poor water-holding ability, and are impermeable to systematic root penetration. Gravel layers or areas having at least 3/4 inch stone size or clean, graded, medium-sized rubble (crushed brick remnants or recycled paving and other materials), provided it is not covered or filled in with sand, are reported to produce large enough air gaps to discourage root growth.

5. **Barrier systems** using commercial root traps, root deflectors, containment devices, metals, screens, plastics, paints, and inhibitors. One of the easiest and most available materials used to control root growth are various types of 2D-type screens and barriers. While some barriers are not completely effective, many types have been shown to be effective. A list of mechanical, biological and chemical tree root growth control barriers, products and systems is shown in Table 3.

a. Copper sulfate-soaked, synthetic, non-woven fabric
b. Copper screen
c. Cupric Carbonate ($CuCO_3$) in latex paint
d. Fiberglass and plastic panels
e. Fiber-welded geosynthetic fabric/mesh
f. Galvanized metal screen
g. Ground-contact preserved plywood
h. *Geomembranes and heavy rigid plastics
i. Infrastructure aprons and footings
j. Metal roofing sheets
k. Multiple layers of thin plastic sheets
l. Nylon fabric/screen
m. Permeable woven geosynthetics
n. Rock-impregnated tar paper/felt
o. *Slow-release chemical barriers
p. Thin layered bitumen & herbicide mixtures
q. Woven and non-woven slit-film plastic sheets

*Common commercial tree growth control products available

Table 3. Selected list of tree root growth control barriers (after Coder, FOR98-11, 1998)

The costs of these products will likely continue to decrease as the demand for these products increases in the future. Of the barriers shown in the list, three types are most commonly used: traps (root engaging and constricting), deflectors (walls), and inhibitors (chemical constraints). Combined features of the barrier, the site, and barrier installation and maintenance are critical to their effectiveness, but no barrier should be assumed to stop all roots under all conditions. Most types of mechanical and chemical barriers have limited effectiveness lives and this should be factored into any long-term cost analysis. The reader is directed to the Table 3 reference source and other related publications for details on commercially-available root barriers.

6. **Directed growth systems** to concentrate roots in desired directions, guide root growth along channels, allow root survival in desired areas, and create root culverts or layers. As noted earlier, roots are opportunistic and grow and proliferate where there are good supplies of resources. Understanding root elongation, colonization, and survival processes allows growth-favoring soil layers, corridors, and areas to be designed for directing or deflecting roots away from infrastructures where tree roots can be harmful. Several methods or systems are used to attract, deflect, channel or lead roots in a direction or area as needed. One attraction method used is called "baiting" and involves providing ideal essential soil condition resources in a direction away from an infrastructure. The net result is a much higher survival and growth rate in that part of the root system as opposed near infrastructures where root damage can occur. Water, growth nourishment elements, and oxygen should be limited and compaction should be maximum near infrastructures.

   Another method is to "shepherd" roots to desirable locations using trenches, channels, layers, raceways, tunnels, and other devices that are surrounded by root control obstacles, barriers, or resource constraints. Growth channels filled with rich, well-aerated, ecologically healthy growth medium will encourage root colonization and survival in areas away from sensitive infrastructure targets.

7. **Selection of desired species** of trees that require lower soil oxygen environments, have improved root morphology, and are more effective species for long-term solutions. This method focuses on choosing and planting available tree species that can survive under rather limited or harsh environmental conditions. Several tree species are available that are small in size, have shallow and less aggressive rooting, and are slower growing. Dam owners, however, should be reminded again that trees in general are not a good plant option and have no place on dams; instead, more desirable, native grasses should be planted and maintained.

8. **Creating avoidance zones** to separate tree growth from earthen dam embankments and dam appurtenances where root damage may be critical thus establishing biological-free zones that reduce potential problems. This method simply recognizes that there are places where trees are acceptable and other places, namely dams, where they are not (see Figure 6).

The most practicable of these methods for use on earthen dams are those associated with intelligent design development, exclusion zones, kill zones, and barriers. Within this group of suitable methods the combination of intelligent design development and exclusion zones are the most effective. With an understanding of the previous meshing of soil properties with healthy tree root elongation, it is not difficult to develop an intelligent design scheme for new dams and the remedial repair of existing dams. An intelligent design philosophy associated with dam embankment design and construction would involve proper embankment soil compaction as the means of exclusion of root elongation.

In summary, there are many tools, methods and options for minimizing or preventing tree root-caused damage to earthen dams. The most important management (and design) concept to understand is how tree roots are invited to be associated with interstitial elements and colonize soil matrices and discontinuities, and resource availability areas. Our responsibilities as owners and dam design engineers must lie with creating and using any or a combination of the numerous root growth control tools and techniques that are tree-literate so that trees do not have the opportunity to become a safety problem to embankment dams and their appurtenances in the first place.

Exclusion by Embankment Compaction

Design and construction practices of using optimum compaction of embankment soils reduce potential settlement of embankments, increases shear strength of the embankment soils, decreases the permeability of the embankment soils, and minimizes long-term changes in the physical and engineering properties of soils. When embankment soil compaction results in the attainment of desirable objectives from a geotechnical engineering behavior perspective of earthen slopes, compaction of embankment soils also precludes tree root growth and elongation as a result of exclusion of most of the requirements for healthy root elongation and tree growth. As has been previously noted, densely compacted soils discourage root elongation through increased resistance, lowered oxygen levels, and reduced available water. Traditional embankment soil compaction specifications require that the soil be compacted to about 95 to 98 percent of the standard Proctor maximum dry density as determined by ASTM D-698. Furthermore, most properly written soil compaction specifications generally require that compaction moisture contents be maintained about two percent below to three percent above optimum moisture content. At these degrees of compaction and at these moisture contents, soil oxygen content, water content, and soil pore size are not available for healthy root elongation and tree growth. Even if there is sufficient moisture content in the soil to otherwise sustain healthy root elongation, the soil pore sizes are so small that available pore water cannot be effectively moved to the root system. Consequently, the compacted dam embankment fill soil produces an exclusion system that mechanically impedes healthy root elongation and tree growth. Table 2 provides a summary of minimum air voids for various soil types required to impede root elongation for healthy root and tree growth.

Maintenance Mowing and Kill Zones

The second most effective method of controlling woody vegetation and tree growth on dam embankments is through the use of native grass or ground cover with maintenance mowing, and using kill zones where necessary around critical structures to control trees and other undesirable nuisance-types of vegetative growth. Maintenance mowing should be done ***at least*** twice per year with one mowing scheduled for spring after initiation of new spring growth and the second mowing scheduled for late fall immediately prior to the first killing frost or freeze (See Chapter 7). The spring mowing should be a very close cutting of all vegetation to allow maximum sunlight to penetrate to desirable grass cover species. The fall cutting should not be as close as the spring cutting to provide maximum resistance to surface runoff erosion and to provide cover for desired wildlife species (quail, rabbit, grouse, songbirds, etc.).

In areas where regular maintenance mowing is not practical to control woody vegetation and tree growth, the selective use of herbicides might become necessary to control small woody vegetation and tree growth. There are many commercially available herbicides that are environmentally safe to use in most applications. However, one must always be careful in the use, or overuse of herbicides, because they are design to kill and/or impede (slow) plant growth. Overuse of herbicides may contaminate areas of the dam embankment to such an extent that desirable grass cover cannot be effectively grown. One must always follow manufacturers recommendations when using herbicides, or better yet, solicit the advice of the nearest USDA/NRCS agent prior to using herbicides to control woody vegetation and tree growth on earthen dams.

Chemical Barrier Systems to Inhibit Root Growth

Commercially available barrier systems are effective in controlling root elongation and growth; however, many of these barrier systems are relatively expensive and cannot be justified for placement over the entire earthen dam embankment. These barrier systems are often economical for placement on portions of earthen dams where accessibility is difficult after construction and/or where particularly problematic and nuisance woody vegetation and tree growth is likely to occur.

One typical biocide product, called "Biobarrier©" is marketed and promoted, among other applications such as sidewalk and landfill cap protection, to prevent tree and plant roots from penetrating dams. The product consists of long-term, slow release nodules containing Trifluralin herbicide, that are bonded to a geotextile fabric as shown in Figure1.

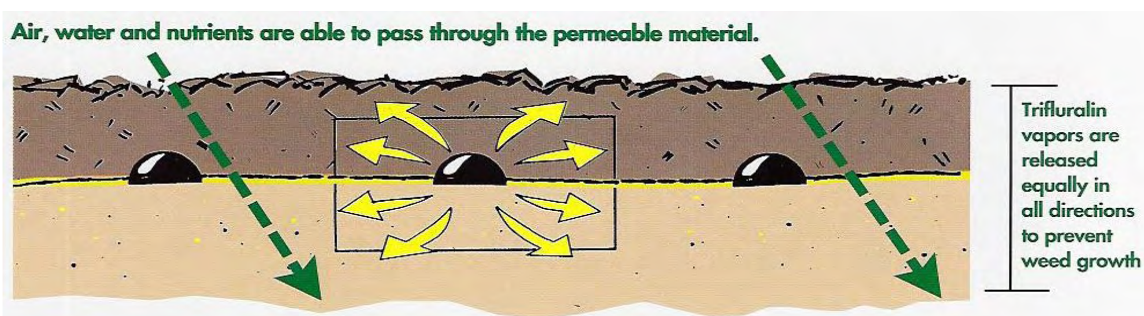


Figure 1. Chemical biocide barrier installation showing slow-releasing biocide nodules attached in a woven fabric matrix and installed under a cover of soil, mulch, gravel or stone (Biobarrier©).

This particular barrier is environmentally acceptable to EPA and indicated to be effective against all types of roots around pipes, hardscapes, and dams and levees. While the product is guaranteed for 15 years, its life is inversely proportional to environmental temperature conditions.

For example, its effectiveness is expected to be about 40 years at 20°C (68°F) and about 100 years at 15°C (60°F). For deep soil cover, it is expected to last 100 years; for near soil-surface weed control installations, where temperatures are higher and cycle daily, the projected life is expected to exceed the guaranteed 15-year life. Figures 2 and 3 show an application of this product on a 25-foot high and 350-foot long earthen dam to prevent deep penetration of deep-rooting native trees and woody vegetation such as willows, sagebrush, and chokecherries.

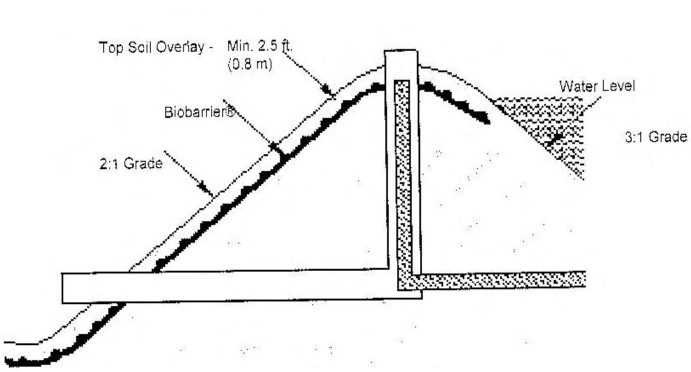


Figure 2. Earth dam installation of chemical

Figure 3. Installed chemical barrier on a dam in Montana (Kershner, 1992)

Herbicidal Applications

Herbicidal delivery to control undesirable vegetation depends on several considerations which include (a) types of plants and weeds (herbaceous, vines, trees, brush, phreatophytes, etc.), (b) site conditions (geology/sinkholes/karst), topography, (c) proximity to water bodies, (d) riparian land use, (e) sensitive environmental factors (Federal, state & local regulations; potential off-site wind drift over water or land), and (f) application factors (dosage, placement, retention time, plant growth stage, physiological factors, and method of application). A very important consideration is for the user to follow the herbicide manufacturer's warnings and instructions. The user is also encouraged to consult with a local county extension office or agent to obtain advice on the best and safest herbicide to use and on what recommended application technique to use. While there are several herbicidal delivery methods available, the most common techniques are shown below in Figure 4.

- Foliage spraying
- Tree injection
- Frill or girdle treatment (slash through bark then spray or paint)
- Basal bark spraying
- Cutting tree and poisoning stump
- Soil treatment
- Other

Figure 4. Herbicide delivery application methods

Some of these techniques and herbicides used are illustrated in Figures 5a – 5f. The U. S. Department of Agriculture (SCS, now NRCS) published a useful methods, treatment points, and time of treatment guidelines for controlling trees and brush on dams, including some of the applications listed in Figure 4 (USDA, 1988). Table 4 summarizes the USDA recommendations. With the exception of Krenite, which is applied to the foliage, 2,4-D is the only approved herbicide for poisoning trees on dams. 2, 4-D is manufactured by several companies and is sold under several trade names. In all cases, the user is cautioned again to follow the manufacturer's instructions and should consider the manufacturer's label instructions to supercede recommended instructions in the USDA table.

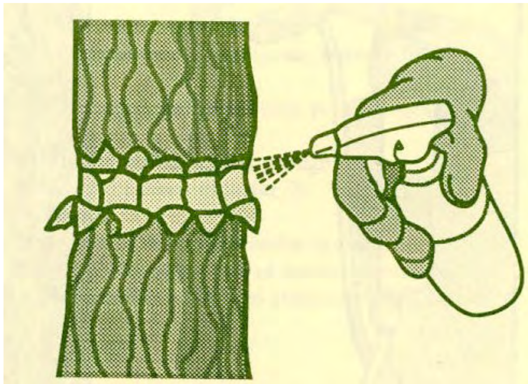


Figure 5a. Frill cut application.

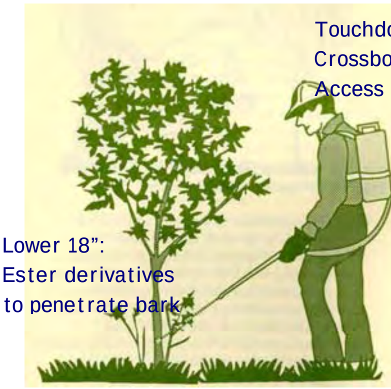


Figure 5b. Basal bark spraying.

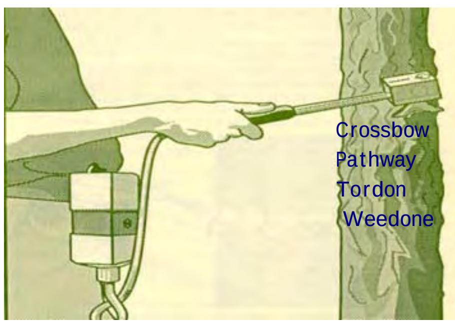


Figure 5c. Hypohachet application.

Figure 5d. Cut-stump application.

Figure 5e. Backpack foliar application on dam.

Figure 5. Applications and techniques for different herbicidal deliveries to trees and brush, with example commercially-available herbicides listed.

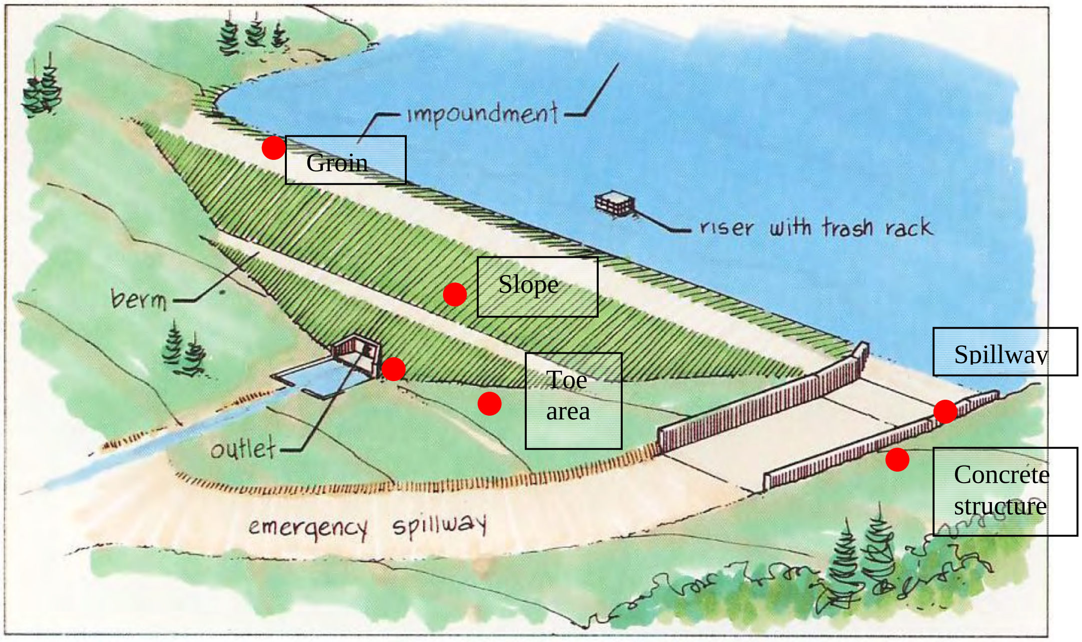
Figure 5f. Tractor spraying application on dam.

Method of Application	Recommended Time
• Cutting trees and poisoning stumps • Injection • Foliage spraying • Frill treatment (trees larger than 4" dbh) • Basal spraying (trees smaller than 6" dbh) • Prescribed burning (trees smaller than 2" dbh)	• Growing season • Anytime • Last two (2) months of growing season • Anytime • Growing season • See technical specifications

Table 4. Recommended methods and time of herbicide treatment application (USDA, 1988).

USDA recommends that trees killed by herbicide should be removed within the year following treatment to prevent front slope from falling into the reservoir and plugging the spillway. Downed trees on the back slope should also be removed to prevent potential problems of seepage, erosion, burrowing animals, etc.

The reader is referred to the USDA guideline for detailed discussion on each of the six treatment methods listed in the above table. These methods can be applied to establish tree and woody plant clearance or avoidance zones on and around dams as illustrated in Figure 6.



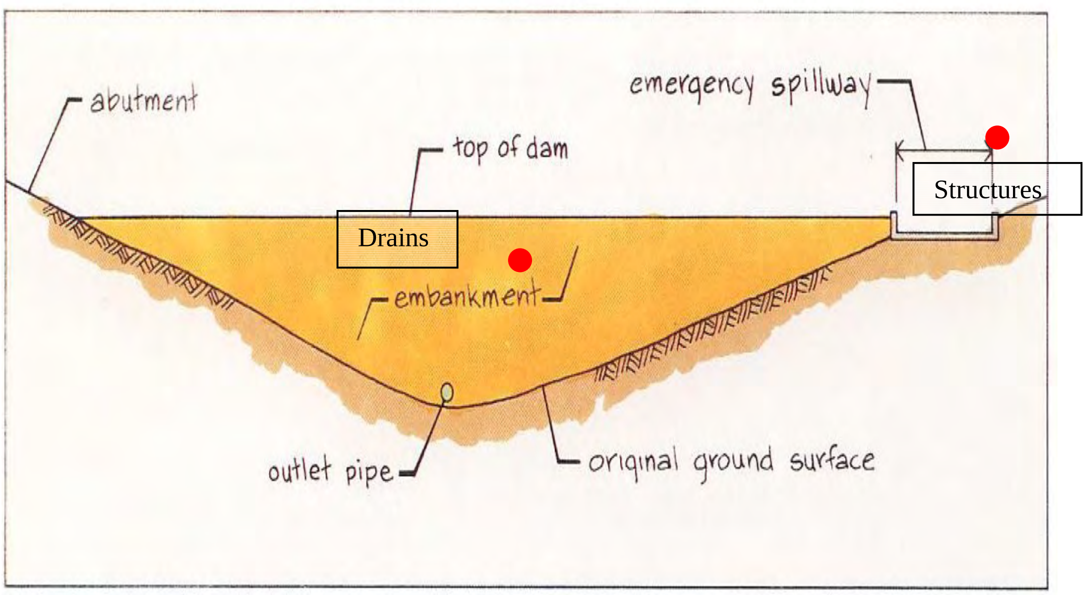


Figure 6. Tree clearance zones for embankment dams and dikes.

Desert Plants

Deep-rooted desert plants, when left unchecked, can propagate rapidly on earthen dams located in arid and semi-arid regions of the U. S. Some of these deep-rooted plants include Desert Broom shown in Figure 7, Salt Cedar, Mesquite, Cypress, Cottonwood and Paloverde. All of these species require considerable effort to control and should not be allowed to become established anywhere on dams. Palm trees can be a problem in that they are shallow-rooted, but develop a large root ball that can produce large cavities when toppled during high winds. Upstream and downstream access roads, in place at many dams, should be utilized to create a buffer zone between these species and the toe of dams.

Figure 7. Deep-rooting Desert Broom Plant

The Maricopa County, Arizona, Flood Control District (MCFCD) recommends, in cases where deep-rooted plants are two feet in height or less, that they be controlled with a 3-5% solution of Roundup® Pro (Renckly and Drake, 1999). If the plants are over two feet in height they should be hand cut to ground level. The stumps should be treated within the first five minutes by an almost straight mix of either Roundup Pro® or Garlon 3A-Garlon 4®, depending on the temperature conditions. MCFCD recommends that when treating Salt Cedar near waterways that Rodeo be sprayed at a 3-5% solution with six ounces of Siltwet® per acre added. This is sprayed on plants two feet in height and under. Plants over two feet are hand cut and the stump treated with an almost straight solution of Rodeo® within five minutes of cutting the plant.

Revegetation on earthen dams is recommended to minimize erosion on the embankment slopes and to provide natural landscaping for earthen dams. MCFCD recommends hydro-seeding over labor-intensive hand-seeding to revegetate dam embankments. Figure 8 illustrates hydro-seeding operations on a floodway dam. Seed, water, tack material and a wood fiber or paper mulch are mixed in a hydro-seeder and sprayed directed onto the slopes. The seeds are encapsulated in the mulch and tack material until enough moisture is present to begin the germination process.

Figure 8. Hydro-seeding operations on a floodway dam in Maricopa County, Arizona (Renckly & Drake, 1999).

MCFCD has found that it takes 2 to 3 years before “significant” vegetative cover results are achieved because of the arid climate and high degree of embankment compaction. MCFCD determines the desirable seed mix by first laying out a test acre on the dam embankment and a plant count is then taken of all the different plant species that are native to the area and placed on the test acre. This plant count is converted by the seed supplier into the amount of seed needed to germinate the desired amount of the species per acre. The amount of pure live seed (PLS) applied for individual plant species also varies by availability from the local seed supplier. Table 4 shows a seeding mixture specified for one of the District’s dams and is typical of specified hydro-seeding mixes. No deep-rooted species are allowed in the seed mix.

MCFCD has found that revegetation efforts have successfully reduced erosion problems, but has attracted both desirable and undesirable animals.

SEEDING MIXTURE

Common name	Scientific Name	Pounds of Seed Per Acre
Purple three-awn	Aristida purpurea	4
Indian Wheat	Plantago insularis	3
Needle Grama	Bouteloua arstiodoides	1
Desert Marigold	Baileya multiradiata	1
Mexican Gold Poppy	Eschschotzia mexicana	1
Creosote	Larrea tridentata	8
Brittle Bush	Encelia farinosa	2.5
Bursage	Ambrosia deltoidea	2

** **Note: Apply 1500 pounds of wood fiber mulch in Hydro-seed mix, plus 150 – 200 pounds tack material per acre.**

Table 4. Typical seed list specified for a flood control dam managed by the Maricopa County, Arizona, Flood Control District (Renckly & Drake, 1999)

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Chapter 6
Dam Remediation Design Considerations

Specific dam remediation design considerations, procedures, and techniques will be considered for each of the previously identified dam safety inspection and evaluation zones. Figure 1 presents these zones as a review prior to discussion of potential dam remediation design considerations for each zone. Dam remediation design alternatives presented herein should be considered examples. These remediation design examples should not be considered the only alternatives for use in dam remediation design to correct deficiencies associated with tree and woody vegetation growth on earthen dams. Some additional dam remediation design alternatives presented for correction of tree and woody vegetation growth related deficiencies also provide positive correction of other deficiencies and protection against other types of earthen dam deterioration.

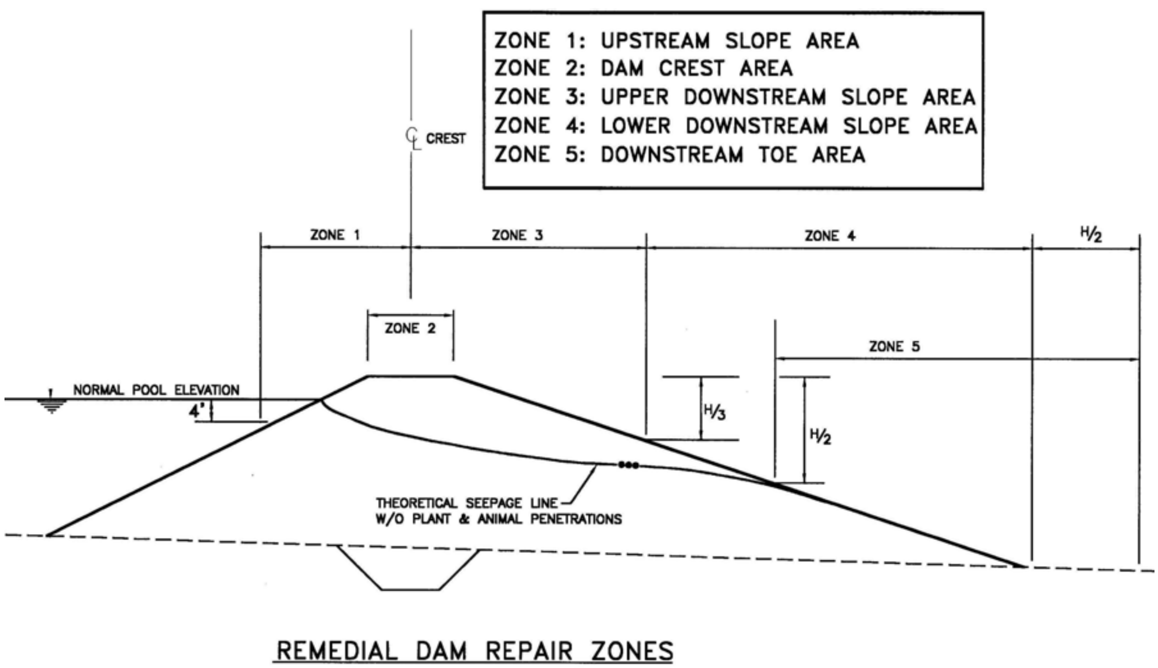


Figure 1

Inspection and Evaluation Zone 1

Figure 2 illustrates potential problems that can occur in Zone 1 with respect to tree and woody vegetation growth on earthen dams. This illustration also depicts the occurrence of wave erosion, vehicle access, and surface runoff erosion. Potential problems illustrated include instability of relatively large trees on the upstream slope and dam crest, and alteration of the seepage line as a result of wave erosion.

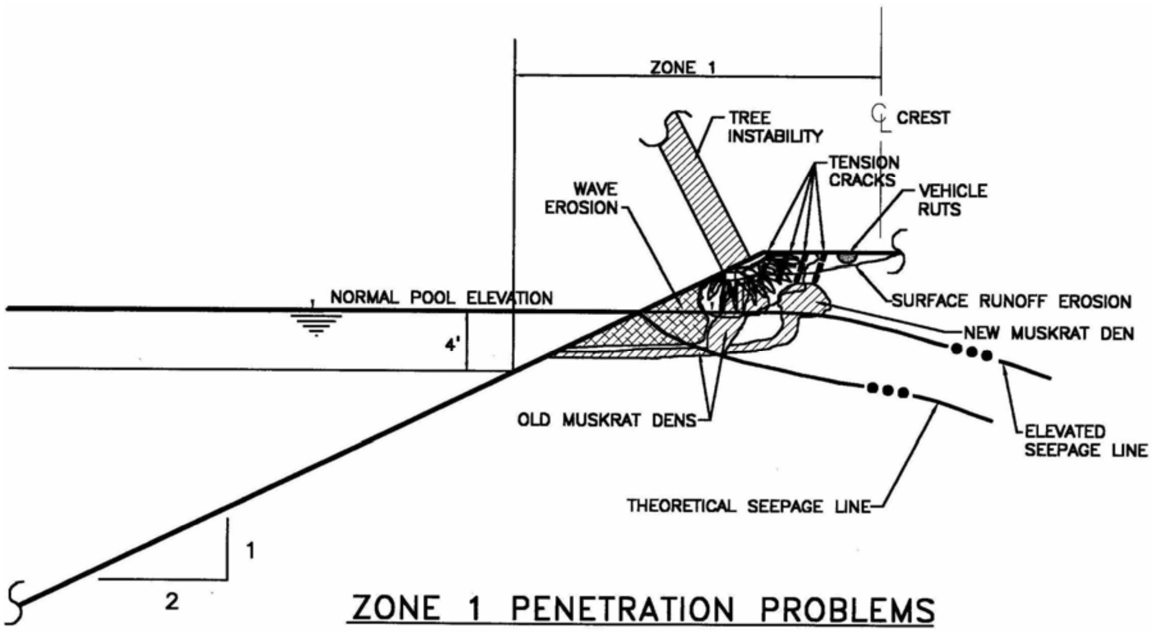


Figure 2

Dam remediation design techniques necessary to address potential problems illustrated in Figure 2 are illustrated in Figures 3 and 4. Dam remediation construction typically requires lowering of the normal pool elevation and/or complete drawdown of the retained reservoir. This is particularly true for dam remediation construction in Zone 1. The normal pool elevation should be lowered as far ahead of the scheduled dam remediation construction as practicable.

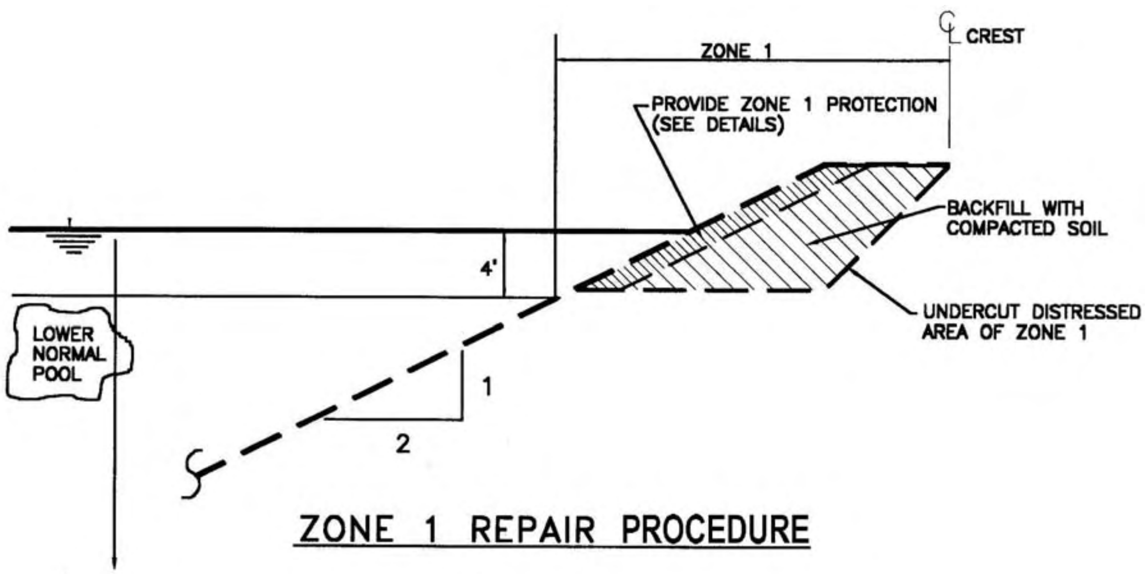


Figure 3

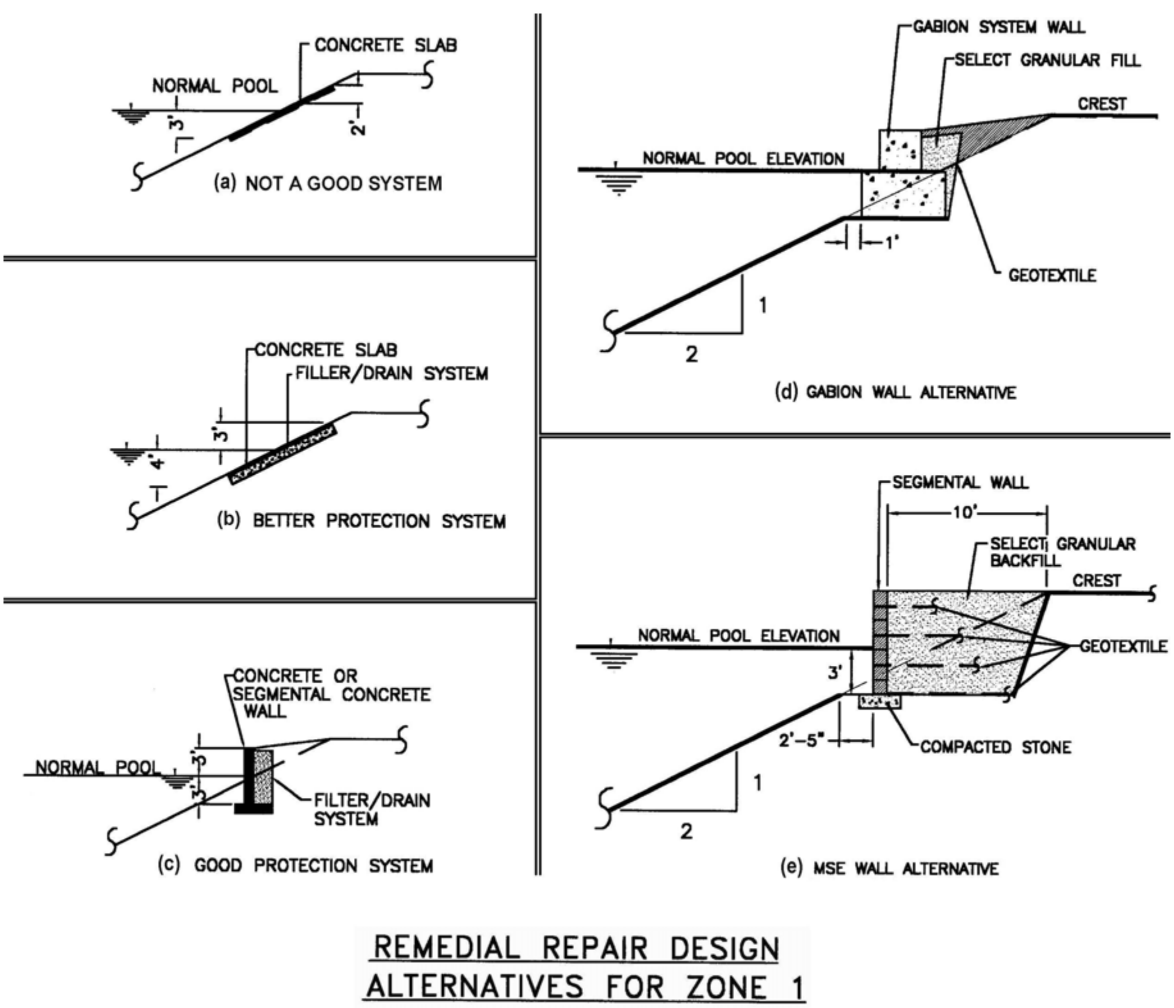


Figure 4

Tree and woody vegetation growth in Zone 1 must be undercut to remove all stumps, rootballs, and root systems developed by tree penetrations as illustrated in Figure 3. The required depth of undercutting typically extends to near the limits of Zone 1, which is about four feet below normal pool elevation. In the case of earthen dams with narrow crest widths, the backslope of the undercut area will typically extend to near the centerline of the dam crest or the downstream limits of Zone 1. Subsequent to undercutting affected areas of Zone 1, the undercut area must be thoroughly inspected to confirm that all major root systems (greater than about one-half inch in diameter) have been removed during the undercutting operation. Following inspection and approval of the undercut area by the engineer, suitable backfill should be placed in the excavation and properly compacted to the dam remediation design limits. Backfill should consist of approved embankment fill material and should be compacted to a minimum of 95 percent of the maximum dry density of the fill soil as determined by the standard Proctor compaction test (ASTM D-698). In conjunction with the undercutting and backfilling, the dam remediation design should include a slope protection system to deter future tree and woody vegetation growth and reduce the potential for wave and surface runoff erosion.

Figures 4(a) through 4(c) illustrate various configurations of rigid (concrete) upstream embankment slope protection systems. Figure 4(a) illustrates a concrete slab being placed directly on the upstream slope from about three feet below to about two feet above normal pool elevation. While this system is somewhat limited relative to the area of protection, the most critical aspect of this system is that it provides no filtration and/or drainage system beneath the concrete slab. Continual wave action and the buildup of hydrostatic pressures beneath the concrete slab will eventually result in downward movement of the slab. Figure 4(b) illustrates a better dam remediation design utilizing a concrete slab slope protection system. This slope protection system has been improved over the original system by covering a larger area of the upstream slope and by providing a filter system beneath the concrete slab protection system. The author is of the opinion that the dam remediation protection system shown in Figure 4(c) is the most desirable and cost effective design for use of reinforced concrete for a protection system. The reinforced concrete wall provides a gentle slope to flat backfill area that can easily be maintained by mowing to preclude tree and woody vegetation growth. In addition, this dam remediation design alternative can be used to provide a wider effective dam crest and provides excellent protection against wave erosion.

NOTE: Reinforced concrete wall and slab systems constructed on the upstream slope must always be provided with filtration/drainage systems to reduce the potential for development of excessive hydrostatic pressures and internal erosion and scour of soil from beneath the structures. The referenced figures are presented for illustrative purposes and should not be used for actual dam remediation design without proper design analyses to confirm any indicated dimensions of the drawings.

Alternative flexible upstream slope protection system designs for use in Zone 1 are shown in Figures 4(d) and 4(e). The author has utilized both of these flexible slope protection systems effectively to reduce potential tree and woody vegetation growth on upstream slopes and to provide resistance to wave and surface erosion. Figure 4(d) illustrates a typical gabion wall system while Figure 4(e) illustrates the use of a Mechanically Stabilized Earth (MSE) wall system for protection of the upstream slope of an earthen dam.

NOTE: Granular backfill material used in design and construction of these flexible wall systems must be protected against soil contamination and internal erosion of retained soil by an effective geotextile filter/drainage material and/or a graded aggregate filter. These figures are presented herein for illustrative purposes and should not be used for actual design without proper design analyses to confirm any indicated dimensions of the drawings.

Inspection and Evaluation Zones 2 and 3

Potential problems associated with tree and woody vegetation growth on earthen dams in identified Zones 2 and 3 are illustrated with dam remediation design procedures in Figure 5. Potential problems illustrated for Zone 2 include the growth of mature trees having stump diameters greater than twelve inches. Mature trees having stump diameters greater than eight inches are illustrated at various locations throughout Zone 3 and in the overlap area of Zones 2 and 3.

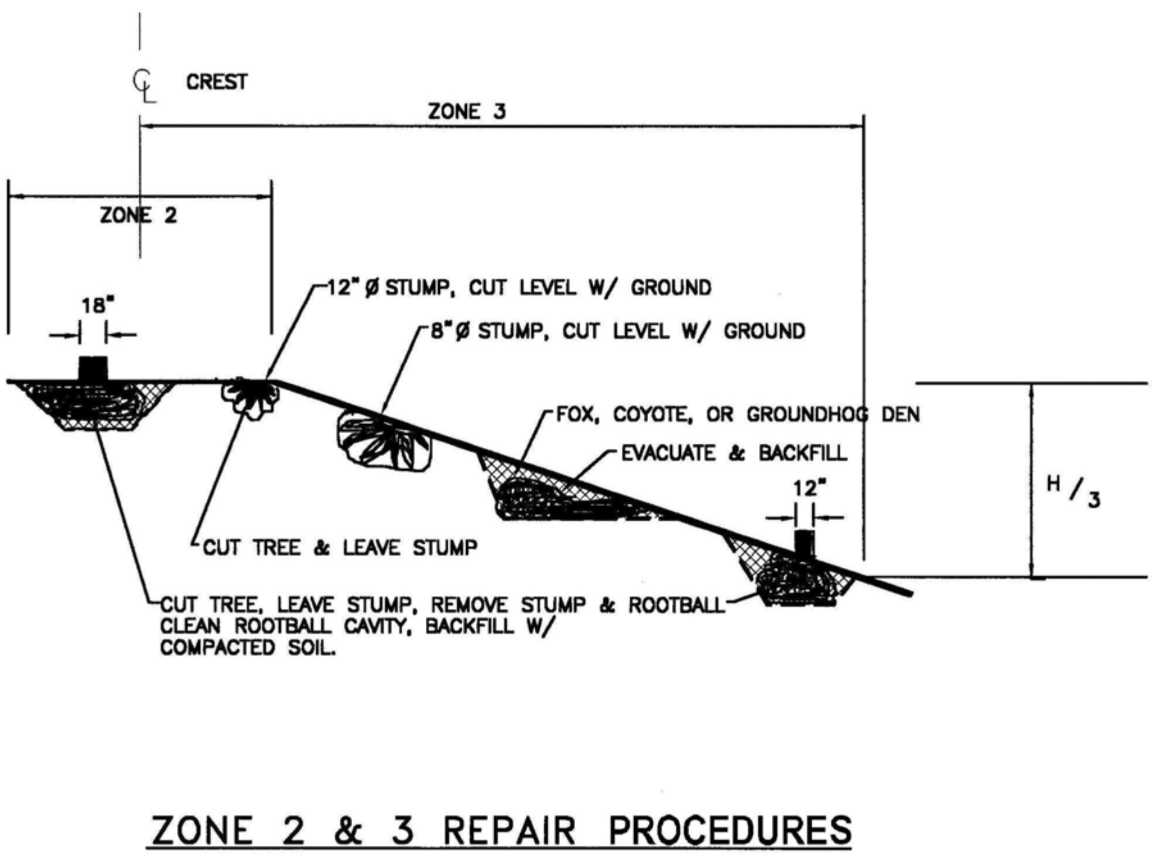


Figure 5

Two dam remediation design procedures are illustrated in Figure 5 for removal of trees of various sizes. This illustration implies that trees located in the overlap area of Zones 2 and 3 having stump diameters less than about twelve inches could be cut flush with the ground and left in place for future treatment of the decayed stump and rootball system. However, removal of all stumps, rootballs and root systems is always the better and more conservative approach to removal of mature trees. Subsequent to cutting of trees having stump diameter less than about twelve inches in the overlap area of Zones 2 and 3, the surface of the stump can be treated with a protective coating similar to polyurethane that will prolong the decaying process. Conversely, the referenced illustration indicates that any trees in Zone 2 upstream of the overlap area of Zones 2 and 3 having stump diameters of twelve inches or greater should be treated by total removal of the tree, stump, rootball, and root system. The suggested dam remediation design and construction procedure suggested for complete removal of trees, stumps, rootballs, and root systems in Zones 2 and 3 consists of the following activities:

1. **Cut** the tree approximately two feet above ground leaving a well-defined stump that can be used in the rootball removal process;

2. **Remove** the stump and rootball by pulling the stump, or by using a track-mounted backhoe to first loosen the rootball by pulling on the stump and then extracting the stump and rootball all together (this is much the same procedure a dentist would use in extracting a tooth);

3. **Remove** the remaining root system and loose soil from the rootball cavity by excavating the sides of the cavity to slopes no steeper than 1:1 (horizontal to vertical) and the bottom of the cavity approximately horizontal; and

4. **Backfill** the excavation with well-compacted soil placed in relatively thin lifts not greater than about eight inches in loose lift thickness. Compaction of backfilled soils in these tree stump and rootball excavations typically requires the use of manually operated compaction equipment or compaction equipment attached to a backhoe.

NOTE: All disturbed areas must be protected by seeding and mulching.

Figure 5 further illustrates that trees located in Zone 3 that have stump diameters greater than about eight inches should be treated by total removal. The removal procedure should be the same as previously described for larger trees in Zone 2. Trees having stump diameter of less than about eight inches could be cut flush with the ground and treated with a waterproofing sealant similar to polyurethane to prolong the stump and rootball decaying process. Again, complete removal of the stumps, rootballs, and root systems of all mature trees is a better and more conservative method of remediation.

Inspection and Evaluation Zone 4

Figure 6 illustrates potential problems associated with tree and woody vegetation growth in Zone 4 of an earthen dam with suggested dam remediation design and construction procedures.

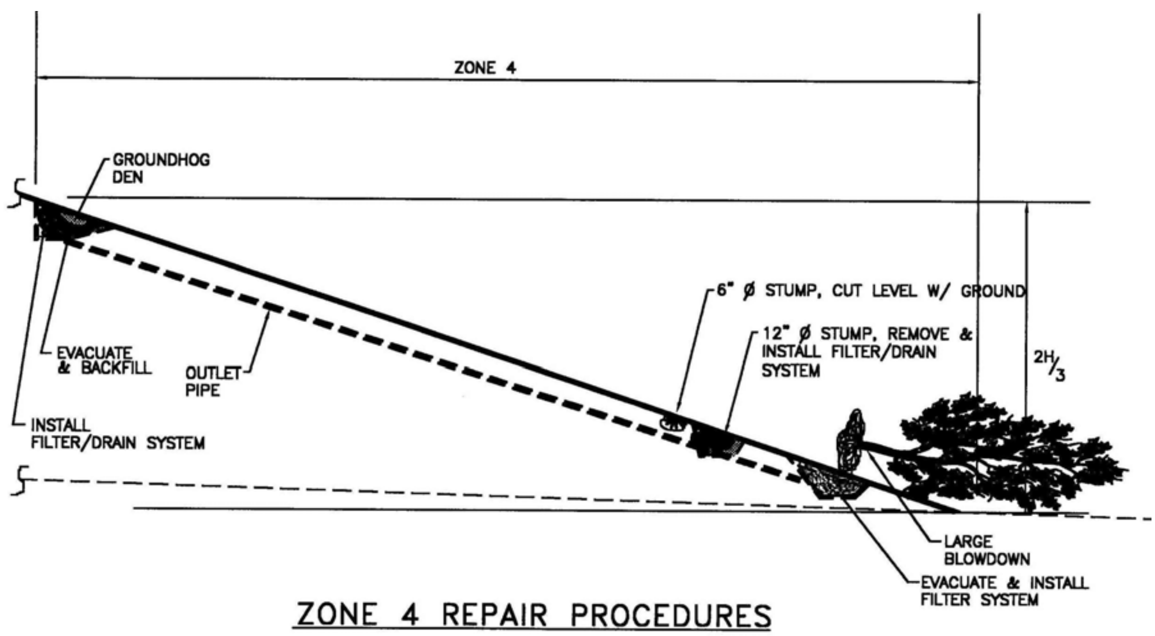


Figure 6

Young immature trees having stump diameters less than about six inches can be removed by cutting flush with the ground and treating the stump with a wood preservative and/or sealant to prolong the decaying process. This procedure is based upon the fact that immature trees of this size typically have not developed a rootball and/or root system that will significantly impact the zone of saturation or the seepage line in Zone 4.

Trees having stump diameters greater than about six inches must be treated by complete removal; however, the dam remediation design and construction procedure for total removal of trees in Zone 4 is somewhat more complicated than total removal of trees in previously discussed zones. Treatment of mature tree penetrations in Zone 4 involves the following activities:

1. **Cut** the tree approximately two feet above ground level leaving a prominent stump for use in the rootball extraction process;

2. **Remove** the stump and rootball by pulling the stump or extracting with a track-mounted backhoe after loosening the rootball by pulling on the stump from different directions;

3. **Clean** the rootball cavity to remove loose soil and the remaining root system by excavating the rootball cavity with maximum 1:1 (horizontal to vertical) side slopes and a horizontal bottom; and

4. **Install** a subdrain and/or filter system in the tree penetration excavation and backfill with compacted soil placed in maximum loose lifts of eight inches.

Note: Backfill placed in all tree removal excavations must be compacted to a minimum of 95 percent of the maximum dry density as determined by ASTM D-698.

Note: Subdrain and/or filter systems installed in tree removal excavations in Zone 4 may be incorporated into major subdrain systems to be installed in the overlap area of Zones 4 and 5.

Inspection and Evaluation Zone 5

The author identified Zone 5 as one of the two most critical zones for tree and woody vegetation growth on an earthen dam. Figure 7 illustrates some of the problems that can occur with tree and woody vegetation growth in Zone 5. The major adverse feature in Zone 5 is typically the interception of the downstream embankment slope by the seepage line. The author is a strong advocate of the installation of embankment subdrain systems during dam remediation design and construction even though the earthen dam may have been provided with an embankment subdrain system during original design and construction.

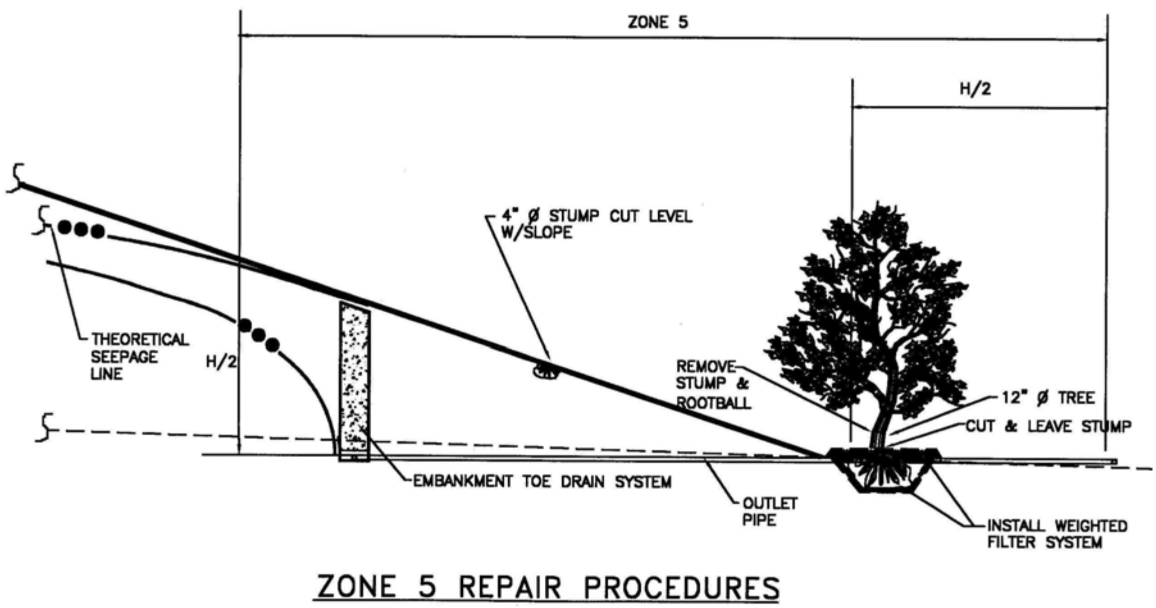


Figure 7

One must understand the impact of tree removal in Zone 5 on the seepage line and the quantity of seepage that will occur subsequent to dam remediation in this zone. As indicated by Figure 7, trees in Zone 5 having stump diameters less than about four inches can be cut flush with the ground and the stump treated with a waterproof sealant to prolong stump and rootball decay. Trees having stump diameters greater than about four inches must be removed completely. If the embankment toe drain or subdrain system is installed in advance of tree removal in Zone 5, the rootball cavity can be backfilled with compacted soil, provided seepage does not emerge from the excavation and/or the tree is located beyond the toe of the embankment slope. Tree rootball cavities existing beyond the toe of the downstream embankment slope generally require the installation of a filter system and in some cases a weighted filter system as indicated in Figure 7. The weighted filter system may be converted to a weighted drain system by installing a drain and outlet pipes connected to the outlet pipe of the embankment subdrain system.

Summary of Dam Remediation Design Considerations

A summary of dam remediation design considerations for treatment of tree and woody vegetation on earthen dams is presented below. Dam remediation design procedures and techniques are presented for treatment of various size trees in the identified dam safety inspection and evaluation zones.

Remedial Repair Zone	Procedures and Techniques
Zone 1	Remove all trees, stumps, rootballs, and root system; clean rootball cavity; and backfill with properly placed and compacted soil backfill. Install tree and woody vegetation and wave erosion protection system on the upstream slope from about four feet below normal pool elevation to about three feet above normal pool elevation.
Zone 2	Cut trees in overlap area of Zone 2 and Zone 3 having stump diameters of twelve inches or less flush with the ground and treat the stump with a waterproof sealant to prolong stump decay.

Completely remove trees having stump diameters of about twelve inches and greater, and backfill rootball cavity with properly compacted backfill soil.

Zone 3

Cut trees having stump diameters of about eight inches and less level with the ground and treat the stump with a waterproof sealant to prolong stump and rootball decay.

Completely remove all trees having stump diameters greater than about eight inches and backfill the cleaned rootball cavity with compacted backfill soil.

Zone 4

Cut all trees having stump diameters of six inches or less flush with the ground and treat the stump with a waterproof sealant to prolong stump and rootball decay.

Remove all trees having stump diameters greater than about six inches, install subdrain and/or filter systems, and backfill with properly compacted soil around the filter/drain system.

Zone 5

Cut all trees having stump diameters of about four inches and smaller flush with the ground and treat the stump to prolong stump and rootball decay.

Install a major embankment toe drain or subdrain system to lower the phreatic surface, filter, collect, and discharge embankment seepage. Incorporate major subdrain with tree rootball and stump removal where possible.

Remove all trees located beyond the toe of the downstream slope having stump diameters greater than about four inches. Install weighted filters and/drain systems in rootball cavities where seepage boiling and soil piping is likely to occur.

Tree and Woody Vegetation Growth Control Program

Many individual dam owners and small dam owner organizations are not financially capable of undertaking comprehensive dam remediation projects in one major construction contract. Therefore, they must undertake dam remediation programs in a sequential manner. The following sequential dam remediation program for controlling tree and woody vegetation growth provides the owner, regulator, and engineer with a reasonable opportunity to effectively evaluate the condition of an earthen dam and to prioritize dam remediation relative to observed dam safety issues.

1. **First Year**: Cut all tall grasses, weeds, underbrush, and trees and woody vegetation having stump diameters of four inches or less flush with the ground and treat all cut stumps with a waterproof preservative to prolong rootball and stump decay.

2. **Second Year**: Cut all trees in Zones 1 through 4 having stump diameters of six inches or less flush with the ground and treat the stumps to prolong stump and rootball decay. Keep all zones mowed and/or maintained to preclude renewed growth of previously cut woody vegetation. Repair most severe animal penetrations that exhibit seepage flows and/or cause unstable slope conditions on Zones 1, 4, and 5.

3. **Third Year**: Initiate comprehensive remedial dam repair investigations, analyses, and preliminary design. Remove all trees from Zones 1 through 3 having stump diameters less than about eight inches by cutting flush with the ground and treating the stump with a preservative to prolong stump and rootball decay.

4. **Fourth Year**: Finalize remedial dam repair design and begin construction of remedial repairs for all plant and animal penetrations that require special remedial dam repair design considerations.

5. **Fifth Year**: Finalize remedial dam repair construction and begin an operation and maintenance program that will preclude the need for future remedial dam repair associated with plant and animal penetrations of earthen dams.

NOTE: **Earthen dams that exhibit severe dam safety deficiencies and dam safety issues that cannot be prolonged as a result of potential imminent dam failure are not subject to the use of this type of sequential dam remediation program!!!**

Chapter 7
Economics of Proper Vegetation Maintenance

Regular maintenance on a dam, especially attention to trees and brush, is known to be critical to dam safety for several reasons (Tschantz, 2000):

- Overturning or uprooting trees causing large voids and reduced freeboard; and/or reduced cross-section for maintaining stability
- Decaying roots of dead trees causing potential seepage paths and piping problems
- Interfering with effective dam safety monitoring, inspection and maintenance for seepage, cracking, sinkholes, slumping, settlement, deflection, and other signs of stress
- Hindering desirable vegetative cover and causing embankment erosion
- Obstructing emergency spillway capacity
- Falling trees causing possible damage to spillways and outlet facilities
- Clogging embankment underdrain systems
- Cracking, uplifting or displacing concrete structures and other facilities
- Inducing local turbulence and scouring around trees in emergency spillways and during overtopping
- Providing cover for burrowing animals
- Loosening compacted soil
- Allowing roots to wedge into open joints and cracks in foundation rock along abutment groins and toe of embankment, thus increasing piping and leakage potential.

State and federal dam safety officials and other dam safety experts agree that trees have no place on dams. Federal agencies and some states do not allow trees to grow on dams. However, it is estimated that about a third of the nation's 77,000 inventoried dams have sufficient woody vegetation to hinder effective dam safety inspections (ASDSO, 2000; Tschantz, 2000). Most states require dam owners to remove trees and undesirable vegetation, but the cost of clearing and grubbing trees and restoring the dam embankment slopes and crest is often cost prohibitive for many dam owners, usually running into thousands of dollars. It would seem that regular control of woody vegetation and maintaining the surface on an earthen is relatively inexpensive, compared to removing trees on and repairing damage from neglected dams such as shown in Figure 1.

Figure 1. Restored Downstream Slope on Fishing Creek Dam, Maryland (1991-92)

Likewise, it is important that owners maintain *desirable* vegetation on their dams on a regular schedule to avoid the expense of periodically removing undesirable heavy brush and mature trees. Early control is generally viewed to be the most cost-effective means of avoiding potential adverse effects on these structures from their continued growth (USBR, 1989). The bulk of maintaining a dam usually involves keeping the grass mowed and brush trimmed. An important question arises, ***"How much is a dam owner justified in spending to maintain a dam on a regular or annual basis to avoid having to bear the heavy cost of removing trees?"*** A correlative question then follows, ***"How often should a dam be mowed to control undesirable woody growth?"***

This chapter attempts to answer these questions, but there are many variables and site-specific factors which need to be considered. Some assumptions also need to be made.

Tree Removal Costs

The cost of clearing and grubbing a dam depends on the size and type of trees, growth density, total job size (i.e., number of acres of trees), location of growth (crest and/or both faces?), embankment face steepness, slope condition (such as degree of wetness or surface texture), degree and type of required surface treatment (backfilling, use of herbicides or bio-barriers, mulching, seeding, fertilizing, etc.), and regional labor and construction differences.

The reader is referred to Table 1 in Chapter 2 and Figure 2 below for unit area tree removal cost comparison experiences reported in a survey by eight state dam safety officials in different regions of the country. The survey data shows that the cost of clearing and grubbing trees and other woody vegetation varies widely within and among states, but generally ranges from about $1000 to $5000 per acre, depending on site-specific conditions (Tschantz, 2000).

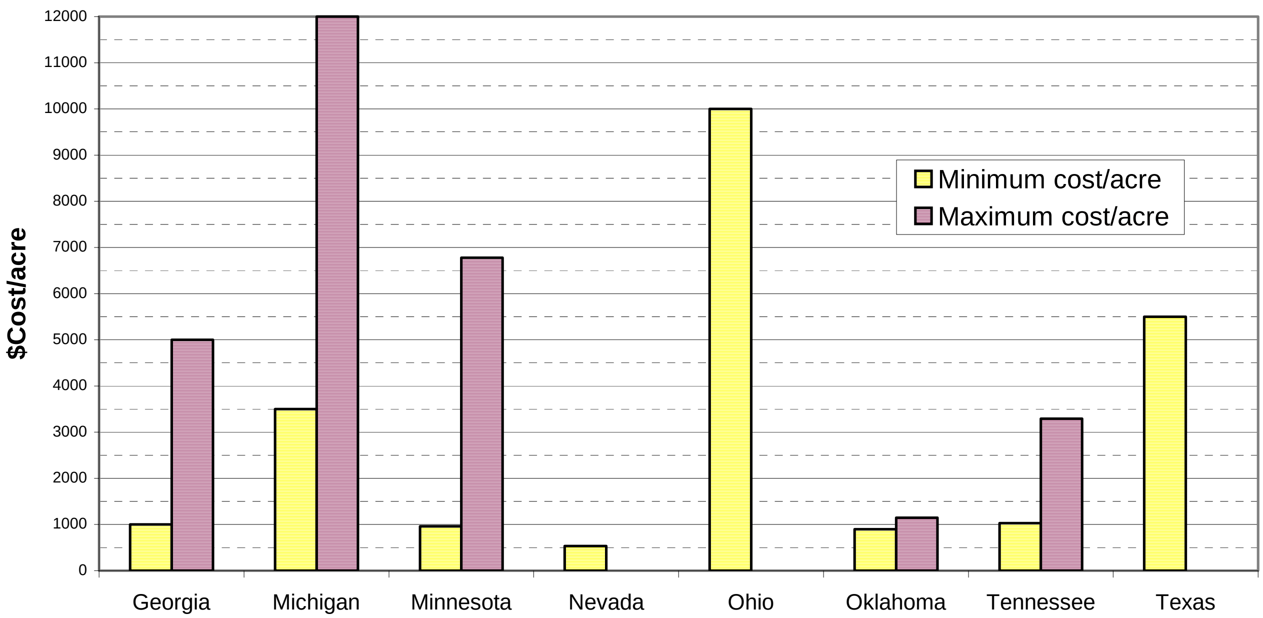


Figure 2. Comparison of tree removal costs per acre of dam surface area reported by 8 states.

These data compare favorably with the $1500 - $3000 bid price data for three Southeastern states discussed earlier in Chapter 2 for cutting trees, removing stumps and rootballs, and grubbing the area to remove roots for different dam conditions. While not included in the above Figure 2 chart data, Massachusetts' dam safety personnel reported in 2000 that, based on its own in-house experience, some local consultants and other sources, "broad area" tree removal costs ranged from $5000 and $6000 per acre or from about $800 to $1000 for individual 18-24 inch trees in their region. One dam safety official, from Tennessee, provided detailed cost data for clearing trees from seven dams in that state from 1995-1999. The cost for clearing and grubbing trees and for reseeding for one typical dam in 1998 is described for the reader in Table 1.

Dam Height	22.3 ft.
Length of Dam	830 ft.
Freeboard above Normal Pool	8 ft.
Density of trees ≤ 6 inches diameter primarily on downstream face	"Moderate"
Approximate surface area of downstream face	≅1.3 acres
Approximate dam face slopes	3H:1V
Amount of brush cutting	"Moderate"
Stumps grubbed out	Yes
Amount of hand work	"Considerable"
Total job cost for clearing, grubbing & reseeding	$4275
Unit area job cost	$3290/acre
Year job completed	1998

Table 1. Tree clearing/grubbing and reseeding cost for a "typical" dam located in Fayette Co., Tennessee (Bentley, 2000)

For comparison purposes, general sitework cost information is available from various construction cost books. General cost data for cutting and clearing out individual trees and for clearing wooded area is shown in Table 2 from one source (BNi, 2001). Indices are normally provided for factoring in regional cost differences. Other cost book sources provide detailed material, labor and equipment requirements for estimating site clearing costs (Means, 2001).

Clear small size wooded area:	
• Light density	$3,607/acre
• Medium density	$4,900/acre
• Heavy density	$5,880/acre
Cut trees & clear out stumps:	
• 9 to 12 inches diameter	$290 per tree
• To 24 inches diameter	$370 per tree
• 24 inches and up	$490 per tree

Table 2. General tree cutting and clearing construction cost data (Bni, 2001).

Similar general tree clearing and grubbing, chipping, seeding, mulching and fertilizing data for estimating construction costs in various regions of the country are also available from other sources (Means, 2001; AC&E, 2002). For example, 2001 Means cost data gives tree cutting, chipping, clearing, and grubbing costs for trees 6-inches or less to be $2975/acre and stump removal to be $1425/acre for a total unit cost of $4400/acre. For trees up to 12 inches the cost is $6925/acre, and for trees up to 24 inches the cost is $15,250/acre (Means, 2001). If burning is allowed, the cut and chip costs can be significantly reduced. Hydro or air seeding, including seed & fertilizer is estimated to be 35¢/square yard (about $1700/acre) (Means, 2001). Mulching would add to this cost.

Maintenance Costs

For most dams, maintenance means keeping the crest and dam embankment slopes mowed and trimmed. The cost of mowing a dam depends on many factors, including geographical location, accessibility, condition of slopes as discussed above, degree of public use and desired aesthetics, type of vegetation and frequency of mowing. Cost also depends on whether the work is done directly by private owners, subcontracted commercially, or done by in-house state or federal maintenance crews. Table 3 summarizes these factors. The availability of slope mowers as illustrated in

Table 3. Factors Affecting Dam Maintenance Cost

• Region of country	• Embankment slope steepness
• Type of ground cover & vegetation	• Mowing frequency
• Accessibility to dam	• Local labor costs
• Surface condition	• Type of maintenance provider
• Size of job (surface area)	• Degree of public use; aesthetics

Figure 3 illustrates the use of a slope mower for easing the burden of maintenance for state and federal agencies and for other multiple or large dam owners.

Figure 3. Example of slope mower (Terratrac© photo used with permission from AEBI North America, Inc.)

Most public works dams usually get mowed at least twice a year, in the early fall and late spring. Many subdivisions, homeowner associations, and/or residential developments typically mow dams, located in high-visibility areas, about once a month to every six weeks. One geotechnical consultant, who specializes in embankment dam rehabilitation, uses a "rule of thumb" mowing estimate of about $100 per acre with a minimum fee of $200 to $250 per mowing job (Marks, 2000). 1998 bid prices for mowing general right-of-way areas along East Tennessee highways averaged about $32 per acre, with a range of about $28 to $38 per acre for four jobs (TDOT-Region 1, 2000).

The U. S. Corps of Engineers, Nashville District, furnished recent annual mowing costs for three District dams, including some proximate recreation zones, having total mowing areas ranging from 8 to 27 acres. The average mowing cost for these three dams was about $55/acre and ranged from $43.42 to $78.24/acre (Corps, 2000).

The Tennessee Valley Authority furnished similar estimated in-house annual mowing cost data associated with general dam safety grounds maintenance activities for its dams. However, TVA's annual cost data included labor, supervision, slope mower fuel, parts, equipment, etc. and averaged slightly over $600/acre for 31 saddle and main embankment dams with a cost range from about $45 to $2000/acre (TVA, 2000).

A dam owner is advised that, in addition to mowing cost, the total annual maintenance expenditure should also include the expenses of dam inspection(s), minor repairs and rehabilitation of various structural components, removal of obstructions from emergency and service spillways, and other safety or operational costs associated with maintaining a dam.

Example maintenance cost analysis

The following example illustrates a rational procedure for answering the two earlier questions: 1) how much should a dam owner spend yearly to maintain a typical earthen dam to control trees and woody vegetation growth while avoiding bearing the cost of removing mature trees at a later date?

and 2) how often should an earthen dam be mowed to maintain acceptable ground covering vegetation? Maintenance expense in this example is for mowing only. Assumptions for this example are as follows:

1. **Dam Description:**
   - Length = 900 feet
   - Crest width = 15 feet
   - Embankment slopes (upstream and downstream) = 3:1 (horizontal to vertical)
   - Height = 35 feet
   - Normal pool = 10 feet below crest
   - Nearly vertical end abutments
2. **Economic Analysis Assumptions:**
   - 30-year project analysis period
   - Annual rates of return rates = 4, 6, 8, 10, and 15%
   - Zero annual inflation on recurring costs
3. **Maintenance Assumptions:**
   - Assume that 10-year old brush and trees are mature enough to significantly hinder effective inspection. Trees of this age can reach in size from 6 to 8 inches in diameter, depending upon species, tree density and other environmental conditions
   - Mowing costs = $100 per acre (with a minimum fee of $250 per mowing)
   - Trees can grow on all exposed upstream and downstream embankment slopes and the crest of the dam
   - Assume tree removal, including clearing and grubbing, costs = $2500/acre
   - Seeding & mulch not included in surface restoration costs.

Economic Analysis Calculations

Charts have been prepared and attached at the end of this chapter as a tool in helping to estimate mowing areas (or tree stand estimates) for different dam configurations. Chart 1 can be used to determine dam embankment slope area in acres for four slopes ranging from 1.5:1 to 3:1 (horizontal to vertical) and for dam lengths of 200 and 500 feet. Linear interpolations and ratio extrapolations can be made for other slope configurations and dam embankment lengths, respectively. Note that when determining the area of an upstream embankment slope, the equivalent dam height entered into the chart is the vertical distance between normal pool and crest elevation. Chart 2 is used to estimate dam crest area for three convenient lengths; crest areas for other actual dam crest lengths can be calculated from direct ratios. A self-guiding Chart 3 is provided to allow for small abutment area reduction corrections to be estimated and applied to slope area determined from Chart 1.

For the assumed example dam given above, make the following computations:

1. Use the attached charts to estimate total mowable and potential tree-covered dam area:

   (a) Downstream Embankment Slope (35 ft. high, 3:1 slope, 900 ft. length):
   A_1 = 1.28 acres x 900/500 = 2.3 acres (Use Chart 1; no abutment area reduction correction∗)

   (b) Crest (15 ft. wide, 900 ft. length)
   A_2 = 0.17 x 900/500 = 0.31 acres (Use Chart 2)

   (c) Upstream Embankment Slope (10 ft. high exposure, 3:1 slope, 900 ft. length):
   A_3 = 0.37 x 900/500 = 0.67 acres (Use Chart 1)

   (d) Estimated total dam area to be restored ≈ 2.3 + 0.3 + 0.7 = 3.3 acres

2. Estimated 10-year cycle clearing and grubbing job costs, over a 30-year analysis period, starting with end of 10^{th} year:

   Total Estimated Cost = 3.3 acres x $2500 per acre = $8250

∗ For this example, the abutment slopes are assumed vertical or 0^o, but total slope area reduction for a 30^o abutment would be only ≈ 0.25 acres (see Chart 3).

3. Find the annual break-even cost balance between mowing and recurring clearing and grubbing, using the sinking fund factor (SFF), assuming 4, 6, 8, 10, and 15% discount rates for a 30-year period. A sinking fund is an equivalent annual amount to be set aside and left to grow at a certain interest rate into a specified amount at the end of a predetermined time period.

It is assumed in this example that mowing and clearing and grubbing costs do not change over the 30-year analysis period and that the dam safety inspections are not hindered for up to 10-year tree growth. By assuming a zero inflation rate for these costs, the results of this exercise are not dependent on the selected period of analysis; therefore, the annual values are valid for a 50- or 100-year period as well as for a 30-year period.

- Annualized clearing and grubbing cost = $8250 x (SFF, i, N years)

  where the SFF = $i/[(1 + i)^N – 1]$

  and i = discount rate (expressed as fraction)
  N = time period, in years, between tree clearing and grubbing

- Mowing job cost = 3.3 acres x $100/acre = $330

- Equivalent number of mowings per year = (Annualized clearing & grubbing costs)/($330 per mowing)

The following Table 4 shows that the annualized clearing and grubbing costs and equivalent number of annual mowings varies somewhat with the discount rate. For this example, at a 6% discount rate, this dam owner would be able to justify about two mowings per year at $330 per mowing to avoid having to shell out $8250 every 10 years for clearing the dam of trees and woody vegetation. The owner could afford to mow once or twice a year, even at a relatively high 10%

Assumed discount rate, i	Annualized 10-yr frequency clearing and grubbing cost	Equivalent number of mowings per year
4%	$687	2.1
6%	$626	1.9
8%	$569	1.7
10%	$518	1.6
15%	$406	1.3

Table 4. Annualized Cost Comparison for Assumed $2500 per acre for a 10-Year Cycle Clearing and Grubbing Payout.

discount rate. By mowing on a regular basis, the owner would also realize side benefits of a more aesthetically pleasing dam -- one that would be viewed more as a community asset than a liability, be accessible and inspection friendly, and be less attractive to unwanted burrowing animals.

If $5000 per acre or $16,500 for 3.3 acres, rather than the $2500 per acre and $8,250 per job, had been assumed for tree clearing costs over the 10-year cycle control period, the justifiable annual costs for mowing would double for the same discount rates. For this higher restoration cost, the owner would be justified to mow 3 or 4 times per year, depending on the cost of money. The following Table 5 illustrates this assumption.

Assumed discount rate, i	Annualized 10-yr frequency clearing and grubbing cost	Equivalent number of mowings per year
4%	$1374	4.2
6%	$1252	3.8
8%	$1138	3.4
10%	$1036	3.1
15	$ 813	2.5

Table 5. Annualized Cost Comparison for Assumed $5000 per acre for a 10-Year Cycle Clearing and Grubbing Payout.

For a more conservative 5-year tree growth cycle and a $2500 clearing and grubbing cost assumption, the annualized clearing and grubbing costs would be $1523, $1464, $1406, $1351, and $1224 for the same discount rates, respectively. The corresponding justifiable mowings would be 4.6, 4.4, 4.3, 4.1, and 3.7 per year. Similarly, justifiable mowings for an assumed $5000 clearing and grubbing cost would double the justifiable mowings to 9.2, 8.9, 8.6, 8.2, and 7.4 per year. Figure 4 compares 5 and 10-year annualized costs for $2500/acre clearing and grubbing payouts.

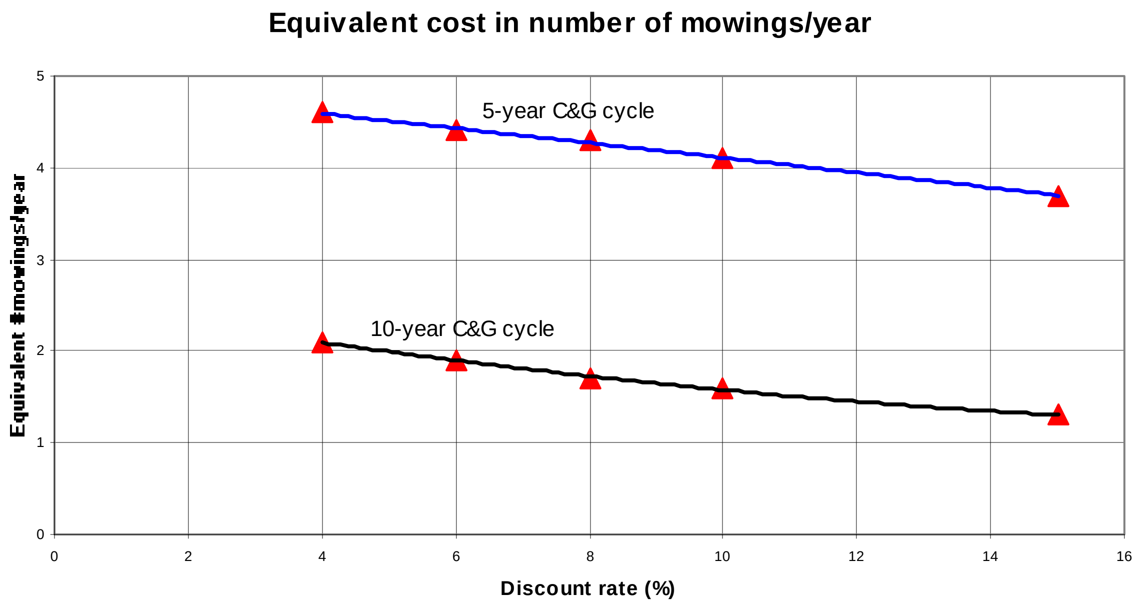


Figure 4. Comparison of Annual Tree Clearing and Grubbing Costs for 5 and 10-Year $2500/acre payouts.

Realistically, unit area costs would likely be reduced substantially for more frequent clearing and grubbing or bush hogging of smaller growth. Obviously, the above values will be different if the costs are assumed to escalate each year. For example, assuming a modest 3% annual inflation factor results in an increase in the clearing and grubbing cost from $8250 to $14,900 for a 30-year analysis period.

Summary

Cost data obtained from the private, state and federal sectors show that dam maintenance and tree removal and dam restoration costs can vary widely, depending on several factors.

It has been demonstrated, by way of example and reasonable cost assumptions, that dam owners can economically justify mowing their embankments 2 to 8 times a year, depending on local factors and costs, to prevent trees and other woody vegetation from maturing to a point that could compromise dam safety and require major capital outlays. It appears extremely economically efficient for dam owners to control woody growth on at least an annual basis, to avoid the large cost of removing mature brush and trees every 5 to 10 years and to comply with state inspection requirements.

So, how much should a dam owner spend on maintaining his dam? At least enough to keep it mowed and trimmed a couple times a year – probably something in the neighborhood of $500 to a $1000 annually for most dams, if contracted. Keeping a dam mowed a minimum of twice a year does not appear to be an unreasonable financial burden for most small dam owners. A dam owner must understand that spending a few dollars on annual vegetative maintenance and upkeep, such as mowing, will pay dividends over the long run for an asset (and potential liability) such as a dam.

References

1. Architects, Contractors, and Engineers (AC&E), Guide to Construction Costs, Division #2 – Sitework & Demolition, Cyber Classics, Inc., 2002.

2. Association of State Dam Safety Officials (ASDSO), State Survey: Animal and Vegetative Impacts on Dams, Part I - Vegetation on Dams (7 questions), September 1999

3. Association of State Dam Safety Officials (ASDSO), State Survey, Percentage of Trees on State-regulated Dams (2 questions), January 2000.

4. Bentley, L., Memorandum: Cost of Dam Clearing on Seven Tennessee Dams, February 2000.

5. BNi Building News, General Construction 2001 Costbook, Sections 02110.01-02110.50 (Sitework), 2001, p. 18.

6. Marks, B. D., S&ME Engineering, Inc., Arden, N. C., Faxed communication on recent contractor-bid clearing and grubbing costs, February 23, 2000.

7. Means, R.S., Building Construction Cost Data 2001, Site Preparation Section 02230, 2001, pp. 42-43.

8. Soil Conservation Service, U. S. Department of Agriculture, South Technical Service Center, Fort Worth, Engineering Technical Note 705, Operations and Maintenance Alternatives for Removing Trees from Dams, April 1981, 8 pp.

9. Tschantz, B. A., Overview of Issues and Policies Involving Woody Plant Penetrations of Earthfilled Dams, Presentation and Proceedings, ASDSO/FEMA Specialty Workshop on Plant and Animal Penetrations on Dams, Nov. 30 - Dec. 30, 1999, 8 pp.

10. Tschantz, B. A., Current Problems, Practices and Policies on Tree and Woody Plant Penetration of Dams, paper presented at ASDSO National Dam Safety Conference, Providence, R. I., September 2000.

11. Tennessee Department of Transportation (TDOT), Region 1 Supervisor, Mowing contract bid data – 1998, March 2000.

12. U. S. Bureau of Reclamation, U. S. Department of the Interior, Guidelines for Removal of Trees and Other Vegetative Growth From Earth Dams, Dikes, and Conveyance Features, Bulletin No. 150, Water Operation and Maintenance, December 1989, pp. 1-3.

13. U. S. Corps of Engineers, Nashville District, email information furnished by D. Williams, March 2000.

14. Tennessee Valley Authority, Knoxville, TVA Maintenance Data, Email attachment information furnished by J. Morse, April 2000 and August 2001.

Chart 1. Dam face area for different geometries

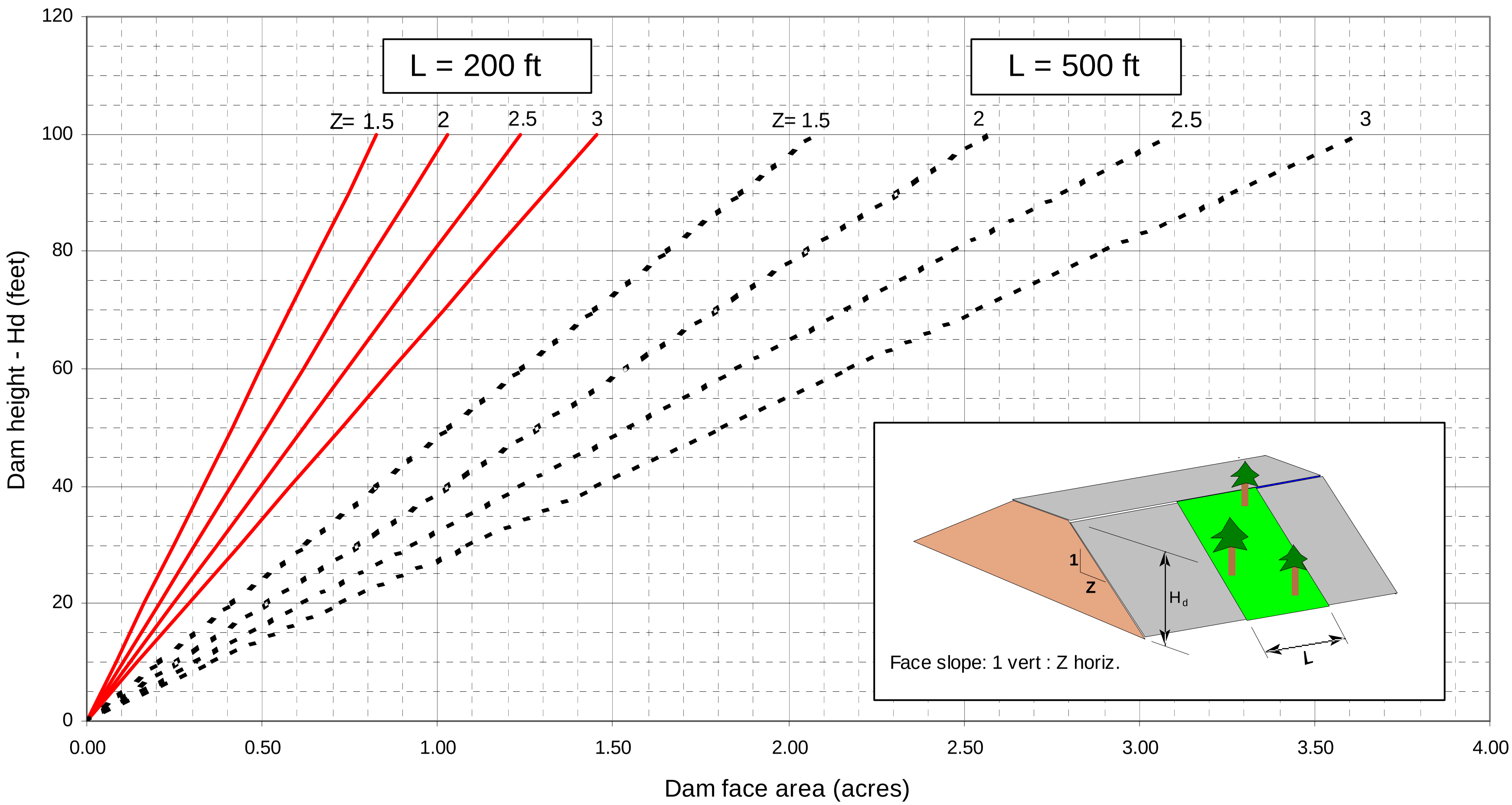


Chart 2. Dam crest area by width and length

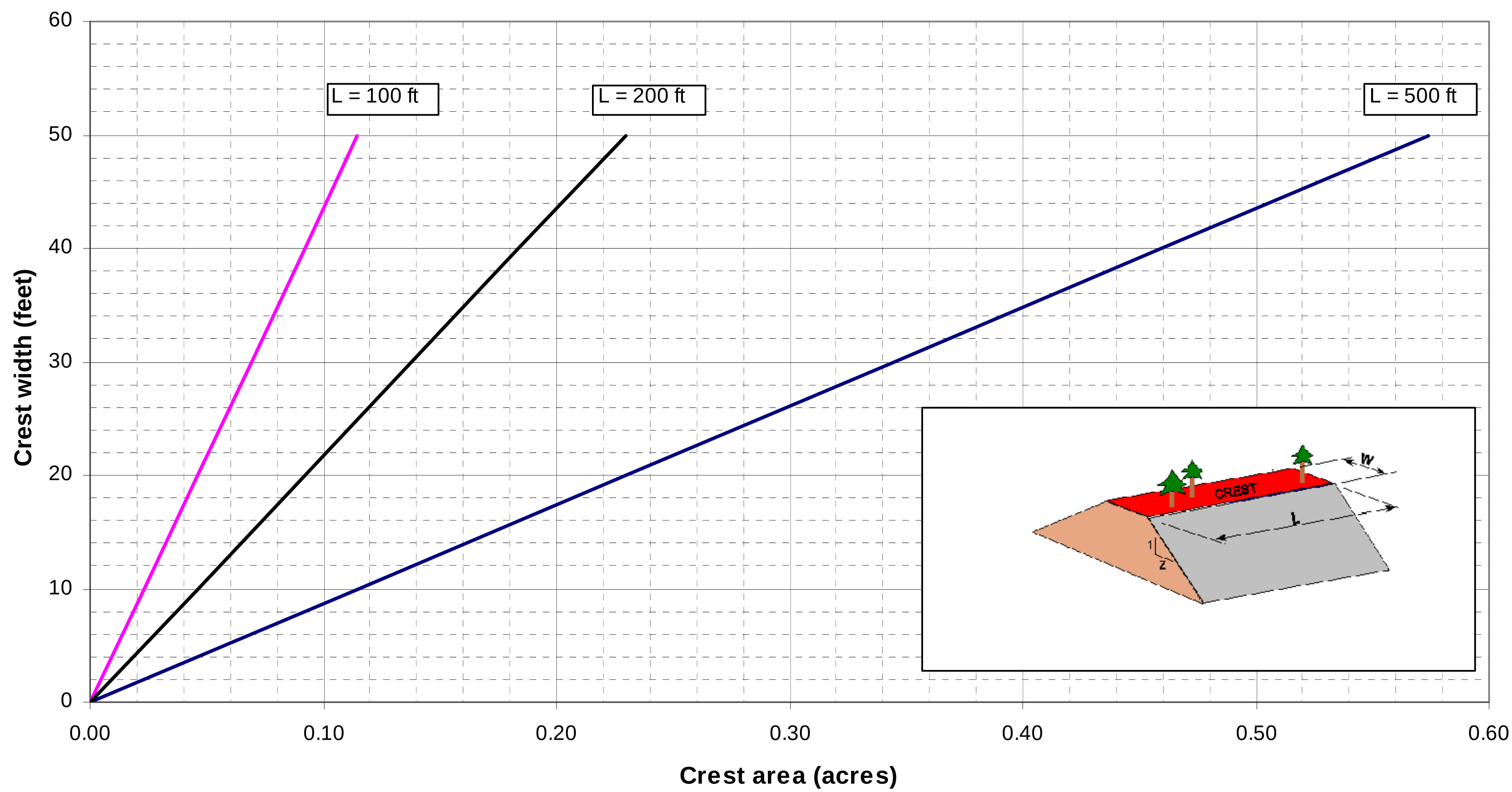
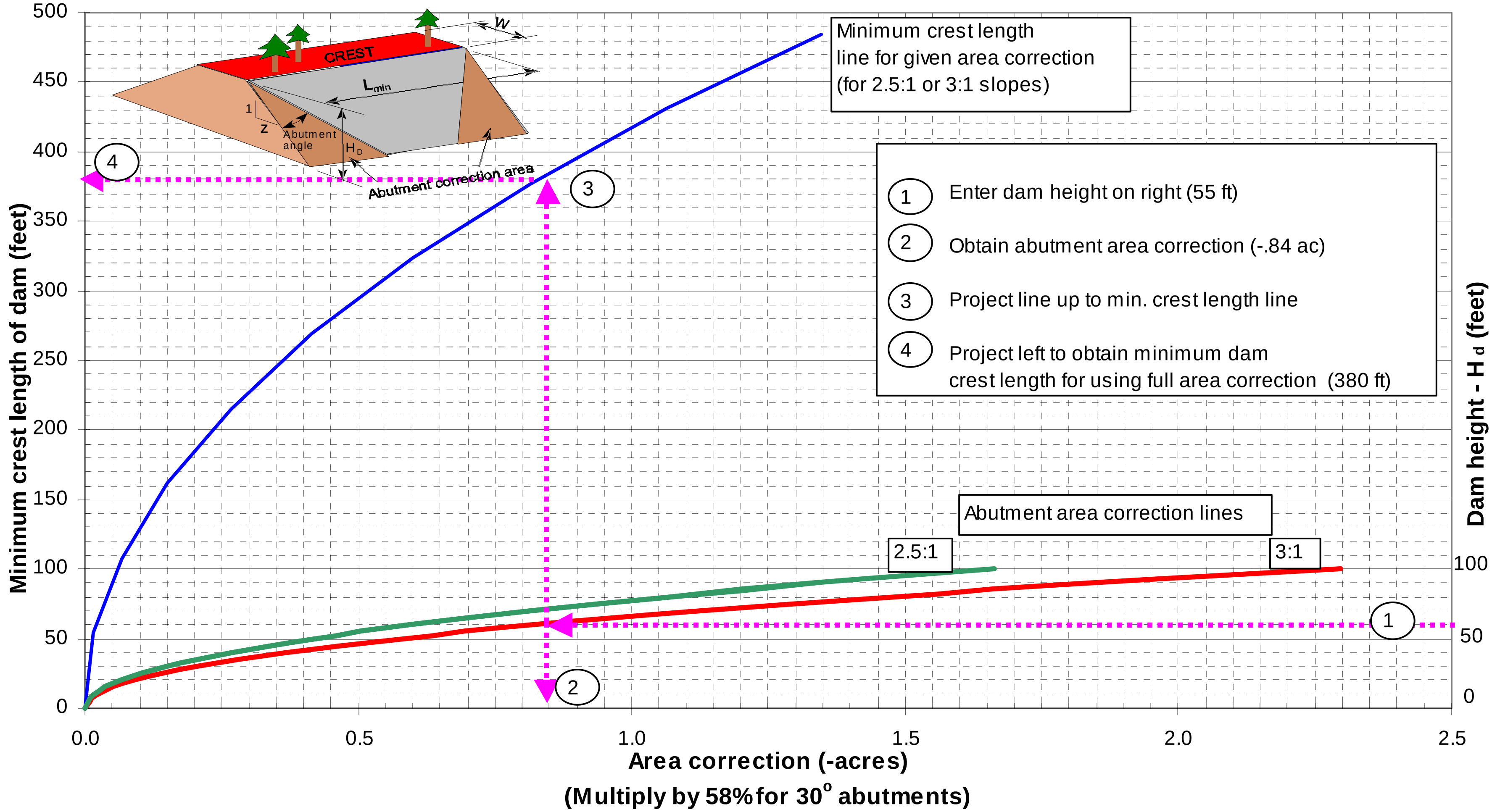


Chart 3. Abutment area corrections vs. dam height for 2.5H:1V & 3H:1V side slopes, with 45° abutment angle and corresponding minimum dam crest length



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Decommissioning (Removal, Retirement, Deactivation) of Dams

Charles Karpowicz, P.E.[1]

In addition to the design, evaluation, remediation, operation, and maintenance of dams, decommissioning has also become a valuable aspect of managing dams.

The Federal Guidelines for Dam Safety provide the most complete and authoritative statement available of the desired management practices for promoting dam safety and the welfare of the public and includes the reference to the "ultimate disposition" of dams. Also several states have developed programs and have become very active with decommissioning.

Most of the following overview information is taken from the United States Society of Dams (USSD) Committee on Dam Decommissioning, Denver, CO. The USSD Guidelines on Dam Decommissioning Projects are expected to be released in 2014. It covers all aspects of decommissioning including the very critical chapter on sediment management. Although "Googling" will produce thousands of references on this subject, the USSD Guidelines on Dam Decommissioning Projects are believed to be the most comprehensive guideline available for dam safety engineers.

Decommissioning is defined as the full or partial removal of an existing dam and its associated facilities or significant changes to the operations.

The building of dams to provide for growth, development, and national security has been an important part of economic and social development of the United States. Thousands of existing dams now support a multitude of benefits.

Several changes have occurred in the past decade to limit the construction of new dams and to create more interest in the removal of existing dams: most of the viable sites for large dams have been developed; environmental philosophies of our country are often at odds with the construction of, and the continued use of dams and reservoirs; the cost of upgrading and maintaining many older dams to meet present safety standards is becoming significant; and many older dams, especially those associated with abandoned or outdated industrial and navigation facilities are no longer needed.

There are many reasons for removing a dam - obsolescence, environmental concerns, economics, safety criteria, risk reduction, and operation and maintenance costs.

Dam construction, repair, and operational costs of today far exceed those of even a decade past. Many older dams do not meet current safety criteria for floods or earthquakes. The benefits provided by the dam, such as hydropower production, may not justify repairing or rebuilding the dam. Along with keeping a dam compliant with existing safety criteria, legal liability in the event of a sudden uncontrolled release of water is an increasing concern.

One of the most common environmental considerations is fisheries habitat for selected species, especially salmonids and other migratory fish that are threatened or endangered. Another common environmental issue is wetlands that are widely regarded as valuable ecological

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resources. Productive wetlands are sometimes inundated in reservoirs, but new wetlands and aquatic habitat are created in areas upstream.

Sediment accumulating and stored in reservoirs becomes an environmental concern when decommissioning is contemplated. Disposal of contaminated sediments that would be excavated or dredged prior to dam removal may be a significant issue.

Impacts to upstream and downstream infrastructure may be of concern, since foundations for bridge piers and abutments, as well as any shallow pipelines or other utilities that cross the channel may be subjected to increased scour potential from higher flow velocities than for which they were designed.

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If the dam owner can benefit substantially from ongoing operation of the dam and reservoir, it is normally feasible to maintain and upgrade the facilities to improve dam safety and comply with regulatory requirements. Where the benefits of the dam have been substantially reduced, there is often reluctance to invest in dam repairs, albeit with increased liability. In this case dam decommissioning may be considered for economic (and liability) reasons, as the long-term costs and risks for continued operation of the dam may very well exceed those for dam decommissioning.

The economic considerations associated with decommissioning a dam are significant, as for operating and improving an aging dam. Careful advance planning is required, including analysis of alternatives, preliminary cost estimates, permitting requirements and consensus-building with concerned parties that must be identified.

The environmental permitting process begins early, and may significantly impact costs for design, construction and maintenance of the decommissioned facility. Permits must be obtained from federal, state and local regulatory agencies, which sometimes take conflicting positions on a number of issues.

Planning a dam decommissioning project is much like the original construction project, except the end product is considerably different. All decommissioning projects are likely to be subject to National Environmental Policy Act mandates. Therefore, it is critical to identify all issues and obtain stakeholder concurrence early in the process. The process begins with the study of all alternatives including repair and upgrade and decommissioning.

Selected Resources

- American Rivers, Dam Removal Center, http://www.americanrivers.org/initiatives/dams/dam-removal-resource-center/
- DeGraff and Evans; "The Challenges of Dam Removal and River Restoration"
- Gough, Philipsen, Schollema, and Wanningen; "From Sea to Source", fish migration restoration
- Pohl, "Bringing Down Our Dams: Trends in American Dam Removal Rational"
- USSD, Committee on Dam Decommissioning; Guidelines on Dam Decommissioning Projects; to be released 2014, http://ussdams.com/proceedings/2012Proc/855.pdf
- UC Riverside, CA, Clearinghouse for Dam Removal Information (CDRI), http://library.ucr.edu/wrca/collections/cdri/

Reference

- USSD, Committee on Dam Decommissioning; Randle, et al; http://www.ussdams.org/c_decom.html

VIRGINIA DAM SAFETY PROGRAM

Dam Failures in Virginia

Dam Failures in Virginia since 1995:

- At least 97 dam failures.
- Four lives lost.
- 52 dams were complete loss.
- 22 public roads destroyed.
- 11 roads are still closed today.

Historic dam failures include:

- The Saltville Muck Dam failure in 1924 caused 19 deaths and destroyed the town of Saltville.
- The Timberlake Dam failure in 1995 caused 2 deaths and over one million dollars in flood damage.
- The Lake Powell Dam failure in 1999 cost VDOT over $250,000 to repair the roadway. A subsequent failure in 2004 resulted in the roadway being permanently closed. Neighborhood property values dropped about 30 percent due to the permanent loss of the lake.
- A series of dam failures during 2004 contributed to 2 deaths in Hanover County.

Deficient spillway capacity is the most common cause of dam failures.

Dam failures caused by deficient spillways:

- 15 in 2011 during Irene.
- 17 in 2004 during Gaston.
- 15 in 1999 during Floyd.

For more information on the Virginia Dam Safety Program managed by the Virginia Department of Conservation and Recreation, contact:

Robert Bennett,
Department of Conservation and Recreation,
Director of Dam Safety and Floodplain Management,
at 804-786-3914 or
robert.bennett@dcr.virginia.gov.

DCR
Virginia Department of Conservation & Recreation

(DCR-VSWCB-034) (03/14)

VIRGINIA DAM SAFETY PROGRAM

Dam Failures in Virginia

TWO EXAMPLES OF DAM FAILURES CAUSED BY DEFICIENT SPILLWAYS:

Placid Bay dam failure, Westmoreland County

- More than $700,000 in damage.
- Loss of roadway and utilities.
- 50 homes had no vehicle access for two weeks.

Byrd's Mill dam failure, Caroline County

- $1,000,000 in damage.
- Two public roadways destroyed.
- One road is still closed today.

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at 804-786-3914 or
robert.bennett@dcr.virginia.gov.

DCR
Virginia Department of Conservation & Recreation

Dam Safety Web Sites

DCR, Virginia Dam Safety and Floodplain Management (with link to State Regulations)
http://www.dcr.virginia.gov/dam_safety_and_floodplains/

FEMA Dam Safety Publications
http://www.fema.gov/dam-safety-publications-resources

www.fema.gov/resource-document-library

FEMA Dam Owners Guidance Manual FEMA-145 from ASDSO
http://www.damsafety.org/media/Documents/FEMA/145_GuidanceManual_87.pdf

FEMA guide for downstream property owners
www.livingneardams.org

PMP, NOAA, National Weather Service
http://www.nws.noaa.gov/oh/hdsc/studies/pmp.html

http://www.nws.noaa.gov/

http://radar.weather.gov/ridge/Conus/northeast.php

http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml

http://nws.noaa.gov/glossary/index.php?letter=a

HEC-HMS, HEC-RAS, US Army Corps of Engineers software
http://www.hec.usace.army.mil/software/

Federal Government User Guides
http://directives.sc.egov.usda.gov/

US Army Corps of Engineers Manuals (Dams - EM 1100-2-1900 to EM 1110-2-2504)
http://140.194.76.129/publications/eng-manuals/

US Army Corps of Engineers/DEQ Joint Permit Applications (JPA)
http://www.nao.usace.army.mil/technical%20services/Regulatory%20branch/JPA.asp

NRCS National Engineering Handbook (Dams - Part 628)
http://policy.nrcs.usda.gov/RollupViewer.aspx?hid=17092

NRCS SITES program for analyzing spillway erosion
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/ndcsmc/?cid=stelprdb1042198

http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/alphabetical/water/hydrology/?&cid=stelprdb1042517

US Bureau of Reclamation Dam Safety
http://www.usbr.gov/ssle/damsafety/

http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/SmallDams.pdf (important design doc.)

SMS 8/27/2013

Dam Safety Web Sites

NRCS Dam Safety Resources
http://www.damsafety.info/

FERC Dam Safety Program
http://www.ferc.gov/industries/hydropower/safety.asp

Soil and Water Conservation District references?
http://vaswcd.org/

Association of State Dam Safety Officials
http://www.damsafety.org/

Virginia Lakes and Watersheds Association
http://www.vlwa.org/

Virginia Town Hall (Laws and Legislation)
http://townhall.virginia.gov/index.cfm

Virginia Dam Safety Act (Dam Safety 10.1-604 to 10.1-613.5)
http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+TOC10010000006000000000000

Code of Virginia (Title 10, Chapter 6 contains dam safety - same as above link)
http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+TOC

Federal Dam Safety Act
http://thomas.loc.gov/cgi-bin/bdquery/z?d107:HR04727:@@@L&summ2=m&

Richmond Times Dam Safety Data Base (not 100% accurate but only public access on line list)
http://datacenter.timesdispatch.com/databases/virginia-dams/?appSession=739175441425116&RecordID=&PageID=2&PrevPageID=3&cpipage=1&CPISortType=&CPIorderBy=

Transferring CAD to GIS how to
http://webhelp.esri.com/arcgiSDEsktop/9.3/index.cfm?TopicName=Transforming_CAD_datasets

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VDEM 24 hour contact number for EAP
VA Emergency Operations Center
804-674-2400

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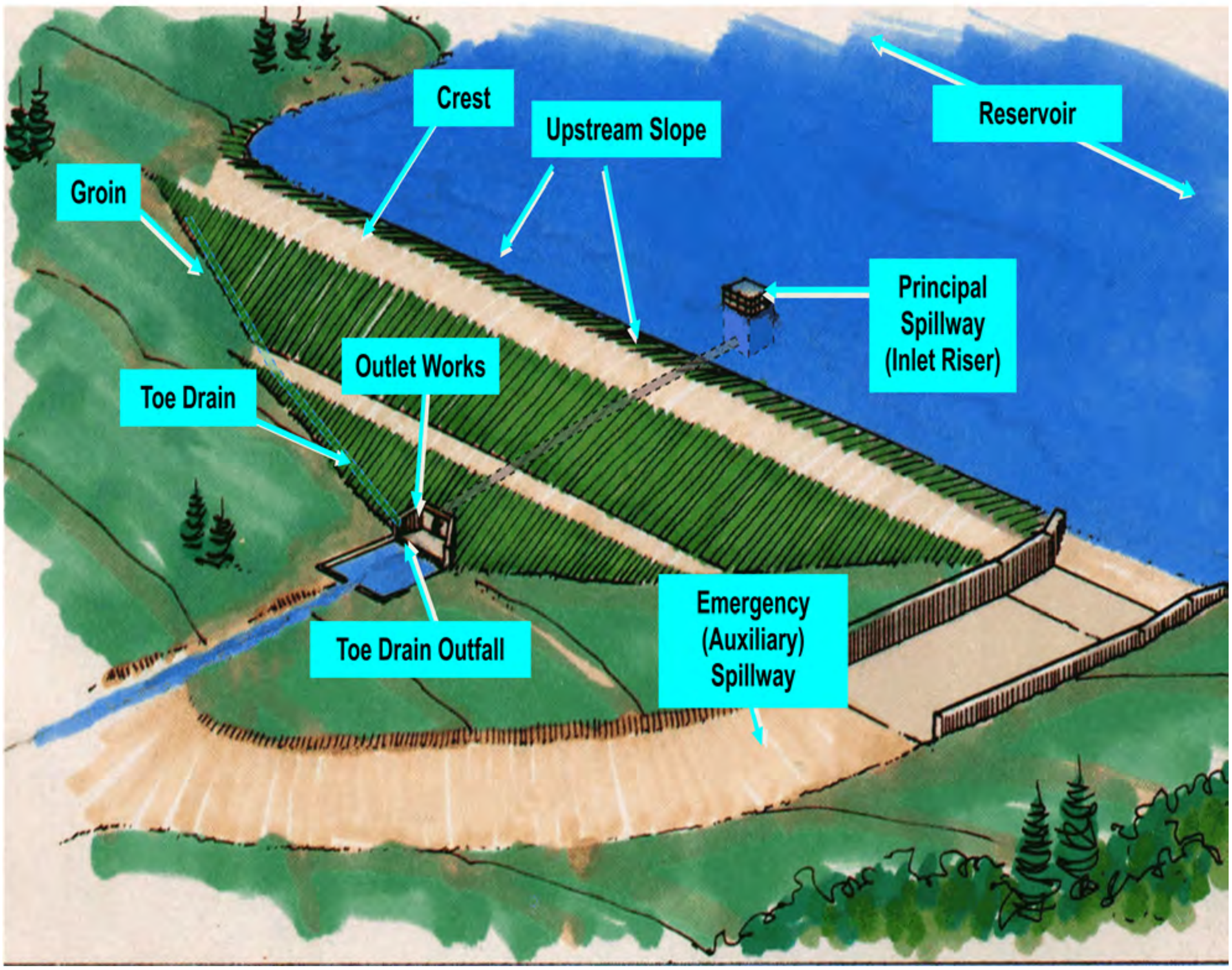
Parts of an Embankment Dam



Virginia Department of Conservation & Recreation