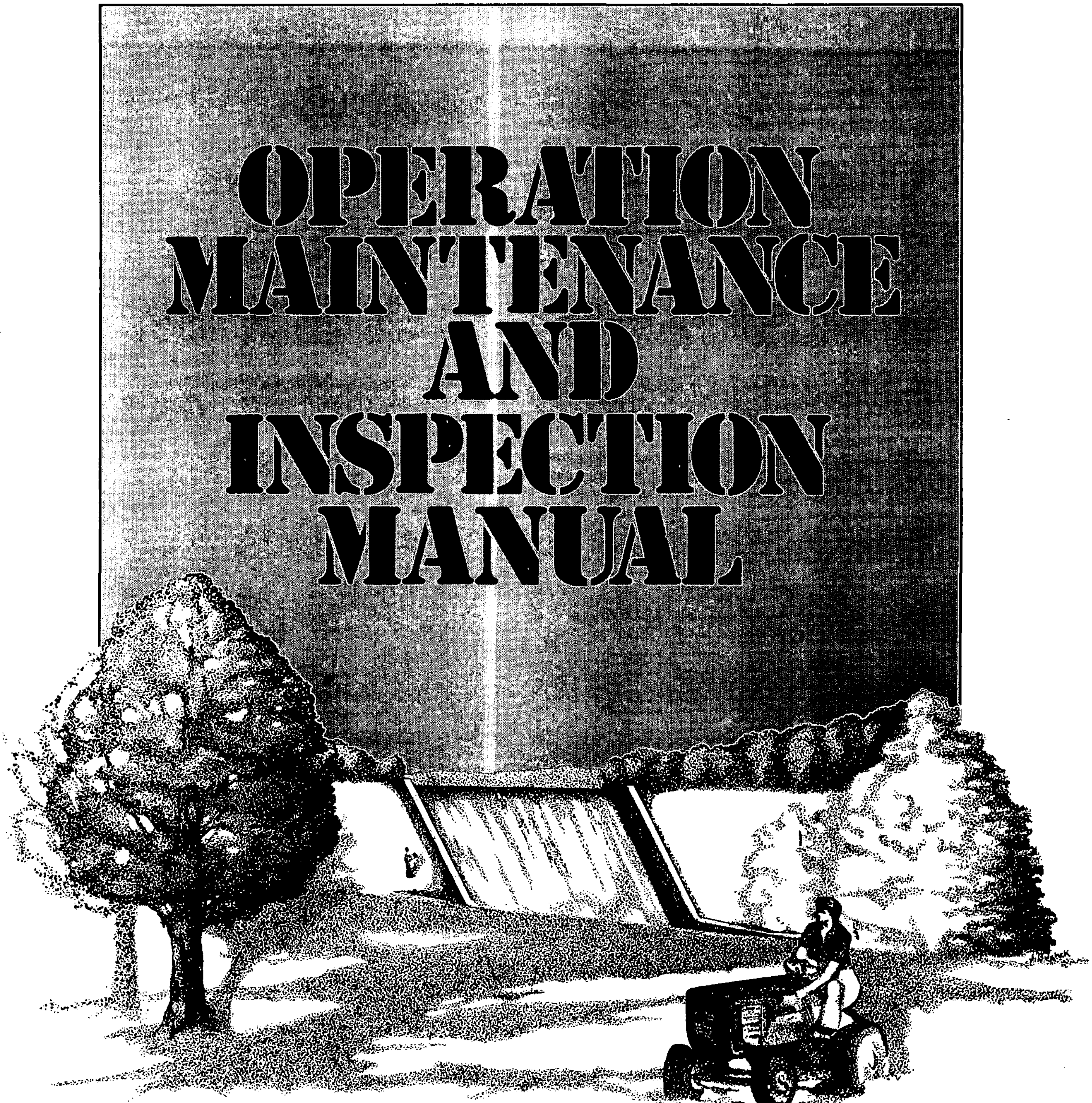
OPERATION MAINTENANCE AND INSPECTION MANUAL



FOR DAMS, DIKES AND LEVEES

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DIVISION OF WATER
DAM INSPECTION SECTION

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PREFACE

To: Mom & Dad

This manual was developed to assist owners in their regular maintenance, operation, and inspection activities. The information presented should also be valuable to many engineers. Recommendations and suggestions noted herein represent 20 years of experience by the Ohio Department of Natural Resources (ODNR), Division of Water, in issuing construction permits for new dams and inspecting existing dams. Emphasis has been placed on small earth structures, the dams most commonly found in Ohio. However, much of the information will apply to dams of all types and sizes and also to dikes and levees.

The manual is divided into four basic sections: dam failures and emergency procedures; maintenance of embankments; maintenance of spillway and control structures; and operation. Each of the sections on maintenance also covers items to look for during an inspection. The section on dam failures and emergency procedures covers indicators of potential failure and what to do in an emergency to save the dam and recommended procedures for warning downstream areas. An Index of Common Problems has been included at the front of the manual following the Table of Contents.

Throughout the manual, there are numerous recommendations to contact an engineer experienced with dams when certain observations are made. The importance of these recommendations cannot be over emphasized. Dams are complex structures and the causes and remedies of certain problems may not be obvious to a layperson.

This manual has been prepared to be placed in a notebook. The use of a notebook will provide space for the owner to include such items as past inspection reports and correspondence, current inspection observations, operation and maintenance records, plans and other construction records, if available, and any other information pertinent to the dam. This should provide a means whereby owners can keep accurate and up-to-date records of their dams.

Certain information in this manual was taken in part from existing publications. These sections are noted, i.e. *Ohio Pond Management*(7) with detailed references listed at the end of the manual.

The manual was prepared by George E. Mills, a professional engineer of the Dam Inspection Section of the Division of Water. Mr. Mills has worked in the Division of Water for 14 years in both the Dam Permits and Dam Inspection Sections.

This manual was prepared and edited under the general direction of J. Bruce Pickens, Administrator, Dam Inspection Section. The author would also like to acknowledge and thank Joel A. Reed, who helped edit and prepared the illustrations, and Kimberly S. Coe, Kathryn B. Corson, Val A. Zampedro, Paul G. Novak, Richard W. Warden of the Dam Inspection Section, Charles L. Hahn of the Dam Permits Section, and all others in the Department of Natural Resources who assisted in the preparation, illustration, editing and writing of this publication.

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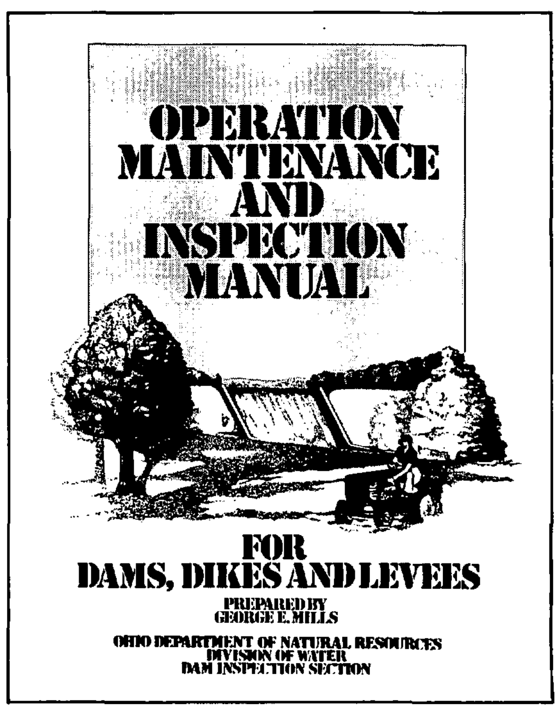


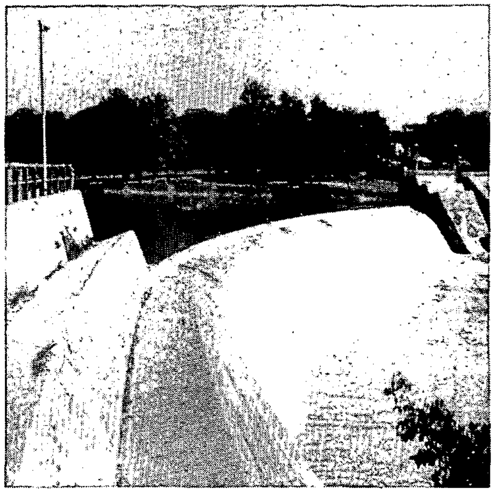
CONTENTS

INDEX OF COMMON PROBLEMS

PART I

INTRODUCTION

INTRODUCTION



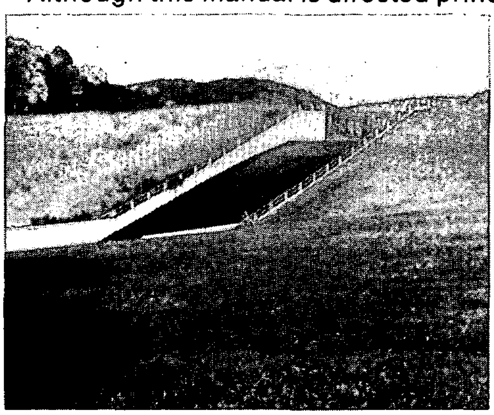
Left:
A concrete dam.

How important is maintenance? If designed and constructed properly, should not all dams be maintenance-free? The answers to these questions may seem obvious, but several small dams in Ohio fail every year due to the lack of timely maintenance. In most cases, failure could have been prevented if these "structures" had been properly maintained. Dams, dikes, and levees must not be thought of as part of the natural landscape, but as man-made structures which must be designed, inspected, operated, and maintained accordingly. Maintenance is an ongoing process that not only involves such routine items as mowing the grass and clearing the trashrack, but also includes regularly inspecting the structure and properly operating its components.

Major rehabilitation of a dam, dike, or levee should not be necessary if the dam was designed in accordance with good engineering practice, was built using good construction standards, and is operated and maintained properly. Engineers generally agree that the design of a dam is not complete until after the dam has been built and the reservoir has filled with water. Design engineers should inspect their dams periodically after construction to ensure that the design is working and the structure is properly operated and maintained.

The objective of the Ohio Department of Natural Resources dam safety program is to provide for safe dams, dikes, and levees in Ohio. However, this objective cannot be accomplished without the continued cooperation of owners and their personnel, engineers, and contractors. This manual was developed to assist owners in their regular maintenance, operation, and inspection activities. Many of the ideas for this manual came from owners. The information provided herein is intended to help owners maintain safe dams, dikes, and levees.

Although this manual is directed principally toward the maintenance of dams, many of the subjects covered are equally applicable to the maintenance of dikes and levees.



Left:
An earth dam.

In this manual the word *dam* refers to an artificial barrier together with its associated (or appurtenant) works which either does or may impound water or liquefied material. The artificial barrier may be composed of timber, rock, concrete, earth, steel, or a combination of these materials. Associated works include spillways, and water supply and lake drain structures. Most dams in Ohio have an earth embankment, one or two spillways, and a lake drain. Dikes and levees are generally earth embankments and may include associated works such as pumps and drains. Other terms are defined in the glossary.

DAM SAFETY LAWS

Ohio law (Sections 1521.06 and 1521.062 of the Revised Code) requires that a permit application be made to construct new dams, dikes, and levees, and that existing dams, dikes, and levees be inspected periodically to assure that their continued operation and use does not constitute a hazard to life, health, and property. Dams less than 10 feet high, as measured from the natural streambed to the spillway level, are not subject to the referenced permit and inspection requirements. The ODNR, Division of Water, is responsible for administration of the dam safety laws in Ohio.

Over 6,500 dams are included in an inventory of those that may need inspection under Ohio law. Available funds and staffing will not permit a thorough inspection of each dam every five years as mandated by state law. The current program in Ohio involves regular and more thorough inspection of dams identified as having the greatest potential for damage in the event of failure. Less hazardous structures are inspected as time and funds permit and upon request.

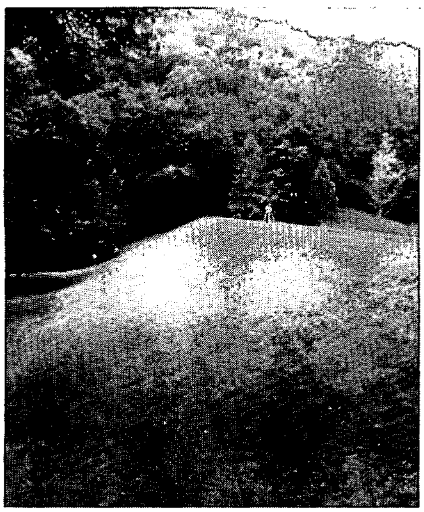
The National Dam Safety Act (Public Law 92-367) passed by Congress in 1972 called for an inventory of dams in the United States and a one-time inspection of those dams that could create the most hazard in the event of failure. In Ohio, 227 dams were inspected under this federal program, which ended in 1981.

Owners of dams should be aware that they are legally responsible for the operation, maintenance, and inspection of their structures. Negligence by owners in fulfilling their responsibilities can lead to the creation of extremely hazardous conditions to downstream residents and properties.

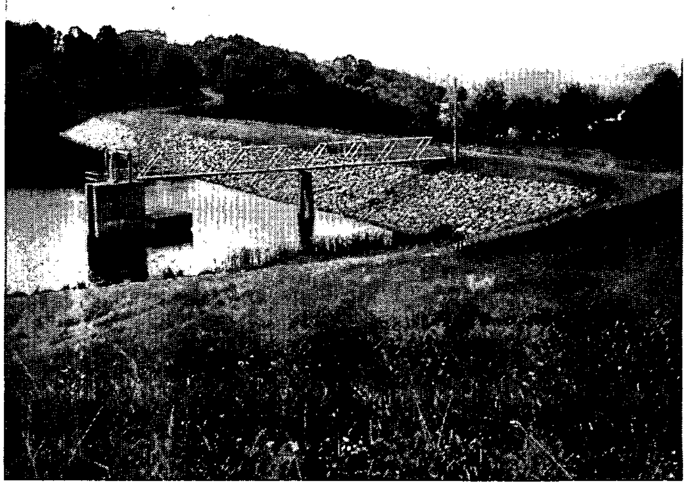
Failure of a dam can result in loss of life, considerable loss of capital investment, loss of income, and property damage. Loss of the reservoir can cause hardship for those dependent on it for their livelihood or water supply and will upset the ecological balance of the area. In the event of failure, the owner can be subject to a barrage of liability claims and possibly even criminal charges.

If a failure occurs during a severe flood, it is likely that downstream residents will blame their damage on the dam failure even though it may have contributed only a small portion of water to the flood. It is very difficult, if not impossible, to prove in court that the failure had little or no effect on the downstream area during passage of the flood. Consequently, dam owners are often held liable for downstream damages.

One question frequently asked by owners is the availability of financial assistance from either the state or federal government for dam repair. There is no federal or state financial assistance available as of the date of this publication. Technical advice is available from the ODNR Dam Inspection Section upon request.



A well maintained embankment slope.



An embankment with associated works (principal spillway, emergency spillway and lake drain control tower adjacent to principal spillway).

PART

FAILURE AND EMERGENCY ACTIONS

II

EARTH DAM FAILURES

Owners of dams and operating and maintenance personnel must be knowledgeable of the potential problems which can lead to failure of a dam. These people regularly view the structure and, therefore, need to be able to recognize potential problems so that failure can be avoided. If a problem is noted early enough, an engineer experienced in dam design, construction, and inspection can be contacted to recommend corrective measures, and such measures can be implemented. IF THERE IS *ANY* QUESTION AS TO THE SERIOUSNESS OF AN OBSERVATION, AN ENGINEER EXPERIENCED WITH DAMS SHOULD BE CONTACTED. Acting promptly may avoid possible dam failure and the resulting catastrophic effect on downstream areas. Engineers from the Dam Inspection Section of the Department of Natural Resources are available at any time to inspect a dam if a serious problem is detected or if failure may be imminent. Contact:

Ohio Department of Natural Resources
Division of Water
Dam Inspection Section
Fountain Square, Building E-3
Columbus, Ohio 43224
In an emergency, call (614) 265-6731 or
(614) 466-3048
during non-business hours

Since only superficial inspections of a dam can usually be made, it is imperative that owners and maintenance personnel be aware of the prominent types of failure and their telltale signs. Earth dam failures can be grouped into three general categories. These are: overtopping failures, seepage failures, and structural failures. A brief discussion of each type follows.

Overtopping Failures

Overtopping failures result from the erosive action of water on the embankment. Erosion is due to uncontrolled flow of water over, around, and adjacent to the dam. Earth embankments are not designed to be overtopped and therefore are particularly susceptible to erosion. Once erosion has begun during overtopping, it is almost impossible to stop. A well vegetated earth embankment may withstand limited overtopping if its top is level and water flows over the top and down the face as an evenly distributed sheet without becoming concentrated. The owner should closely monitor the reservoir pool level during severe storms.

Seepage Failures

All earth dams have seepage resulting from water percolating slowly through the dam and its foundation. Seepage must, however, be controlled in both velocity and quantity. If uncontrolled, it can progressively erode soil from the embankment or its foundation, resulting in rapid failure of the dam. Erosion of the soil begins at the downstream side of the embankment, either in the dam proper or the foundation, progressively works toward the reservoir, and eventually develops a "pipe" or direct conduit to the reservoir. This phenomenon is known as "piping." Piping action can be recognized by an increased seepage flow rate, the discharge of muddy or discolored water, sinkholes on or near the embankment, and a whirlpool in the reservoir. Once a whirlpool (eddy) is observed on the reservoir surface, complete failure of the dam will probably follow in a matter of minutes. As with overtopping, fully developed piping is virtually impossible to control and will likely cause failure.

Seepage can cause slope failure by creating high pressures in the soil pores or by saturating the slope. The pressure of seepage within an embankment is difficult to determine without proper instrumentation. A slope which becomes saturated and developes slides may be showing signs of excessive seepage pressure.

Structural Failures

Structural failures can occur in either the embankment or the appurtenances. Structural failure of a spillway, lake drain or other appurtenance may lead to failure of the embankment. Cracking, settlement, and slides are the more common signs of structural failure of embankments. Large cracks in either an appurtenance or the embankment, major settlement, and major slides will require emergency measures to ensure safety, especially if these problems occur suddenly. The lake level should be lowered, the appropriate authorities notified (see page 10), and professional advice sought. If the observer is uncertain as to the seriousness of the problem, the Dam Inspection Section should be contacted immediately (see page 7).

The three types of failure previously described are often interrelated in a complex manner. For example, uncontrolled seepage may weaken the soil and lead to a structural failure. A structural failure may shorten the seepage path and lead to a piping failure. Surface erosion may result in structural failure.

Minor defects such as cracks in the embankment may be the first visual sign of a major problem which could lead to failure of the structure. The seriousness of all deficiencies should be evaluated by someone experienced in dam design and construction. A qualified professional engineer can recommend appropriate permanent remedial measures.

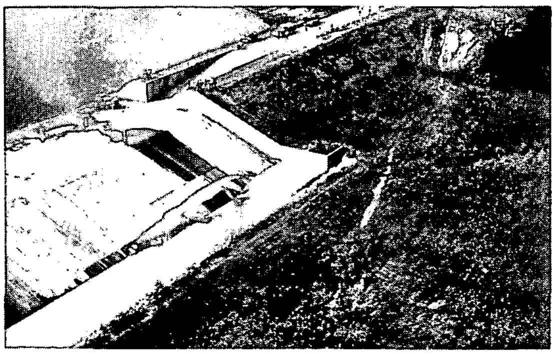
The next section on Emergency Actions and Procedures includes information on what to do in the event that a serious problem is detected or failure of the dam appears imminent. Also described are temporary actions and repairs which can be tried if any of the three types of failure are identified.

EMERGENCY ACTIONS AND PROCEDURES

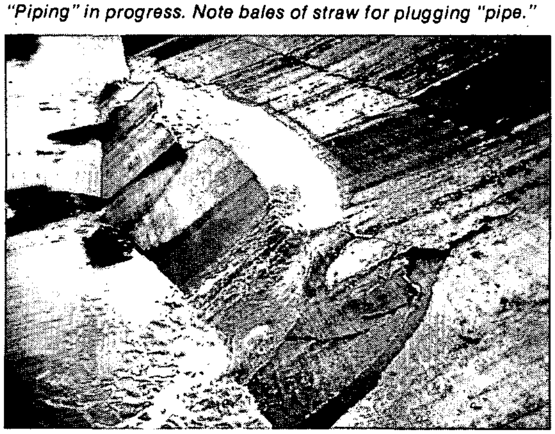
Dam owners and operating personnel must be prepared to act promptly and effectively when a dam begins to show signs of failure. Early identification of a hazardous situation may provide additional time to warn and evacuate downstream residents and to implement measures to prevent or delay dam failure. Because failure of a dam may take only minutes or hours, it is imperative to have a detailed plan of action ready for use. The emergency plan should include procedures for notification and coordination with local law enforcement and other governmental agencies, information on potential areas of inundation, plans for warning and evacuation, and information on resources and procedures for making emergency repairs.

Identification of Emergency Conditions

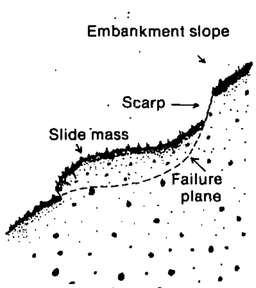
Early identification of hazardous conditions at a dam will allow prompt implementation of emergency actions and procedures. Dam owners and operators should be familiar with the principal types of failure and their telltale signs as described in this and the preceding section on Earth Dam Failures. If any of the following conditions are noted, the emergency plan should be implemented *immediately*.



"Piping" in progress. Note bales of straw for plugging "pipe."



1. *The dam is overtopping or nearly overtopping.* The dam owner or operator should closely monitor the level of the reservoir during periods of heavy rainfall and runoff. If the spillway and reservoir storage capacities are exceeded, overtopping will occur. Overtopping could result if a large slide in the upstream or downstream slope of the embankment significantly lowered the dam crest. Blockage of pipe spillways may also cause overtopping of a dam.
2. *Piping (internal erosion of soil from the dam or its foundation) has developed.* Piping is usually indicated by a rapid increase in seepage rate, a muddy discharge at or near the downstream toe, sinkholes on or near the embankment, and/or a whirlpool (eddy) in the reservoir. Boils at or near the downstream toe may be indications that piping is beginning.
3. *A large slide develops in either the upstream or downstream slope of the embankment and threatens to release the impounded water.*
4. *Sudden and rapid failure of an appurtenant structure threatens complete failure of the dam and release of its impoundment.*



Identification of any of these conditions at a dam should be cause for alarm and the emergency plan should be implemented promptly. If there is a question as to the severity or urgency of the suspected problem, contact the Dam Inspection Section at (614) 265-6731 or at (614) 466-3048 during non-business hours.

Response to and Notification of Emergency Conditions (Emergency Action Plan)

The response to an identified emergency situation should proceed in three steps. First, the owner or person who identifies the emergency should notify local law enforcement officials and those persons residing immediately downstream from the dam. Law enforcement and local officials should then proceed with warning and evacuation procedures for potentially affected areas. Second, the owner or operator should notify the Dam Inspection Section of the emergency. Third, after notifying local law enforcement and state dam safety officials, the owner should initiate efforts to prevent or delay the failure. This sequence of actions is summarized as follows:

Owner/Observer	1. Notify local officials and warn residents living immediately downstream from the dam.
	2. Notify the Dam Inspection Section, ODNR.
	3. Implement actions to prevent or delay failure.
Local Officials	1. Determine affected area.
	2. Implement warning/evacuation plan.

More detailed guidelines for an Emergency Action Plan are available from the Ohio Department of Natural Resources, Dam Inspection Section.

Notification

The first step in developing an Emergency Action Plan for a dam is for the owner to establish a list of agencies/persons to be contacted. Input for this list should be obtained from and coordinated with local law enforcement officials and county disaster assistance personnel. The following agencies can offer emergency assistance in the event failure of the dam appears imminent.

1. Local sheriff, police, and/or fire departments
2. County Disaster Services Agency
3. County Engineer
4. Ohio Department of Natural Resources
   Division of Water
   Dam Inspection Section
   Fountain Square, Building E-3
   Columbus, Ohio 43224
   Telephone Number: (614) 265-6731
   or (614) 466-3048 during non-business hours

A copy of the notification list should be posted in a prominent, readily accessible location at the dam near a telephone and/or radio transmitter, if possible. This list should be periodically (once or twice a year) verified and updated as necessary. The list should include individual names and titles, locations, office and home telephone numbers, and radio frequencies and call signals as appropriate. Special procedures should be developed for nighttime, holiday, and weekend notification and for notification during a severe storm when telephones may not be working or highways may be impassable.

The notification plan should be brief, simple, and easy to implement under any set of emergency conditions.

Warning and Evacuation Plans

Certain key elements of information must be included in every warning and evacuation plan. Information about potential inundation (flooding) areas and travel times for the breach (flood) wave is essential to the development and implementation of these emergency plans. Inundation maps showing potential areas of flooding as a result of dam failure are especially useful. More detailed information about identification of inundation areas and the development of mapping of potential flood areas is available from the Dam Inspection Section, ODNR.

As of the date of this publication, very few inundation maps are available for local officials to use in their emergency warning and evacuation plans. Consequently, local officials and dam owners will have to use common sense in determining necessary areas of evacuation. Areas nearest to the dam must be evacuated first. Flood Hazard Boundary maps can provide rough approximations of necessary evacuation areas. However, the evacuation area should be extended beyond the limits of the maximum flood area shown on these maps as floods resulting from dam failures are usually more widespread and destructive. In making these determinations, it is always better to err on the conservative side.

Whenever possible, warning of a dam failure or an impending dam failure should follow procedures already estabished for other emergencies. However, it must be stressed that warning and evacuation times will be limited and that immediate evacuation must follow. Warnings delivered through personal modes such as telephones, loudspeakers, and face-to-face communications are more effective than warnings delivered impersonally - by sirens for example. Persons delivering the warnings should always say "the dam is failing," and not "flooding is expected." Warnings should be clear and concise. Residents should be advised to move to safety *immediately*. Radio and television news media should be used to the extent available and appropriate. Residents are more likely to respond if they receive warnings from several sources.

Resources and Procedures for Making Emergency Repairs

After making appropriate notifications of a possible dam failure and implementing warning/evacuation procedures, the owner should initiate efforts to prevent or delay failure of the dam. Because of the likely limitation on time, it is important to identify in the emergency plan the location of available resources with which to attempt to avoid (delay or prevent) the failure. Any emergency repair will require equipment, materials, labor, and expertise. For large reservoirs where failure could result in loss of life or severe damage to high-value property, materials (clay, sand, gravel, stone, riprap, sandbags, cement, plastic sheeting, etc.) and equipment for handling these materials should be kept at the site. If this provision is not possible, then prior arrangements for use of locally available off-site materials and equipment should be made in case of emergency. A list of contractors and other labor sources should be maintained.

It is also important to know what types of emergency repairs should be attempted for the different modes of failure. The following descriptions of possible actions to take to avoid failure are offered. Caution must be exercised by those working around the dam during the implementation of any of these emergency measures.

Overtopping

If overtopping appears imminent, the following actions should be taken:

1. Notify local authorities and state dam safety officials of possible failure.
2. Be sure that the spillways are not plugged with debris and are functioning as efficiently as possible. Debris removal may be difficult due to pressure from the high velocity flow and should be accomplished by using long poles or hooks. Personnel should *not* be allowed close to spillway inlets.
3. Open all lake drains or other gates to lower the pool level. Pumps and/or siphons may also be helpful on small reservoirs.
4. Dig a by-pass channel around the dam through an abutment. The location for this channel should be chosen with extreme caution so that the embankment will not be affected by rapid erosion of the channel. This action should *not* be undertaken without the supervision of an experienced professional engineer.

Generally, it is not recommended to temporarily raise the top of embankments with sandbags or by other means to try to prevent overtopping during a severe storm. This action is dangerous because the flood inflow may still increase and result in the overtopping of the raised dam. If the temporarily raised dam fails, the release of an even greater volume and depth of water would result.

A dam being overtopped.

Piping

If piping has developed the following actions should be taken:

1. Notify local authorities and state dam safety officials of possible failure.
2. Open all lake drains and other gates to lower the pool level. Pumps and/or siphons may also be helpful on small reservoirs.
3. Attempt to plug the "pipe" at the upstream end by dumping material into the whirlpool or sinkhole. Straw has been used effectively for this purpose. If straw is not readily available, anything (earth, rock, etc.) should be tried. If the "pipe" is plugged, the owner should be aware that this is only a temporary repair. The reservoir should be fully drained, and a professional engineer should be contacted to recommend permanent remedial measures.

Left: Scarp - The exposed slope above a slide.

Structural Failure of Embankment or Appurtenances

If a sudden and rapid failure of an appurtenance or a large slide in the embankment has occurred, the following actions should be taken:

1. Notify local authorities and state dam safety officials of possible failure.
2. Open all lake drains and other gates to lower the pool level. Pumps and/or siphons may be helpful on small reservoirs.
3. Attempt emergency repairs to prevent or delay failure.

Slides may be caused by seepage pressures, a saturated slope, a slope which is too steep, or possibly an earthquake. Earthquakes, although not common in Ohio, can cause structural damage to the embankment or appurtenances which might lead to complete failure of the dam. If a large slide in the upstream or downstream slope has occurred which significantly lowers the dam crest and threatens to release impounded water, sandbags can be used to temporarily raise the crest to prevent overtopping. On large upground reservoirs, beaching and rapid erosion of the upstream slope by wave action could occur due to high winds. A complete breach of the dam crest may result if the slope protection fails and bare soil is exposed to wave action. A supply of large rock should be available for use during this type of emergency.

Temporary repair of appurtenant structures will depend on the nature of the problem.

Summary

Once again extreme caution should be exercised by those working around the dam during emergency conditions when there is uncontrolled flow of water.

Owners should not allow temporary actions to become permanent repairs. This practice is dangerous because the chance of a rapid and catastrophic failure may increase if the repairs are not adequate. A qualified professional engineer should be contacted to recommend appropriate permanent remedial measures.

PART

MAINTENANCE OF EMBANKMENTS

III

VEGETATION

The establishment and control of proper vegetation is an important part of dam maintenance. Properly maintained vegetation can help prevent erosion of embankment and earth channel surfaces, and aid in the control of groundhogs and muskrats. The uncontrolled growth of vegetation can damage embankments and concrete structures and make close inspection difficult.

Grass Vegetation

Grass vegetation is an effective and inexpensive way to prevent erosion of embankment surfaces. If properly maintained, it also enhances the appearance of the dam and provides a surface that can be easily inspected. Roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. Grass vegetation is least effective in areas of concentrated runoff, such as the contact of the embankment and abutments, or in areas subjected to wave action.

Types of grass vegetation that have been used on dams in Ohio are bluegrass, fescue, ryegrass, alfalfa, clover, and redtop. One suggested seed mixture is:

30% Kentucky Bluegrass *(Poa Pratensis)*
60% Kentucky 31 Fescue *(Festuca arudinacea* Var. Ky. 31)
10% Perennial Ryegrass *(Lolium perenne)*

Deep rooted grasses should be planted in vegetated earth spillways. One hundred percent Kentucky 31 Fescue is excellent for erosion protection. Legumes and crown vetch are not recommended.

Before seeding, fertilizer (analysis 12-12-12) should be applied at a minimum rate of 12 to 15 pounds per 1,000 square feet (500 to 600 lbs. per acre). Lime should be applied at the approximate rate of 100 pounds per 1,000 square feet. Exact quantities necessary will vary with soil type and condition, and can be determined by having the soil tested. The fertilizer and lime should be raked, disced, or harrowed into the soil to a depth of not less than 4 inches. Periodic fertilization may be necessary to maintain vigorous vegetation.

The seed should be thoroughly mixed and evenly sown at the rate of 3 pounds per 1,000 square feet. The seed should be covered with soil to a depth of approximately ¼ inch. Immediately following planting, the area should be mulched with hay or straw at a rate of 2 to 3 tons per acre. Mulching materials should be kept in place with a mulch-anchoring device or with asphalt emulsion. Generally, if permanent seeding cannot be made by September 15 for the northern half of the state, or October 15 for the southern half, two bushels per acre of rye or wheat should be sown to provide temporary cover until spring. Seeding late in the year may result in winterkill of young seedlings. The following spring an inspection of the seeded area should be made to determine if plant survival is satisfactory.

Crown vetch (a perennial plant with small pink flowers) has been used on some dams in Ohio but is not recommended. Crown vetch obscures the embankment surface, preventing early detection of cracks, erosion, and other damage. Large weeds, brush and trees can become established and periodic hand labor is then required to remove unwanted tall vegetation. Crown vetch is not effective in preventing erosion in some areas and is also expensive to establish.

Trees and Brush

Left: Tree roots in an embankment.

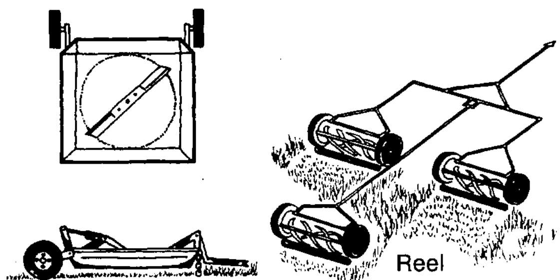
Trees and brush should not be permitted on embankment surfaces or in vegetated earth spillways. Extensive root systems can provide seepage paths for water. Trees that blow down or fall over can leave large holes in the embankment surface that will weaken the embankment and can lead to increased erosion. Brush obscures the surface limiting visual inspection, provides a haven for burrowing animals, and retards growth of grass vegetation. Tree and brush growth adjacent to concrete walls and structures may eventually cause damage and should be removed.

Stumps of cut trees should be removed so vegetation can be established and the surface mowed. Stumps can be removed either by pulling or with machines that grind them down. All woody material should be removed to about 6 inches below the ground surface. The cavity should be filled with well-compacted soil and grass vegetation established.

Stumps of trees in riprap cannot usually be pulled or ground down, but can be chemically treated so they will not continually form new sprouts. Certain herbicides which contain 2, 4-D are effective for this purpose and can even be used at water supply reservoirs if applied by licensed personnel. For product information and information on how to obtain a license, contact:

The Ohio State Department of Agriculture
Pesticide Regulations
8995 E. Main Street
Reynoldsburg, Ohio 43068
Telephone Number: (614) 866-6361

These products should be painted, not sprayed, on the stumps. Other instructions found on the label should be strictly followed when handling and applying these materials. Only a few commercially available chemicals can be used along shorelines or near water.



Mowing and Brush Removal

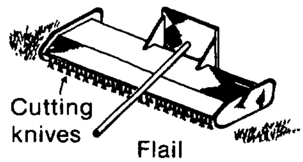
Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require continual maintenance of the vegetal cover. Grass-mowing, brush-cutting, and removal of woody vegetation (including trees) are necessary for the proper maintenance of a dam, dike, or levee. All embankment slopes and vegetated earth spillways should be mowed at least once a year. Aesthetics, unobstructed viewing during inspections, maintenance of a non-erodible surface, and discouragement of groundhog habitation are reasons for proper maintenance of the vegetal cover.

Methods used in the past for control of vegetation but are now considered unacceptable include chemical spraying, burning, and using hand scythes. More acceptable methods include the use of weed whips or power brush-cutters and mowers. Chemical spraying to first kill small trees and brush is acceptable if precautions are taken to protect the local environment.

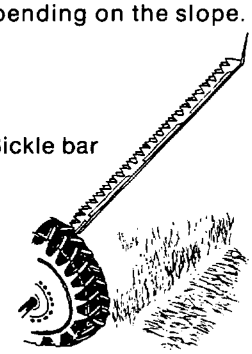
A wide variety of tools, attachments, and power equipment is available for satisfactory maintenance of vegetation. Hand-held brush cutters or weed whips range in weight from about 13 to 28 pounds. Cutting widths range up to about 21 inches, and there are various cutting blades including nylon string, plastic blades, and metal knife blades. These units can be used to cut grass, brush, woody vegetation up to 4 inches in diameter and can be used on almost any slope.

Hand mowers are available in both push and self-propelled models. Width of cut varies up to a maximum of about 36 inches while maximum cutting height is about 4 inches. Hand mowers can be used safely on many slopes.

Garden and lawn tractors are available from 10 to a maximum of about 20 horsepower. They can be provided with wheels of different widths and with turf or agricultural tires. These type tractors may be equipped with four-wheel drive. Power take-off drives are available for attachment to mowers and other accessories. Tractor speeds range to a maximum of about 7 miles per hour. Mower units are normally rotary, but pull-type flail and reel-type units are also available. Cutting height is a maximum of 7 inches and width of cut is from 36 to 60 inches. A garden tractor equipped with a 48-inch mower can mow about one acre an hour, depending on the slope.



Larger farm tractors are available in engine sizes ranging from 22 horsepower up to 50 horsepower and higher. They are available in low-profile models with four-wheel drives, adjustable front and rear wheel widths, agricultural or turf tires, and power take-off drives for various accessory units. Maximum speeds are around 12 miles per hour.



Mowing units, including rotary, reel, flail, and sickle bar types, are available for the larger tractors. The following table indicates the available widths and cutting heights. The tractor

	Cutting Height	*Width of Cut (Single Units)*	*Width of Cut (Gang Units)*
Rotary	1½" to 15"	42" to 84"	15' (Batwing)
Flail	¾" to 5"	36" to 88"	19' (5 units)
Reel	½" to 2½"	18" to 30"	11' (5 units)
Sickle Bar	---	48" to 108"	---

horsepower should be matched to the mowing unit needed for the job per the manufacturer's recommendations.

The garden and farm tractors described in this manual cannot be used safely on slopes steeper than 2½ horizontal to 1 vertical (40% or 21.8° slope). The larger tractors should be obtained with the lowest profile (or center of gravity) necessary for the type of slope to be mowed. Dual wheels or wider tires can be used to increase stability. All of these units should be equipped with safety roll bars designed to support the full weight of the tractor. The following table is a conversion for typical slope terminology:

Slope	Percent of Grade	Slope Angle
1H:1V	100%	45°
1½H:1V	67%	33.7°
2H:1V	50%	26.6°
2½H:1V	40%	21.8°
3H:1V	33%	18.4°

Low-profile tractor with flail unit mowing a 2½H: 1V slope.

Self-contained mowing units are also available with self-leveling suspension for mowing very steep slopes.

It is important to remember to use the proper equipment for the slope and type of vegetation to be cut, to always follow the manufacturer's recommended safe operation procedures, and to not mow when the vegetation is wet.

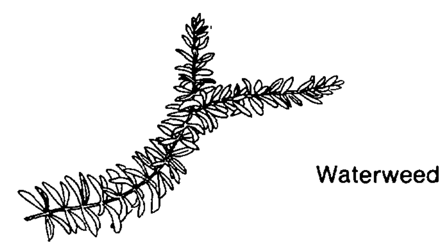
Livestock Control

Livestock should not be allowed to graze on the embankment surface. When the soil is wet, livestock can damage the vegetation and destroy the smooth surface resulting in ponded water or erosion from concentrated runoff. The resulting rough surface is difficult to mow.

Aquatic Vegetation

Control of most aquatic vegetation can be accomplished through the use of chemical herbicides. Aquatic vegetation is classified into three major groups: floating growth, submerged growth, and emergent growth.

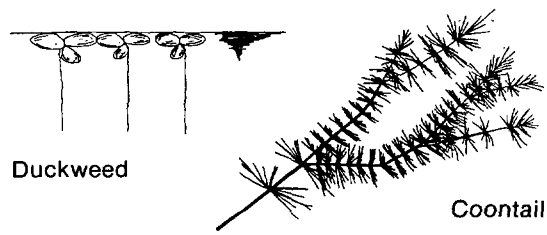
The most common floating growth is filamentous algae - a floating dense mat of hair-like fibers. Most species can be controlled with very low concentrations of copper sulfate, 2.7 pounds per acre-foot of water, or for hard water (over 200mg/l total hardness), 5.4 pounds per acre-foot of water. Application instructions can be found on the product label. Caution should be exercised as copper sulfate can kill new hatches of fish if applied when fish are spawning.



Submerged growth is attached to the lake bottom and has most of its growth below the water surface. It grows mostly in clear, calm, shallow water. Species include *Potamogetons* (pondweed), *Ceratophyllum* (coontail), *Myriophyllum* (water milfoil), *Elodea* (water weeds), and *Najas.*

Herbicides for submerged weeds are available as liquids, powders (to be mixed with water), and granules. Liquids and powders release their active ingredients immediately and work best when used spring through midsummer. Granular herbicides release their active ingredients more slowly and should be used early in the growing season and/or on a spot-treatment basis. The local county extension agent or other knowledgeable person should be contacted for brand name recommendations and information on regulations.

Emergent growth is found along the shoreline and in shallow water where the stems and leaves extend out of the water. Cattails, bulrushes, and spatterdock are frequently found in these areas. A non-chemical method of control is to increase the water depth in the area of growth by maintaining a steep slope, at least 3H:1V, along the shore.



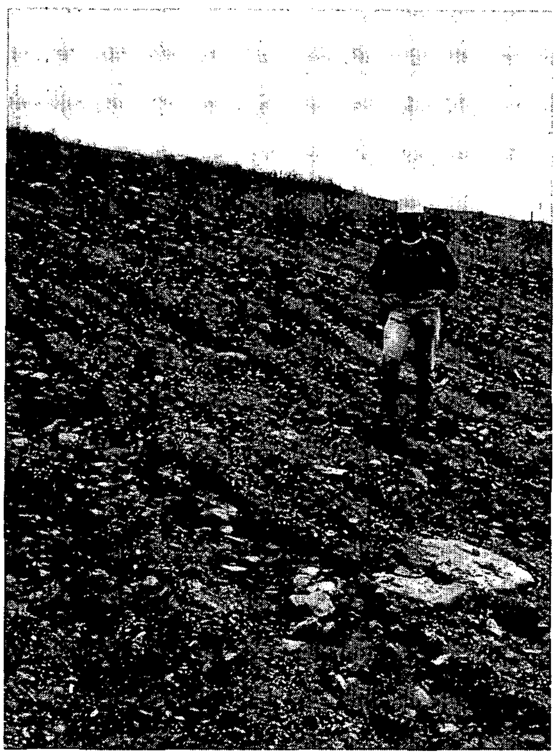
Most herbicides used for land weed control can also be used for emergent growth if combined with a wetting and sticking agent. In addition to commercially available wetting and sticking agents, two tablespoons of liquid household detergent per gallon of herbicide may be used. The mixture is then sprayed until a thin film covers the leaves.

Chara (muskgrass, stonewart), duckweed, and watermeal are growths that do not fit the above categories. Chara grows in dense clumps in shallow areas and is a form of algae. Duckweed has small three-lobed leaves with rootlets that hang down in the water. Watermeal consists of small green grains floating in the water.

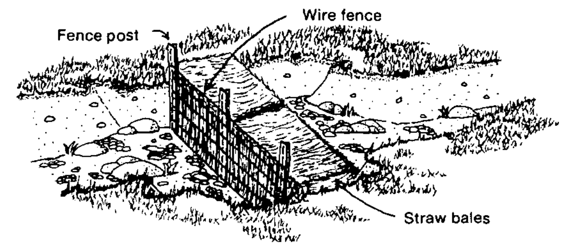
With most commercial herbicides, application instructions, environmental precautions, and a list of weeds controlled will be found on the label. Always READ THE LABEL and never mix different herbicides. Herbicides can be purchased from a local agricultural chemical center. For a more complete discussion of aquatic weed control, see *Ohio Pond Management* (7); available from the local county extension agent, U.S. Department of Agriculture.

EROSION

Whether on a slope, at a groin area, or at a spillway outlet, erosion is one of the most common maintenance problems of embankment structures. Erosion is a natural process, and its continuous forces will eventually wear down almost any surface or structure. Periodic and timely maintenance is essential in preventing continuous deterioration and possible failure.



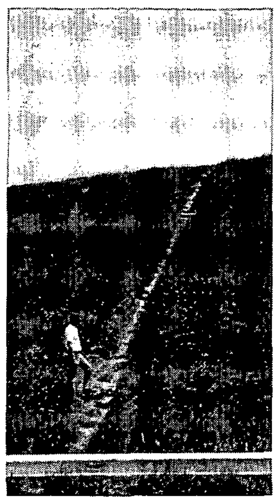
Right: Erosion rills on the downstream slope of an embankment.



Vegetated Surfaces

A sturdy sod, free of weeds and brush, is one of the most effective means of erosion protection. Embankment slopes are normally designed and constructed so that the surface drainage will be spread out in thin layers as "sheet flow" on the grassy cover. When the sod is in poor condition or flows are concentrated at one or more locations, the resulting erosion will leave rills and gullies in the embankment slope. The owner or inspector should look for these areas and be aware of the problems that may develop.

Prompt repair of vegetated areas that develop erosion is required to prevent more serious damage to the embankment. Rills and gullies should be filled with suitable soil (the upper 4 inches should be topsoil, if available), compacted, and then seeded. Methods described in the section on Vegetation (page 15) should be used to properly establish the grassed surface. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repair can be made.

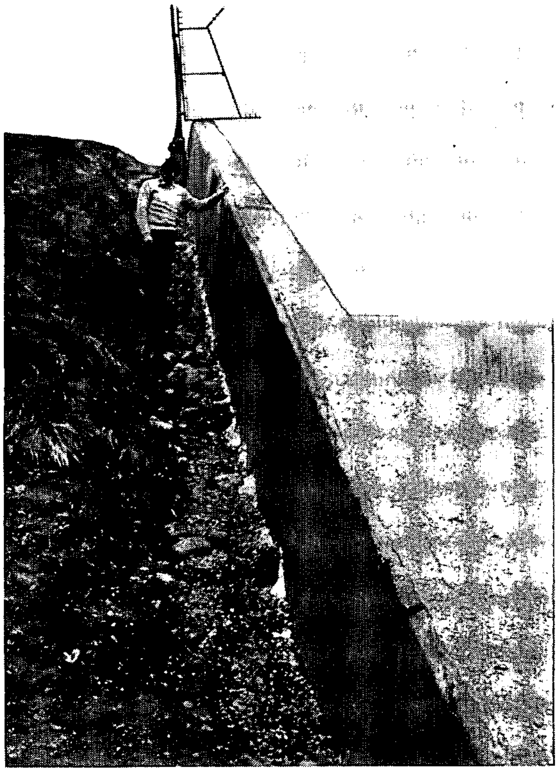


Lower right: Footpath.

Not only should the eroded areas be repaired, but the cause of the erosion should be addressed to prevent a continuing maintenance problem. Erosion might be aggravated by improper drainage, settlement, pedestrian traffic, animal burrows, or other forces. The cause of the erosion will have a direct bearing on the type of repair needed.

Paths from pedestrian traffic are problems common to many embankments. If a path has become established, vegetation in this area will not provide adequate protection and more durable cover will be required, unless the traffic is eliminated. Small stones, asphalt, or concrete have been used effectively to cover footpaths. Embedding railroad ties or other treated wood beams into an embankment slope to form steps is one of the most successful and inexpensive methods used to provide a protected pathway.

Worn areas also result from unwanted two-wheel and four-wheel vehicle traffic. Control of these vehicles is discussed in the section on Vandalism (page 47).



Far left: Settlement and erosion adjacent to a spillway wall.

Upper left: Groundhog burrow and undermining of a concrete gutter.

Lower left: Large void beneath slabs of concrete.

Another area where erosion commonly occurs is the contact between the embankment and the concrete walls of the spillway or other structures. Poor compaction adjacent to the wall during construction and subsequent settlement could leave an area lower than the grade of the embankment. Runoff often concentrates along these structures, resulting in erosion. People frequently walk along these walls, wearing down the vegetal cover. Possible solutions include regrading the area to slope away from the wall, adding more resistant surface protection, or constructing wood beam steps.

Groin Areas

Adequate erosion protection is required along the contact between the downstream face of the embankment and the abutments. Runoff from rainfall concentrates in these gutter areas and can reach erosive velocities because of the steep slopes. Berms on the downstream face that collect surface water and empty into these gutters add to the runoff volume. Sod gutters may not adequately prevent erosion in these areas. Paved concrete gutters do not hold up well, will not slow the velocity of the water, can become undermined, and therefore are not recommended. Groundhogs often construct burrows underneath these gutters, possibly since burrowing is easier due to existing undermining.

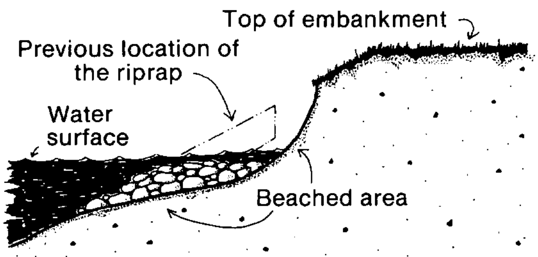
A well graded mixture of rock with stones 9 to 12 inches in diameter or larger placed on a sand filter generally provides the best protection on small dams. Slush-grouted riprap (riprap slushed with a thin concrete slurry) has also been successful in preventing erosion and should be used if large stone is not available or for groins of larger dams.

Erosion adjacent to gutters results from improper construction or design, where the finished flow line of the gutter is too high with respect to adjacent ground. This condition prevents all or much of the runoff water from entering the gutter. The flow concentrates alongside the gutter, erodes a gully, and may eventually undermine the gutter.

Care should be taken when replacing failed gutters or designing new gutters to assure that:

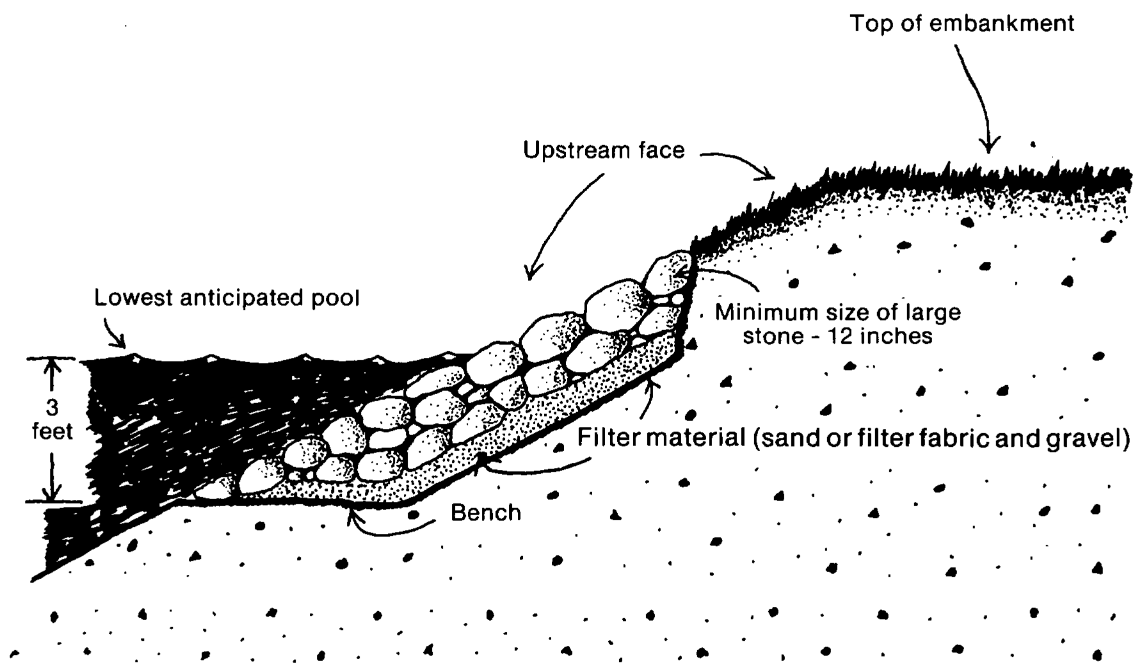
1. The channel has adequate capacity,
2. Adequate protection and a satisfactory filter have been provided,
3. Surface runoff can enter the gutter, and
4. Its outlet is adequately protected from erosion.

Upstream Slope



A serious erosion problem which can develop on the upstream slope is "beaching." Waves caused by high winds or high-speed power boats can erode the exposed face of the embankment. Waves repeatedly strike the surface just above the pool elevation, rush up the slope, then tumble downward into the pool. This action erodes material from the face of the embankment and displaces it farther down the slope, creating a "beach." Erosion of unprotected soil can be rapid and during a severe storm could lead to complete failure of a dam.

The upstream face of a dam is commonly protected against wave erosion and resultant beach-



ing by placement of a layer of rock riprap over a layer of filter material. In some cases other materials such as steel, bituminous or concrete facing, bricks or concrete blocks are used. Beaches are sometimes constructed into small dams by placing a berm (8 to 10 feet wide) along the upstream face a few inches below normal pool. This provides a surface on which the wave energy can dissipate. Generally, rock riprap provides the most economical protection in Ohio.

Beaching can also occur in existing riprap if the embankment surface is not properly protected by a filter. Water running down the slope under the riprap can erode the embankment. Sections of riprap slumped downward are often signs of beaching. Concrete facing used to protect slopes often fails because the wave action washes soil particles from beneath the slabs through joints and cracks. Detection, in this case, is difficult because the voids are hidden and failure may be sudden and extensive. Effective slope protection *must* *prevent soil particles from being removed from the embankment.*

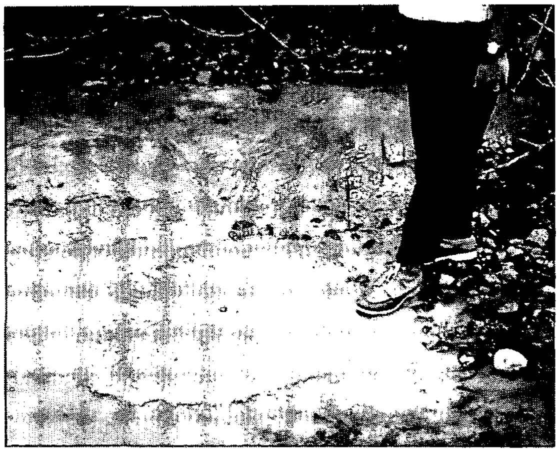
Right: Beaching of an upstream slope.

When erosion occurs and beaching develops on the upstream slope of a dam, repairs should be made as soon as possible. The pool level should be lowered and the surface of the dam prepared for replacing the slope protection. A small berm or "bench" should be made across the face of the dam to help hold the protective layer in place. The bench should be placed at the base of the new layer of protection. Depth of the bench will depend on the thickness of the protective layer. The layer should extend a minimum of 3 feet below the lowest anticipated pool level. Otherwise, wave action during periods when the lake level is drawn down can undermine and destroy the protective layer.

If rock riprap is used, it should consist of a heterogeneous mixture of irregular shapes placed over a sand and gravel filter. The maximum rock size and weight must be large enough to break up the energy of the maximum anticipated wave action and hold the smaller stones in place. Generally, the largest stones should be at least 12 inches in diameter. The smaller rocks help to fill the spaces between the larger pieces forming a resistant mass. The filter prevents soil particles on the embankment surface from being washed out through the spaces (or voids) between the rocks in the riprap. If the filter material can be washed out through these voids and beaching develops, two filter layers will be required. The lower layer should be composed of sand or filter fabric to protect the soil surface. The upper layer should be composed of coarser materials that prevent washout through the voids in the riprap.

A dam owner should expect some deterioration (weathering) of riprap. Freezing and thawing, wetting and drying, abrasive wave action, and other natural processes will eventually break down the riprap. Its useful life varies with the characteristics of the stone used. Stone for riprap should be rock that is dense and well cemented. In Ohio, glacial cobbles, some limestone, and a few types of sandstone are acceptable for riprap. Most sandstones and shales found in Ohio do not provide long-term protection. Due to the high initial cost of rock riprap, its durability should be determined by appropriate testing procedures prior to installation. Sufficient maintenance funds should be allocated for the regular replacement of riprap. When riprap breakdown, erosion, and beaching occur more often than once every three to five years, professional advice should be sought to design more effective slope protection.

SEEPAGE

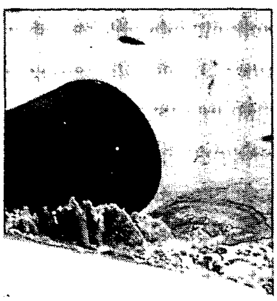


Seepage boil.

Contrary to popular opinion, wet areas downstream from dams are not usually natural springs, but seepage areas. Even if natural springs exist, they should be treated with suspicion and carefully observed. Flows from ground-water springs in existence prior to the reservoir would probably increase due to the pressure caused by a pool of water behind the dam.

All dams have some seepage as the impounded water seeks paths of least resistance through the dam and its foundation. Seepage must, however, be controlled in both velocity and quantity.

Detection

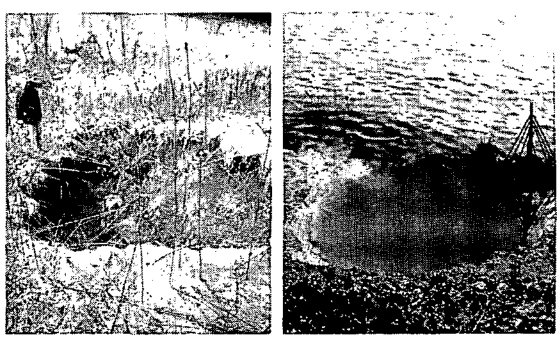


Far left: Uncontrolled seepage along the exterior of a pipe spillway.

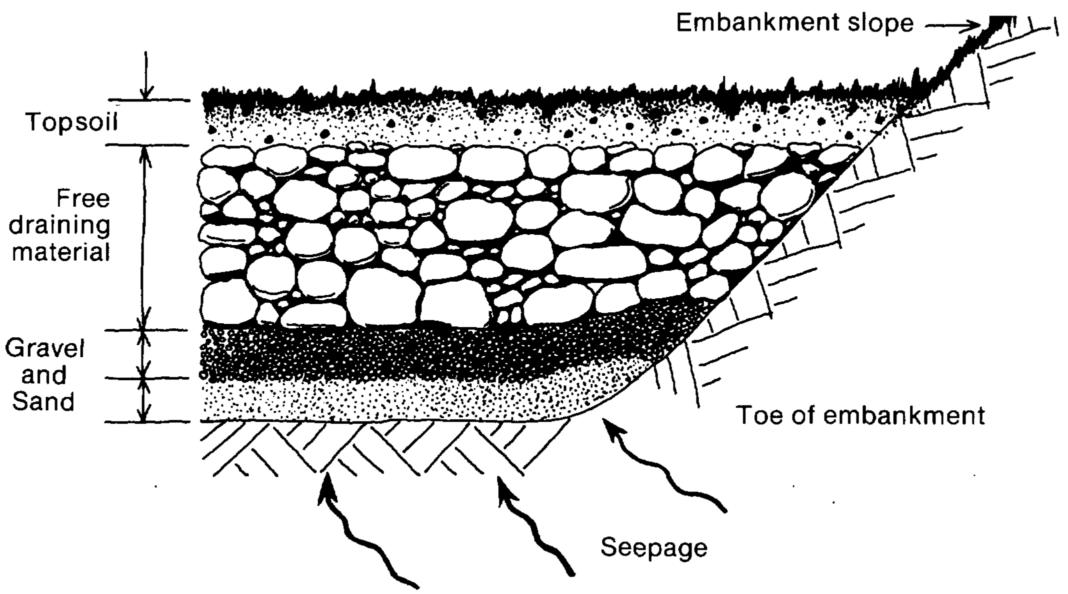
Seepage can emerge anywhere on the downstream face, beyond the toe, or on the downstream abutments at elevations below normal pool. Seepage may vary in appearance from a "soft," wet area to a flowing "spring." It may show up first as only an area where the vegetation is more lush and darker green. Cattails, reeds, mosses, and other marsh vegetation often become established in a seepage area. Downstream groin areas (the areas where the downstream face contacts the abutments) should always be inspected closely for signs of seepage. Seepage can also occur along the contact between the embankment and a conduit spillway, drain, or other appurtenance. Slides in the embankment or an abutment may be the result of seepage causing soil saturation or pressures in the soil pores.

At most dams, some water will seep from the reservoir through the foundation. Where it is not intercepted by a subsurface drain, the seepage will emerge downstream from or at the toe of the embankment. If the seepage forces are large enough, soil will be eroded from the foundation and be deposited in the shape of a cone around the outlet. If these "boils" appear, professional advice should be sought immediately. Seepage flow which is muddy and carrying soil particles may be evidence of "piping," and complete failure could occur within hours. Piping can occur along a spillway and other conduits through the embankment, and these areas should be closely inspected. Sinkholes that develop on the embankment are signs that piping has begun and will soon be followed by a whirlpool in the lake surface and then a rapid and complete failure of the dam. Emergency procedures, including downstream evacuation, must be implemented if this condition is noted.(See sections on Earth Dam Failures, and Emergency Actions and Procedures, pages 7 and 9.)

A continuous or sudden drop in the normal lake level may be an indication that seepage is occurring. In this case, one or more locations of flowing water are usually noted downstream from the dam. This condition in itself may not be a serious problem, but will require frequent and close monitoring and professional assistance.



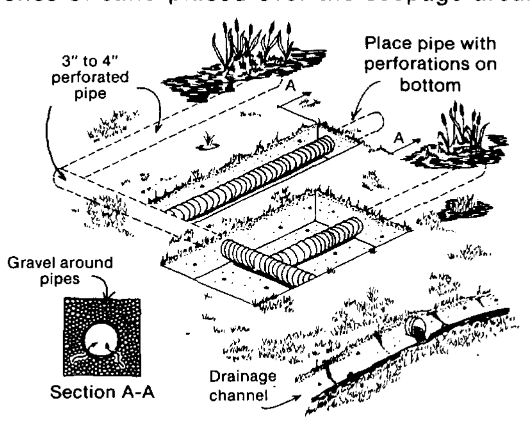
Large sinkhole on the downstream slope and the corresponding sinkhole on the upstream slope at the waterline next to the spillway inlet.



Control

The need for seepage control will depend on the quantity, content, and/or location of the seepage. Controlling the quantity of seepage that occurs after construction is difficult, quite expensive, and not usually attempted unless drawdown of the pool level has occurred or the seepage is endangering the embankment or appurtenant structures. Typical methods used to control the quantity of seepage are grouting, installation of an upstream blanket, or installation of relief wells. Of these methods, grouting is probably the least effective and is most applicable to leakage zones in bedrock, abutments, and foundations. *All of these methods must be designed and constructed under the supervision of a professional engineer experienced with dams.*

Controlling the content of the seepage or preventing seepage flow from removing soil particles is extremely important. Modern design practice incorporates this control into the embankment through the use of cutoffs, internal filters, and adequate drainage provisions. Control at points of seepage exit can be accomplished after construction by using weighted filters and providing proper drainage. The filter and drainage system should be designed to prevent migration of soil particles and still provide for passage of the seepage flow. The bottom layer of the weighted filter should be 6 to 12 inches of sand placed over the seepage area.



The sand layer should be covered with a gravel layer of similar thickness. Larger rock should be placed next, to complete the berm. This method will permit the seepage to drain freely, but prevent piping (removal) of soil particles. The weight of the berm will hold the filter in place and may also provide additional stability to the embankment and/or foundation.

The location of the seepage or wet area on the embankment or abutment is often a primary concern. Excessive seepage pressure or soil saturation can threaten the stability of the downstream slope of the dam or the abutment slopes. An abutment slide might block or damage the spillway outlet or other appurtenances. In these cases, not only must the seepage be controlled but the area must be dried out. This is sometimes accomplished by installing finger drains (lateral drains for specific locations). Seepage control systems must always be free-draining to be effective.

Monitoring

Regular monitoring is essential to detect seepage and prevent failure. Without knowledge of the dam's history, the owner or the inspector has no idea whether the seepage condition is in a steady or changing state. It is important to keep written records of points of seepage exit, quantity and content of flow, size of wet area, and type of vegetation for later comparison. Photographs provide invaluable records of seepage. The inspector should always look for increases in flow and evidence of flow carrying soil particles. The control methods described previously are often designed to facilitate observation of flows. At some locations, v-notch weirs can be used to measure flow rates.

Regular surveillance and maintenance of internal embankment and foundation drainage outlets is also required. Normal maintenance consists of removing any soil or other material that obstructs flow. Internal repair is complicated and often impractical and should not be attempted without professional advice. The rate and content of flow emerging from these outlets should be monitored regularly.

TREATMENT OF CRACKS, SLIDES, SLOUGHING, AND SETTLEMENT

The embankment and any appurtenant dikes must safely contain the reservoir. Cracks, slides, sloughing, and settlement are signs of embankment distress and should indicate to the owner that maintenance or remedial work is required. The cause of the distress should be determined by an experienced engineer *before* undertaking repairs. This step is important because a so-called "home remedy" may also cause greater and more serious damage to the embankment and may eventually result in unwise expenditures for useless repairs.

Cracks

The entire embankment should be closely inspected for cracks. Short, isolated cracks are not usually significant, but larger (wider than 1 or 2 inches), well-defined cracks may indicate a more serious problem. There are two types of cracks: transverse and longitudinal.

- Transverse cracks appear across the embankment and indicate differential settlement within the embankment. Such cracks provide avenues for seepage water and piping could develop quickly.
- Longitudinal cracks run parallel to the embankment and may signal the early stages of a slide or slump on either face of the embankment. In recently built structures, these cracks may indicate inadequate compaction of the embankment during construction.

Small cracks, as they appear, should be documented, examined by an engineer, and then sealed. The seal will prevent surface water from entering the cracks, causing saturation of embankment material, and possibly triggering a slide or other serious problem. Sealing can be accomplished by compacting clay in the cracks. Unless the cracks are large (wider than an inch), this can usually be done in a few minutes using a shovel and a compacting tool. After the cracks have been sealed, the areas should be monitored frequently to determine if movement is still occurring. Slides or crack locations can be documented by staking and/or with photographs. Continued movement is an indication of a more serious problem such as a slide.

Longitudinal crack.

Slides

Slides and slumps are serious threats to the safety of a dam. A massive slide can initiate catastrophic failure of a dam. Slides can be detected easily unless obscured by tall vegetation. Arc-shaped cracks are indications that a slide or slump is beginning. These cracks soon develop into a large scarp in the slope at the top of the slide.

If a slide develops, the scarp should be sealed to prevent rainfall and surface runoff from lubricating the interior slide surface, saturating the embankment, and causing future sliding. Sealing the scarp is only a temporary measure. The need for immediate professional assistance to determine the cause of cracks and slides and to recommend remedial action cannot be overemphasized.

Slides in spillway and outlet areas should be removed immediately since their presence reduces hydraulic capacities. Shallow surface slides can be repaired by removing the slide material and rebuilding the slope to original grade with well compacted impervious clay material. The cause for any slide should be fully determined before implementing permanent repairs to the slope.

Settlement

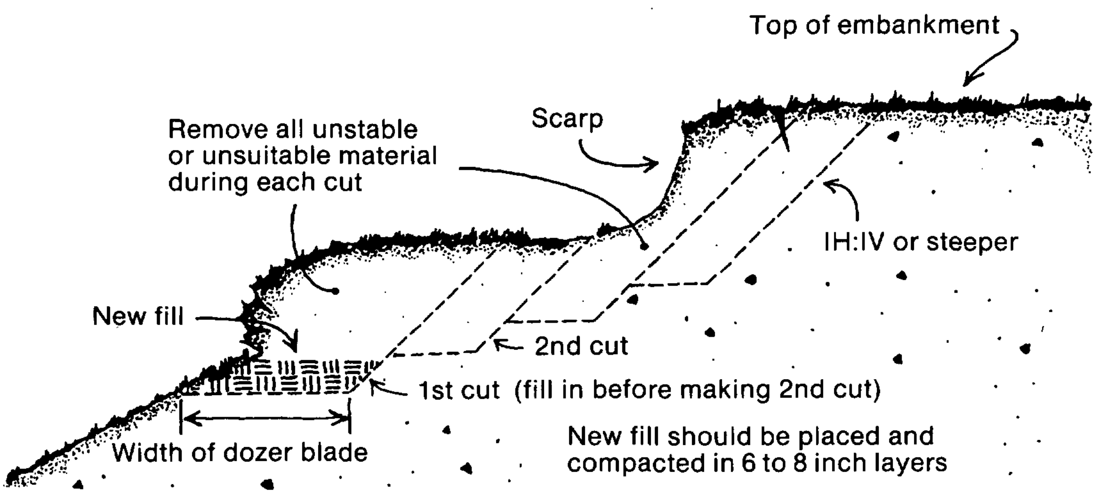
Settlement occurs both during construction and after the embankment has been completed and placed in service. To a certain degree, this is normal and should be expected. It is usually most pronounced at locations of maximum foundation depth or embankment height. Excessive settlement will reduce the freeboard (the difference in elevation between the water surface and the top of the dam) and may increase the probability of overtopping. Any areas of excessive settlement should be restored to original elevations and conditions to reduce the risk of overtopping. A relatively large amount of settlement (more than one foot) within a small area could indicate serious problems in the foundation or perhaps in the lower part of the embankment. Settlement accompanied by cracking often precedes failure. When either

Far right: Slide on the downstream slope of an embankment.

condition is observed, professional advice should be sought. Settlement can be monitored by measuring the differences in elevation between the problem area and permanent reference monuments located away from the dam. Land surveying instruments are required to make these measurements.

Repair

Repair of cracks, slides, and settlement will require the removal of all unsuitable material and the addition of good material to the embankment. Filters and drains may also be necessary to correct these problems. Soil added to restore an embankment should be properly "keyed" into the base material. This can best be accomplished by removing the vegetal cover and all unsuitable material until a good, firm base in undisturbed soil is uncovered. Unsuitable materials include wet, soft, porous, organic, and improperly compacted soils. The surface should then be roughened with a disc or similar device to obtain a good bond between "old" and "new" materials. The new soil should be successively placed in thin layers (6 to 8 inches thick) and each layer compacted before adding more material. Compaction of each layer to 95 percent or above of maximum dry density at 1 percentage point below to 3 percentage points above optimum moisture content based on the Standard Proctor Density Test (ASTM D 698-78) is recommended for cohesive soils used in small dams.



RODENT CONTROL

Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and reservoirs and can be quite dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers may plug the spillway and raise the pool level. Rodent control is essential in preserving a well-maintained dam.

The Groundhog or Woodchuck

The groundhog is the largest member of the squirrel family. Its coarse fur is a grizzled grayish brown with a reddish cast. Typical foods include grasses, clover, alfalfa, soybeans, peas, lettuce, and apples. Breeding takes place during early spring (beginning at the age of one year) with an average of four or five young per litter, one litter per year. The average life expectancy is two or three years with a maximum of six years.

Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of keeping them "cleaned out." Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den to nearby fields, and clawed or girdled trees and shrubs also help identify inhabited burrows and dens.

When burrowing into an embankment, groundhogs stay above the phreatic surface (upper surface of seepage or saturation) to stay dry. The burrow is rarely a single tunnel. It is usually forked, with more than one entrance and with several side passages or rooms from 1 to 12 feet long. (See hunting and trapping regulations, page 26.)

Groundhog Control

Control methods should be implemented during early spring when active burrows are easy to find, young groundhogs have not scattered, and there is less likelihood of damage to other wildlife. In later summer, fall, and winter, game animals will scurry into groundhog burrows for brief protection and may even take up permanent abode during the period of groundhog hibernation.

Groundhogs can be controlled by using fumigants or by shooting. Fumigation is the most practical method of controlling groundhogs. Around buildings or other high fire hazard areas, shooting may be preferable. Groundhogs will be discouraged from inhabiting the embankment if the vegetal cover is kept mowed.

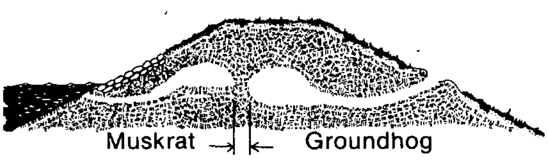
Gas cartridges may be purchased at local farm exchanges or farm supply centers. Also, most county extension offices keep supplies of cartridges for sale. Information about use and availability of gas cartridges may be obtained from:

The U.S. Fish and Wildlife Service
Wildlife Assistance
Room 405, Federal Building
200 North High Street
Columbus, Ohio 43215
(614) 469-5681

Muskrat

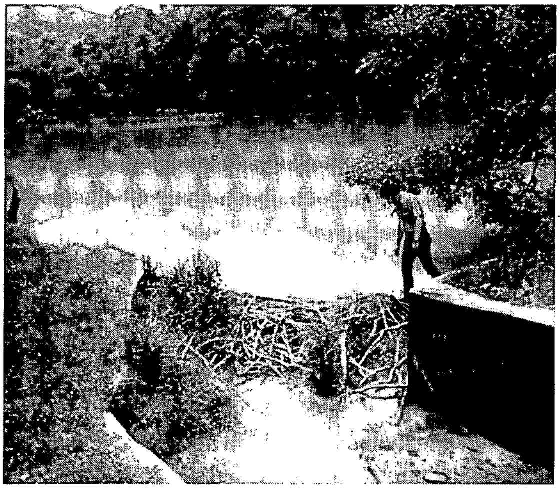
The muskrat is a stocky rodent with a broad head, short legs, small eyes, and rich dark brown fur. Muskrats are chiefly nocturnal. Their principal food includes stems, roots, bulbs, and foliage of aquatic plants. They also feed on snails, mussels, crustaceans, insects, and fish. Usually three to five litters, averaging six to eight young per litter, are produced each year. Adult muskrats average one foot in length and three pounds in weight. The life expectancy is less than two years, with a maximum of four years. Muskrats can be found wherever there are marshes, swamps, ponds, lakes, and streams having calm or very slowly moving water with vegetation in the water and along the banks.

Muskrats make their homes by burrowing into the banks of lakes and streams or by building "houses" of rushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in the water level will cause the muskrat to dig farther and higher to excavate a new dry chamber. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens in the embankment opposite muskrat dens.



Dangerously close burrows

Right: Beaver dam constructed across a spillway channel.



RODENT CONTROL

Muskrat Control

Barriers to prevent burrowing offer the most practical protection to earthen structures. A properly constructed riprap and filter layer will discourage burrowing. The filter and riprap should extend at least 3 feet below the water line. As the muskrat attempts to construct a burrow, the sand and gravel of the filter layer caves in and thus discourages den building. Heavy wire fencing laid flat against the slope and extending above and below the waterline can also be effective. Eliminating or reducing aquatic vegetation along the shoreline will discourage muskrat habitation (see section on Vegetation, page 17).

Trapping with steel traps is usually the most practical method of removing muskrats from a pond. The No. 1 steel trap is effective. However, some muskrat trappers favor the "two trigger" steel trap because it has double action and few muskrats escape once caught. The Conibear trap is also effective for trapping muskrats.

Muskrat trails may be found along the banks of streams and ponds where one can often trace them into shallow water. The Conibear trap is used at the burrow entrance and the No. 1 steel trap works best at trails and slides. The No. 1 steel trap should be sunk in the trail, partly in the mud or sand where the water is 2 or 3 inches deep, and the chain fastened to a stake. Some bait (carrot, apple, or parsnip) should be fastened to a stake set in the mud so that the bait is about a foot above the pan of the trap. The animal, in reaching for the bait, sets its foot upon the pan and is caught. Unless the animal drowns soon after being caught, it is likely to twist off its leg and escape. Consequently, the stake to which the chain is attached should be placed in water at least a foot deep. Traps attached to floats of natural material or rafts have proven successful. (See hunting and trapping regulations below.)

Eliminating a Burrow

The recommended method of backfilling a burrow on an embankment is mud-packing. This simple, inexpensive method can be accomplished by placing one or two lengths of metal stove or vent pipe in a vertical position over the entrance of the den. Making sure that the pipe connection to the den does not leak, the mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and dry earth is tamped into the entrance. The mud-pack is made by adding water to a 90 percent earth and 10 percent cement mixture until a slurry or thin cement consistency is attained. All entrances should be plugged with well-compacted earth and vegetation re-established. Dens should be eliminated without delay because damage from just one hole can lead to failure of a dam or levee.

Beaver

Beaver will try to plug spillways with their cuttings. Routinely removing the cuttings is one way to alleviate the problem. Another successful remedy is the placement of electrically charged wire or wires around the spillway inlet. Trapping beaver may be done by the owner during the appropriate season; however, the nearest ODNR, Division of Wildlife, District Office or state game protector should be contacted first. (See hunting and trapping regulations below.)

Hunting and Trapping Regulations

Because hunting and trapping rules change from year to year, ODNR, Division of Wildlife authorities at one of the following offices should be consulted before taking any action.

- Central Ohio, District 1 (Columbus)—(614) 265-7038
- Northwest Ohio, District 2 (Findlay)—(419) 422-6757
- Northeast Ohio, District 3 (Akron)—(216) 644-2293
- Southeast Ohio, District 4 (Athens)—(614) 594-2211
- Southwest Ohio, District 5 (Xenia)—(513) 372-7668

The following table provides a general guideline for the appropriate hunting and trapping seasons. However, the regulations should be verified yearly.

Animal	Method	Open Season	Where
Beaver	Trapping only	Early December to end of January	Statewide
Groundhog	Gun, longbow, crossbow	Year-round, but restricted during deer gun season	Statewide
Muskrat	Trapping only	Mid-November to end of January (extended to mid-March in northwest counties)	Statewide

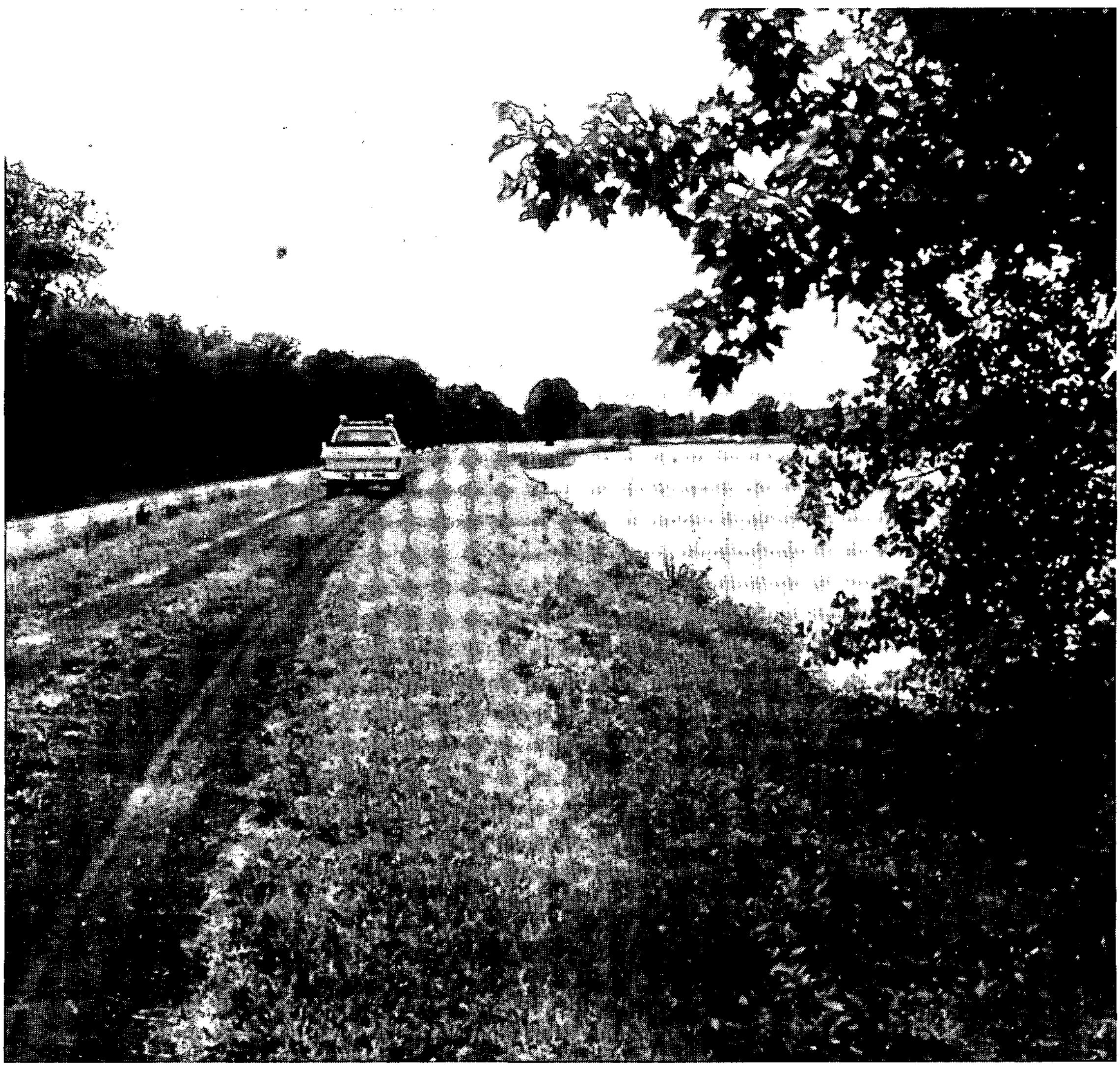
ROAD ON THE CREST OF THE DAM

Roads along or on the crest of dams should be maintained not only to keep the road in passable condition, but more importantly, to prevent damage to the embankment. Roads on dams should be constructed with the proper subbase, base, and wearing surface.

If a designed wearing surface has not been provided, traffic should not be allowed on the crest during wet conditions. Water collected in ruts may cause localized saturation thereby weakening the embankment. Ruts that develop in the crest should be repaired as soon as possible. The crest of the dam should be graded to direct all surface drainage into the impoundment. Road drainage should not be concentrated at one location.

Heavily traveled paved roads may require special means for collection and drainage of surface water. If properly designed and constructed, guard rails, curbs, gutters, and rigid pavement may also be located on the crest of an embankment.

Roads should not be allowed on the embankment slopes unless properly designed and constructed.

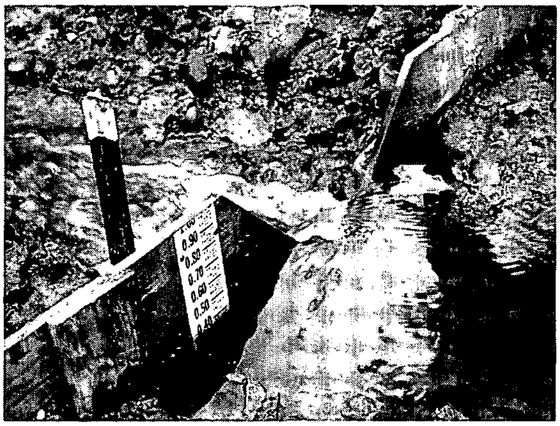


Left:
A road on the crest of a dam.

MONITORING DEVICES

Various devices such as weirs, piezometers, and settlement monuments are used to monitor earth embankments and concrete gravity structures. These devices can be used to determine if the structure is performing as designed, to detect signs of serious problems, or to provide further information after a problem has been detected. Due to expense, the use of extensive instrumentation to ensure safety is usually limited to large dams where failure would result in loss of life and a great deal of damage. A full-scale monitoring and instrumentation program requires professional design and will not be discussed here.

The following devices can easily be used by owners to monitor their embankments.



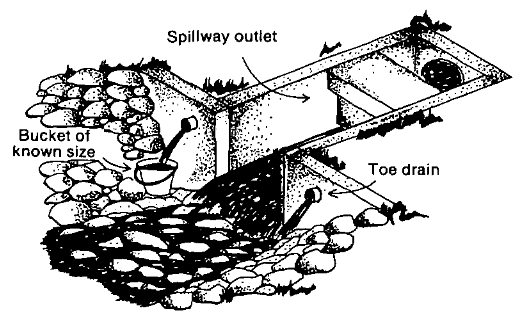
Right: V-notch weir used to measure seepage.

V-notch weir - The v-notch weir is probably the most commonly used device to measure flow rates of seepage (see section on Seepage, page 21). Effective readings must be taken periodically under similar influences, i.e. lake level and local runoff conditions. Many times after installation, the weirs are neglected and a few good readings become useless for lack of comparative data. Consequently, the v-notch weir itself must be maintained.

Flow rates in gallons per minute for small weirs and pipe outlets can be measured by timing how long it takes to fill a bucket of known capacity.

Yardstick or Folding Rule - This portable monitoring device is not only inexpensive but has a number of uses. It can be used to measure cracks, scarps, erosion gullies, settlement, trees, wet areas, and slab or wall movement. Again, records should be kept of all observations for comparative purposes.

Camera - Photographs which have been dated and labeled provide an excellent record of existing conditions, and if taken periodically from the same location, can be used for comparison. Photographs should be taken during all inspections to supplement written and visual observations. They are valuable in documenting the location and severity of wet areas, erosion, and concrete deterioration.



Piezometers, settlement monuments, observation wells, and inclinometers are often found on large dams and are described briefly. The installation requires professional assistance.

Piezometers - Piezometers are instruments used to measure the water pressure in the embankment and foundation soil pores and are installed at various levels in a drill hole. Readings are usually taken by measuring the elevation of water in a standpipe. Seepage pressure can be determined from piezometer readings.

Settlement monuments - Settlement monuments are usually installed along the crest of the dam to check its vertical and horizontal alignments (with known reference points and elevations). Measurements of these monuments must be precise and are obtained using surveying instruments.

Observations Wells - Observation wells can be installed in the embankment or foundation and are used to determine the ground-water level.

Inclinometers - Inclinometers are instruments that are lowered into a vertical casing and measure horizontal deflection. Inclinometers are often used to determine the rate of movement of a slide.

Monitoring by a private owner is usually limited to visual observation. It is very important that the observations are accurate, made periodically, and recorded. An inspection checklist for this purpose has been included at the end of this manual. Owners are encouraged to use photographs with identifying dates and labels as a permanent record to be filed with other dam records.

PART

MAINTENANCE OF SPILLWAYS AND CONTROL STRUCTURES

IV

INSPECTION AND REPAIR OF SPILLWAY CONDUITS

Many dams have pipes (or conduits) that serve as principal spillways. These conduits are required to carry normal stream and small flood flows safely past the embankment throughout the life of the structure. Pipes through embankments are difficult to construct properly, can be extremely dangerous to the embankment if problems develop after construction, and are usually difficult to repair because of their location and size. Maximum attention should be directed to maintaining these structures.

Inspection

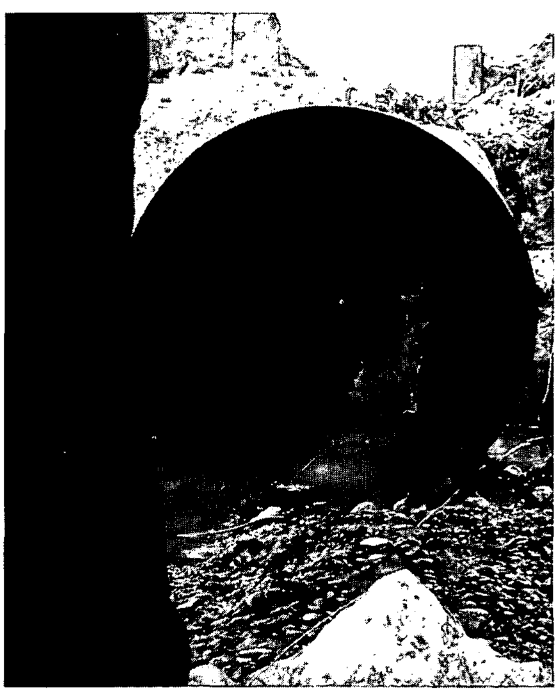
Frequent inspection is necessary to ensure the spillway conduit is functioning properly. All conduits should be inspected thoroughly once a year. Conduits which are 24 inches or more in diameter can be entered and visually inspected. The conduits should be inspected for improper alignment (sagging), elongation and displacement at joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage.

Problems with conduits occur most often at joints, and special attention should be given them during the inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water into the embankment during pressure flow. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

Repair

Effective repair of the internal surface or joint of a conduit is difficult and should not be attempted without careful planning and proper professional supervision. Listed below are comments regarding pipe repairs.

1. Asphalt mastic used as joint filler becomes hard and brittle, is easily eroded, and will generally provide a satisfactory seal for only about five years. Mastic should not be used if the pipe is expected to flow under pressure. For these reasons asphalt mastic is not recommended for other than temporary repairs.
2. The instructions on the label should be followed when using the new thermosetting plastics (epoxy). Most of these products must be applied to a very clean and dry surface to establish an effective bond.
3. Material used as joint filler should be impervious to water and should be flexible throughout the range of expected air and water temperatures.
4. The internal surfaces of the conduit should be made as smooth as possible when repairs are made so that high-velocity flow will not damage the repair material.
5. Oakum or gasket-type material jacked, hammered, or forced into an open crack or joint is one of the most effective methods used to repair large openings (see section on Concrete Repair, page 36).
6. Hairline cracks in concrete are not generally considered a dangerous problem and repair is not needed unless the cracks open up.



Corrosion of a steel spillway pipe.

Far left: Separation at a pipe joint and erosion of embankment material.

Corrosion

Corrosion is a common problem of pipe spillways and other conduits made of metal. Exposure to moisture, acid conditions, or salt will accelerate the corrosion process. Acid runoff from strip-mine areas will cause rapid corrosion of metal pipes. In these areas, pipes made of non-corrosive materials such as concrete or plastic should be used.

Metal pipes are available which have been coated to resist accelerated corrosion. Coatings can be of epoxy, aluminum, zinc (galvanized), or asbestos. Coatings applied to pipes in service are generally not very effective because of the difficulty in establishing a bond. Bituminous coatings cannot be expected to last more than one or two years on flowways.

Corrosion can also be controlled or arrested by installing cathodic protection. A metallic anode such as magnesium is buried in the soil and is connected to the metal pipe by wire. Natural voltage current flows from the magnesium (anode) to the pipe (cathode) and will cause the magnesium to corrode and not the pipe.

Corrosion of metal parts of operating mechanisms can be effectively treated and prevented by keeping these parts oiled and/or painted.

Undermining of the Spillway Outlet

Erosion at the spillway outlet, whether it be a pipe or overflow spillway, is one of the most common spillway problems encountered. Severe undermining of the outlet can displace sections of pipe, cause slides in the downstream slope of the dam as erosion continues, and eventually lead to complete failure of a dam. Water must be conveyed safely from the lake to a point downstream of the dam without endangering the spillway or embankment. Often the spillway outlet is adequately protected for normal flow conditions, but not for extreme flows. It is easy to underestimate the energy and force of flowing water and/or overestimate the resistance of the outlet material (earth, rock, concrete, etc). The required level of protection is hard to establish by visual inspection but can usually be determined by hydraulic calculations performed by a professional engineer.

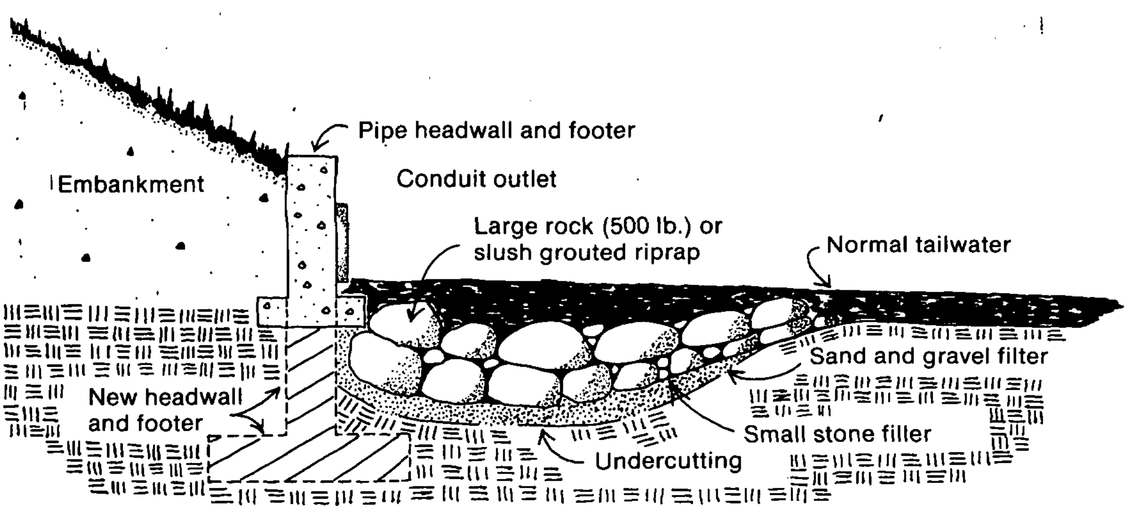
Structures that provide complete erosion control at a spillway outlet are usually expensive to construct, but often necessary. Less expensive types of protection can be effective, but require more extensive periodic maintenance. As areas of erosion and deterioration develop, repairs must be promptly initiated.

The following four factors, often interrelated, contribute to erosion at the spillway outlet.

1. Flows emerging from the outlet are at an elevation above the stream channel. If the outlet flows emerge at the correct elevation, tailwater in the stream channel can be used to absorb a substantial amount of the high velocity flow and the hydraulic jump will be contained in the stilling basin.
2. Flows emerging from the spillway are generally free of sediment and therefore have substantial sediment-carrying capacity. In obtaining the appropriate sediment load, the moving water will scour soil material from the channel and leave eroded areas. Such erosion is difficult to design for and requires the outlet be protected for a safe distance downstream from the dam.
3. Flows leaving the outlet at high velocity can create negative pressures that can cause material to be loosened and removed from the floor and walls of the outlet channel. This action is called "cavitation" when it occurs on concrete or metal surfaces. Venting can sometimes be used to relieve negative pressures.
4. Water leaking through pipe joints and/or flowing along a pipe from the reservoir may weaken the soil structure around the pipe. Inadequate compaction adjacent to the structure during construction would compound the problem.

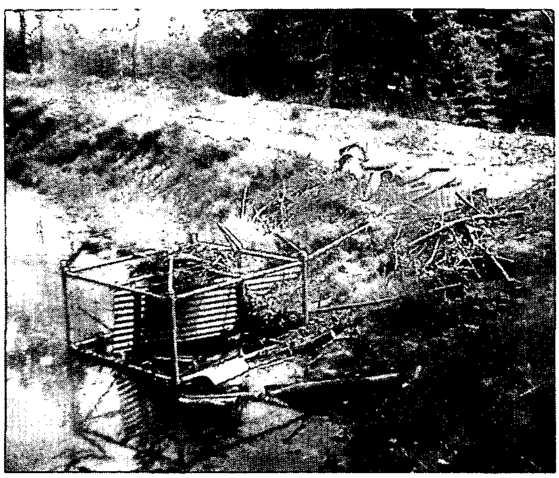
Eroded and undermined areas at spillway outlets can sometimes be repaired by filling these areas with large stone. Stone that is large enough to be effective needs to weigh at least 500 pounds (18 to 24 inches in diameter). Often stone this size is not available or is expensive to buy and haul. Concrete slurry can be used to bind smaller stones together to increase their effective size and weight. Gabions have been used successfully in areas where the velocity is low but should not be used where high velocity and turbulence are expected. Gabions require careful foundation preparation and experienced personnel for installation.

In many cases, professional help should be sought for complete redesign and construction of the outlet.



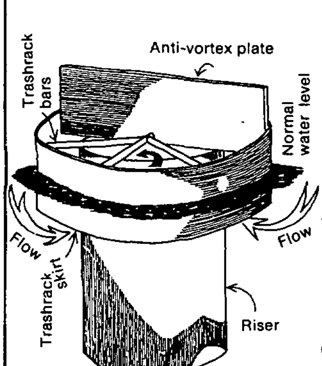
TRASHRACKS ON PIPE SPILLWAYS

Many dams have pipe and riser spillways. Pipe spillway inlets that become plugged with debris or trash reduce spillway capacity. As a result, the potential for overtopping the dam is greatly increased, particularly if there is only one spillway. If the dam has an emergency spillway channel, a plugged principal spillway will cause more frequent and greater than normal flow in the emergency spillway. Since emergency spillways are generally designed for infrequent flows of short duration, serious damage will likely result. For these reasons trash collectors or racks must be installed at the inlets to pipe spillways and lake drains.



Far left: The accumulation of debris around a trashrack after a large storm.

Left: A damaged trashrack caused by the hammering forces of debris.



A well-designed trashrack will stop large debris that could plug the pipe but allow unrestricted passage of water and smaller debris. Some of the most effective racks allow flow to pass beneath the trash into the riser inlet as the pool level rises. Racks usually become plugged because the openings are too small or the head loss at the rack causes material and sediment to settle out and accumulate. Small openings will stop small debris such as twigs and leaves, which in turn cause a progression of larger items to build up, eventually completely blocking the inlet. Trashrack openings should be at least 6 inches across regardless of the pipe size. The larger the principal spillway conduit, the larger the trashrack opening should be. The largest possible openings should be used, up to a maximum size of about 2 feet.

The trashrack should be properly attached to the riser inlet and strong enough to withstand the hammering forces of debris being carried by high velocity flow, a heavy load of debris, and ice forces. If the riser is readily accessible, vandals will throw riprap stone into it. To prevent such vandalism, the size of the trashrack openings should not be decreased, but rock that is larger than the openings or too large to handle should be used.

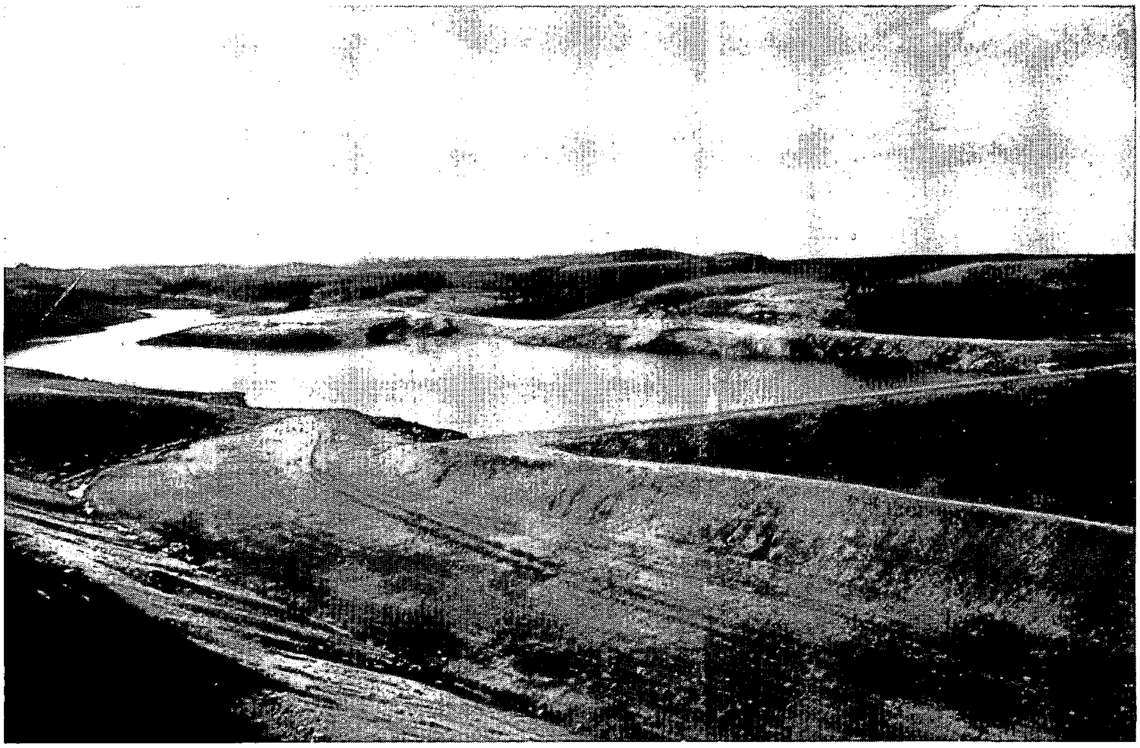
Maintenance should include periodically checking the rack for rusted and broken sections and repairing as needed. The trashrack should be checked frequently during and after storm events to ensure it is functioning properly and to remove accumulated debris.

INSPECTION AND REPAIR OF VEGETATED EARTH SPILLWAYS

Vegetated earth spillways are commonly used as an economical means to provide emergency spillway capacity. Normal flows are carried by the principal spillway, and infrequent large flood flows pass primarily through the emergency spillway. For dams with pipe-conduit spillways, an emergency spillway is almost always required as a back-up in case the pipe becomes plugged. These spillways are often neglected because the owner rarely sees them flow.

Maintenance should include:

1. *Periodic mowing to prevent trees, brush, and weeds from becoming established, and to encourage the growth of grass.* Poor vegetal cover will usually result in extensive and rapid erosion when the spillway flows, and require more costly repairs. Trees and brush may reduce the discharge capacity of the spillway.
2. *Repair of erosion damage, particularly after high flows.* Erosion can be expected in the spillway channel during high flows and can also occur as a result of rainfall and local runoff. The latter is more of a problem in large spillways and may require special treatment, such as terraces or drainage channels. Erosion of the side slopes deposits material in the spillway channel, especially where the side slopes meet the channel bottom. In small spillways, this can significantly reduce the spillway capacity. This condition often occurs immediately after construction, before vegetation becomes established. In these cases, it may be necessary to reshape the channel to provide the necessary capacity.
3. *Reseeding and fertilization as necessary to maintain a vigorous growth of vegetation.* In Ohio, Kentucky 31 Fescue is an excellent grass for erosion protection (see section on Vegetation, page 15).
4. *Removal or relocation of obstructions.* Emergency spillways often are used for purposes other than passage of flood flows. Among these uses are reservoir access, parking lots, boat ramps, boat storage, pasture and cropland. Permanent structures (buildings, fences, etc.) should not be constructed in these spillways. If fences are absolutely necessary, they should cross the spillway far enough away from its control crest so they do not interfere with flow.



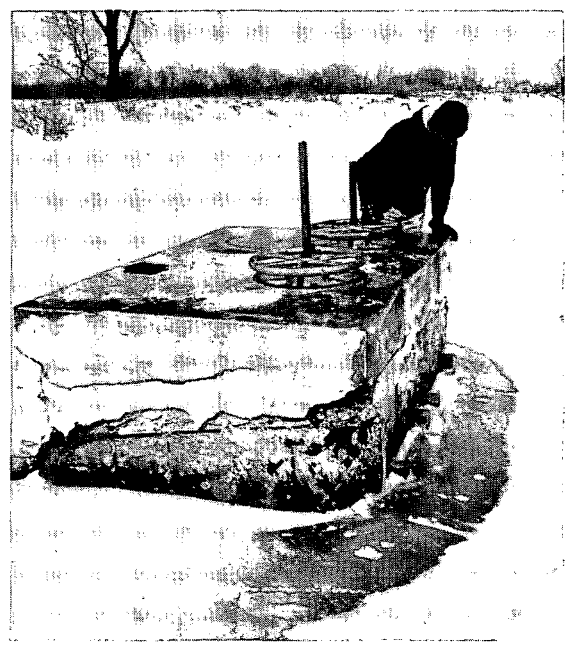
Right: A vegetated earth spillway.

CONCRETE REPAIR

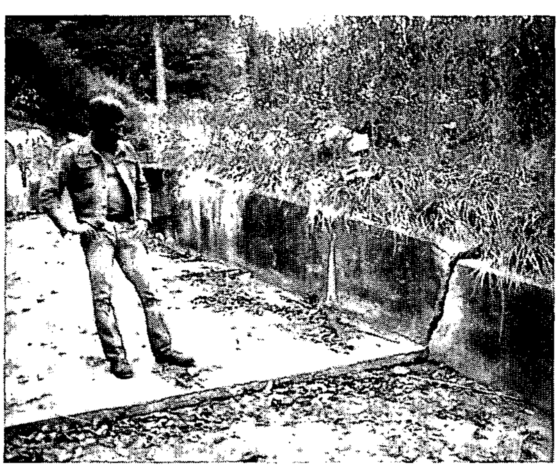
Concrete is an inexpensive, durable, strong and basic building material often used in dams for core walls, spillways, stilling basins, control towers, and slope protection. However, poor workmanship, construction procedures and construction materials may cause imperfections that later require repair. Long-term deterioration or damage caused by flowing water, ice, or other natural forces must be corrected.

Inspection

Concrete surfaces should be examined for spalling and deterioration due to weathering, unusual or extreme stresses, alkali or other chemical action, erosion, cavitation, vandalism, and other destructive forces. Tapping the surface with a hammer or some device will locate "drummy," unsound concrete.

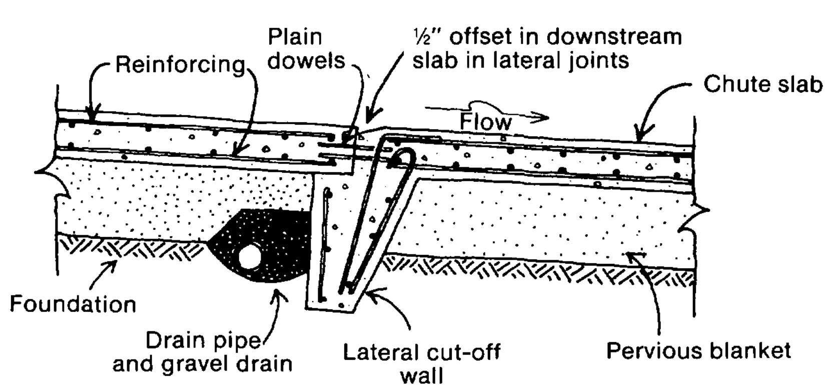


Left: Concrete deterioration caused by weathering.



Far left: Undermining and settlement of a floor slab.

Structural problems are indicated by cracking, exposed reinforcing bars, large areas of broken-out concrete, misalignment at joints, undermining and settlement. Rust stains may indicate internal rusting and deterioration of reinforcement steel. Spillway floor slabs and upstream slope protection slabs should be checked for undermining (erosion of base material). Concrete wall and tower structures should be examined for settlement and their alignment checked. Concrete surfaces adjacent to contraction joints and subject to flowing water are of special concern. The adjacent surfaces must be flush or the downstream one slightly lower to prevent erosion of the concrete and to prevent water from being directed into the joint during high velocity flow. All joints should be kept free of vegetation. All weep holes should be checked for blockage and concrete stain outlines on concrete surfaces studied for an indication of flow characteristics.



CONCRETE REPAIR

General Concrete Repair

Floor or wall movement, extensive cracking, improper alignments, settlement, joint displacement, and extensive undermining are signs of major structural problems. Drainage systems may be needed to relieve excessive water pressures under floors and behind walls. Because of their complex nature, major structural repairs require professional advice and are not addressed here.

Before attempting repair of a concrete surface, all unsound concrete should be removed by sawing or chipping and the patch area thoroughly cleaned. A sawed edge is superior in every way to a chipped edge, and sawing is generally less costly than mechanical chipping.

The U.S. Bureau of Reclamation recommends the following six methods of repair. These techniques require expert and experienced assistance for the best results. The particular method of repair will depend on the size of the job and the type of repair required.

Right: Structural crack caused by wall movement.

1. *The Dry-Pack Method* - The dry-pack method can be used on small holes in new concrete which have a depth equal to or greater than the surface diameter. Prepare a dry-pack mix consisting of 1 part cement to 2½ parts sand. Add enough water to produce mortar that will stick together. Pack the mortar into the hole in thin layers.
2. *Concrete Replacement* - Concrete replacement is required when one-half to one square foot areas or larger extend entirely through the concrete section or where the depth of damage exceeds 6 inches. Normal concrete placement methods should be used. Repair will be more effective if tied in with existing reinforcing steel (rebar).
3. *Replacement of Unformed Concrete* - The replacement of damaged or deteriorated areas in horizontal slabs involves no special procedures other than those used in good construction practices for placement of new slabs. Repair work can be bonded to old concrete by use of a bond coat made of equal amounts of sand and cement. It should have the consistency of whipped cream and should be applied immediately ahead of concrete placement so that it will not set or dry out. Latex emulsions with portland cement and epoxy resins are also used as bonding coats.
4. *Shotcrete (Gunite)* - A popular concrete replacement technique for repairing large areas of severely deteriorated concrete and spalled vertical and overhead faces is the use of pneumatically placed concrete or shotcrete. Shotcrete consists of a mixture of moistened cement and fine aggregate (sand) that is sprayed onto the repair area under pressure. Professional assistance and sophisticated equipment are needed to apply shotcrete.
5. *Prepacked Aggregate with Intruded Mortar* - A special commercial technique has been used for massive repairs, particularly for underwater repairs of piers and abutments. The process consists of: 1) removing the deteriorated concrete; 2) forming the sections to be repaired; 3) prepacking the repair area with coarse aggregate; and 4) pressure grouting the voids between the aggregate particles with a cement or sand-cement mortar.
6. *Synthetic Patches* - One of the most recent developments in concrete repair has been the use of synthetic materials for bonding and patching. Epoxy-resin compounds are used extensively because of their high bonding properties and great strength. In applying epoxy-resin patching mortars, a bonding coat of the epoxy resin is thoroughly brushed onto the base of the old concrete. The mortar is then immediately applied and struck off to the elevation of the surrounding material.

When to Use Each Method

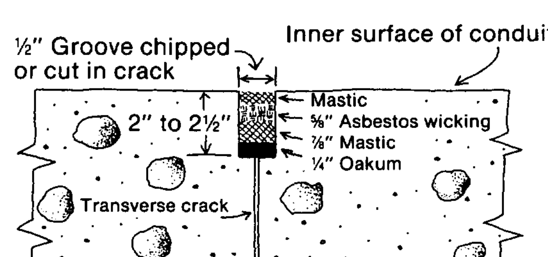
Epoxy-bonded epoxy mortar can be used when the depth of repair is less than 1½ inches. Epoxies can be used to bond new concrete or mortar to old concrete whenever the depth of repair is between 1½ and 6 inches. Concrete replacement techniques (methods 2, 3, 4, or 5) should be used when the depth of repair exceeds 6 inches or the repair area is large.

All concrete repairs must be adequately moist-cured to be effective. The bond strength of new concrete to old concrete develops much more slowly, and the tendency to shrink and loosen is reduced by a long moist-curing period.

Repair of Cracks

Repair of cracks in structures that carry water requires great care and preparation. The following steps are recommended by the U.S. Bureau of Reclamation (1):

1. Cut a groove along the crack ½ inch wide and 2 to 2½ inches deep. A power-driven saw-tooth bit works satisfactorily.
2. Rub a thin layer of internal-set-type mastic onto the interior surfaces of the groove.
3. Tamp oakum tightly into the bottom ¼ inch of the slot.
4. Fill in ⅞ inch of mastic on top of the oakum.
5. Place a ⅝ inch section of tightly twisted asbestos rope wicking into the groove and caulk tightly, using pneumatic tools.
6. Fill the groove with mastic and smooth the surface.



Flow entering the joint of a spillway floor slab.

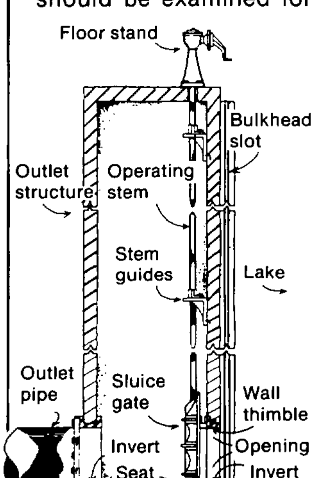
Collapse of a spillway wall section.

MECHANICAL EQUIPMENT

Mechanical equipment includes spillway gates, sluice gates or valves, stoplogs, sump pumps, flashboards, relief wells, emergency power sources, siphons and other equipment associated with spillways, drain structures, and water supply structures.

Mechanical and associated electrical equipment should be checked for proper lubrication, smooth operation, vibration, unusual noises, and overheating. The adequacy and reliability of the power supply should also be checked during operation of the equipment. Auxiliary power sources and remote control systems should be tested for adequate and reliable operation. All equipment should be examined for damaged, deteriorated, corroded, cavitated, loose, worn, or broken parts.

Gate stems and couplings should be examined for corrosion, broken or worn parts, and damage to protective coatings. Fluidways, leaves, metal seats, guides, and seals of gates and valves should be examined for damage due to cavitation, wear, misalignment, corrosion, and leakage. Sump pumps should be examined and operated to verify reliability and satisfactory performance. Air vents for pipes, gates and valves should be checked to confirm that they are open and protected. Wire rope or chain connections at gates should be examined for proper lubrication and worn or broken parts. Rubber or neoprene gate seals should be examined for deterioration, cracking, wear, and leakage. Hydraulic hoists and controls should be checked for oil leaks and wear. Hoist piston and indicator stems should be examined for contamination and for rough areas that could damage packings.



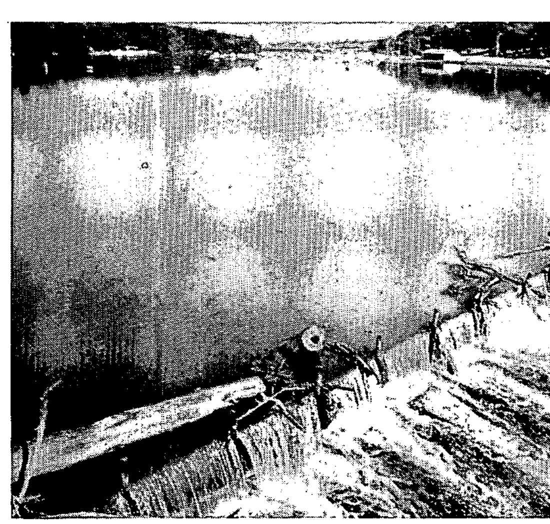
Many dams have structures above and below ground that require some type of access. Water supply outlet works, lake drains, gated spillways, drop box spillways, and toe drain manhole interceptors are typical structures that will require bridges, ladders, or walkways. Care should be taken to properly design, install, and maintain these means of access for the safety of persons using them. State and local codes on safety should be followed. Requirements for walkways may include toe plates and handrails. Fixed ladders should have proper rung spacing and safety climbing devices, if necessary. Access ladders, walkways, and handrails should be examined for deteriorated or broken parts or other unsafe conditions.

Stoplogs, bulkhead gates, and lifting frames or beams should be examined to determine their availability and condition. The availability and locations of equipment for moving, lifting, and placing stoplogs, bulkheads, and trashracks should also be verified.

Flashboards

Flashboards are usually wood boards installed in an upright position along the crest of the spillway to raise the normal pool level. Flashboards should not be installed or allowed unless professional investigation indicates there is sufficient freeboard remaining to safely pass the design flood. Some flashboard installations are designed to fail when subjected to a certain depth of flowing water, thereby recovering the original spillway capacity. However, flashboards designed to fail may not be reliable and are not recommended.

Maintenance generally consists of repairing or replacing broken boards. The support structure for the flashboards should be examined for damage due to wear, misalignment, corrosion, and leakage, and repaired as necessary. The flashboards should be removed periodically (at least once a year) as a check for freedom of movement.



Far right: Flashboards on the crest of a spillway.

PART

OPERATION

V

The operation of a dam may include adjusting reservoir levels, keeping records, ensuring public safety, controlling litter, and opening and closing valves. Proper operational procedures are extremely important in maintaining a safe structure. Many small dams do not require a full-time operator, but should be checked on a regular basis. Special operational procedures to be followed during an emergency should be posted in the event the owner/operator is not available (see section on Emergency Actions and Procedures, page 9).

Information on items such as sedimentation, contacting professional engineers, and stocking fish is also covered in this section.

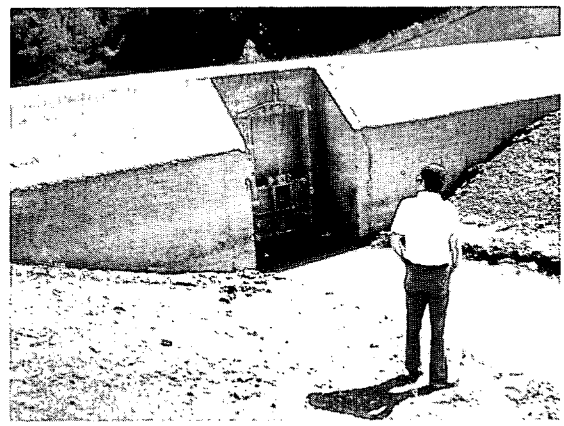
LAKE DRAINS

The lake drain should always be operable in order that the pool level can be drawn down in case of an emergency or for necessary repair. Lake drain valves or gates that have not been operated for a long time present a special problem for owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. An uncontrolled and rapid drawdown could also induce more serious problems such as slides in the saturated upstream slope of the embankment. Drawdown rates should not exceed 1 foot per week for slopes of clay or silt material except for emergency situations. Very flat slopes or slopes with free draining upstream zones can withstand more rapid drawdown rates. Large discharges could also cause downstream flooding. Therefore, before operating a valve or gate, it should be inspected and all appropriate parts lubricated and repaired. It is also prudent to advise downstream residents of large and/or prolonged discharges.

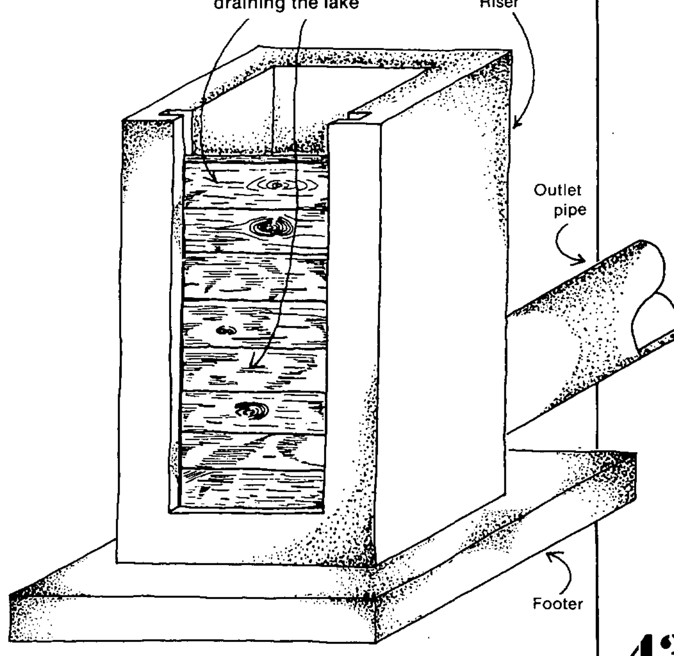
To test a valve or gate without risking that the lake will be drained, one must somehow physically block the drain inlet upstream from the valve. Some drain structures have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called bulkheads) located upstream of the drain valve. Divers can be hired to inspect the drain inlet and may be able to construct a temporary block at the inlet for testing purposes.

Other problems may be encountered when operating the lake drain. Sediment can build up and block the drain inlet. Debris can be carried into the valve chamber, hindering its function if an effective trash rack is not present. The potential that these problems will occur is greatly decreased if the valve or gate is operated and maintained periodically. The gate or valve controlling the lake drain should be operated from the fully closed to fully opened position at least twice a year. It is preferable that the drain be operated four times a year. Early detection of equipment problems or breakdowns and confidence in equipment operability are benefits of periodic operation.

The Ohio Department of Natural Resources, Division of Water, administrative rules require that for all new or reconstructed dams, the drain valve be located upstream from the center line of the dam. Many older dams have drains with valves at the downstream end. If the valve is located at the downstream end of a conduit extending through the embankment, the conduit is under the constant pressure of the reservoir. If a leak in the conduit develops within the embankment, saturation, erosion, and possibly failure of the embankment could occur in a short period of time. A depression in the soil surface over the pipe may be a sign soil is being removed from around the pipe. These older structures should be monitored closely and owners should plan to relocate the valve upsteam or install a new drain structure. Inspectors should closely examine the drain outlet for signs of possible problems.



Left:
A sluice gate at the inlet to a lake drain conduit.



MECHANICAL EQUIPMENT

MECHANICAL EQUIPMENT

Mechanical equipment includes spillway gates, sluice gates or valves for lake drains or water supply pipes, stoplogs, sump pumps, flashboards, relief wells, emergency power sources, siphons, and other devices. All mechanical and associated electrical equipment should be operated at least once a year and preferably more often. The annual test should be conducted through the full operating range under actual operating conditions to determine that the equipment performs satisfactorily. Operating instructions should be checked for clarity and maintained in a secure, but readily accessible location. Each operating device should be permanently marked for easy identification. All operating equipment should be accessible. All equipment controls should be checked for proper security to prevent vandalism.

RESERVOIR LEVELS

RESERVOIR LEVELS

Reservoir pool levels are often controlled by spillway gates, lake drain and release structures, and flashboards. Pool level drawdown rates should not exceed 1 foot per week for slopes composed of clay or silt material except for emergency situations. Very flat slopes or slopes with free draining upstream zones can withstand more rapid drawdown rates. Listed below are conditions or instances in which the pool level might be permanently or temporarily adjusted.

1. A problem develops that requires the pool be lowered. Drawdown is temporary until the problem is solved.
2. Water is released to the downstream channel, supplementing streamflow during dry conditions. This may temporarily lower the lake level.
3. Water supply reservoir levels will fluctuate according to the service area's demand for water. Flashboards are sometimes used to permanently or temporarily raise the pool level of water supply reservoirs. Flashboards should not be installed or allowed unless there is sufficient freeboard remaining to safely pass the design flood (see page 38).
4. The pool level is drawn down in the winter to facilitate repair of boat docks, to retard growth of aquatic vegetation along the shoreline, or to allow additional storage for spring runoff.
5. Pool levels are sometimes adjusted for recreation, hydropower, or waterfowl and fish management.

Riparian Rights (8)

Care should be taken by owners when releasing or impounding water to protect the rights of downstream property owners. The system of riparian rights has been established through the courts and permits each riparian owner to make a "reasonable" use of the water, having regard to the same rights existing for the other downstream riparian owners. An owner could be legally responsible if a sudden release of water caused damages downstream.

RECORD KEEPING

Operation of a dam should include keeping accurate records of the following:

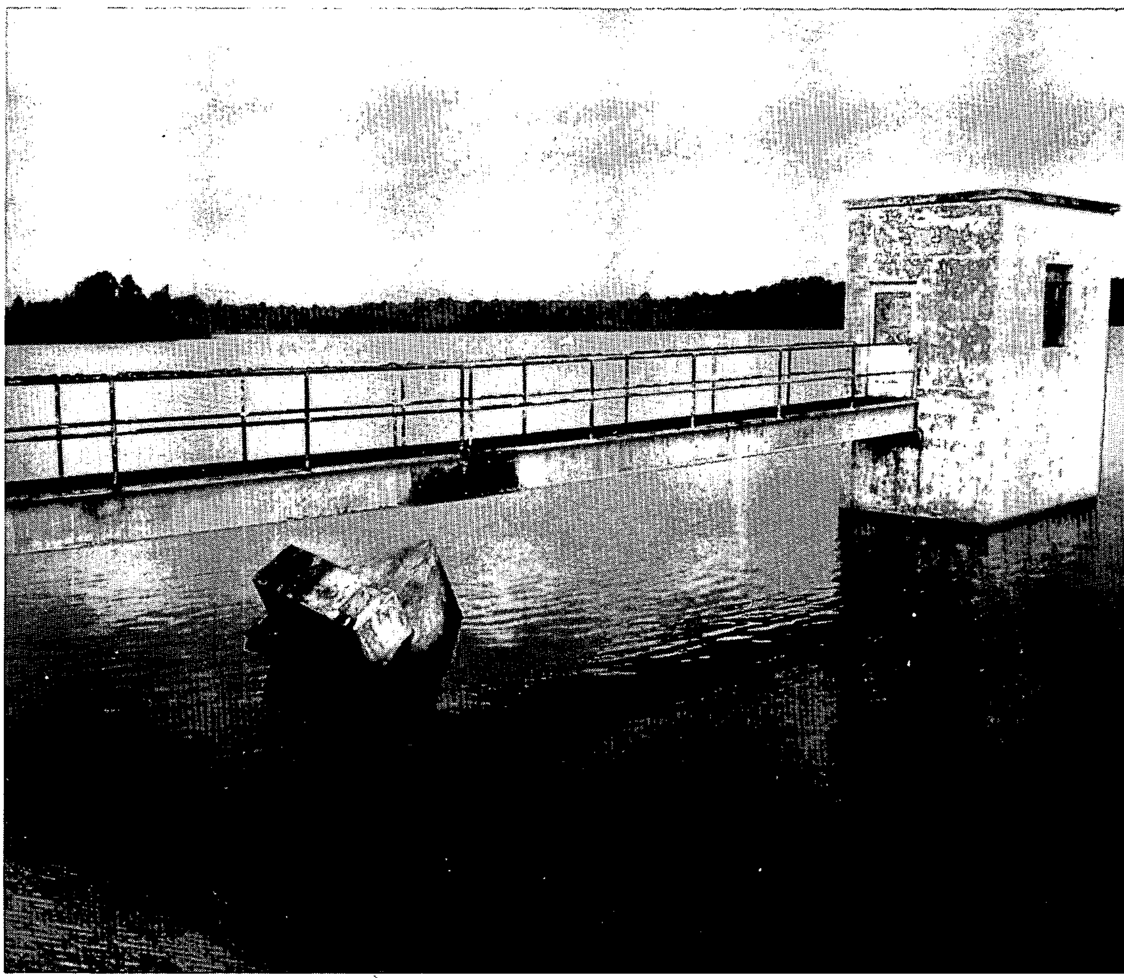
1. *Observations:* All observations should be recorded. Of particular importance is the periodic observation of existing seepage to detect any changes. Photographs are valuable for recording observations and changes.
2. *Maintenance:* Written records of maintenance and major repairs will be important in periodic safety evaluations of the dam.
3. *Rainfall and Pool Levels:* A record of the date, hour, and maximum elevation of extreme high water events and the associated rainfall is especially helpful in evaluating the performance of the dam and its spillway system. Rain gages are available at any local farm or garden store. Lake level staff gages can be easily made or measurement numbers can be painted on existing structures in the pool area. Records should be kept for all lakes that have widely fluctuating water levels.
4. *Drawdown:* A record should be kept of the amount, rate, and reason for pool level drawdown.
5. *Other Operational Procedures:* A complete listing of operational procedures should be maintained.

Suggested checklists are included at the back of this manual for recording inspection observations and maintenance, operation, rainfall, and pool level events.

The owner should maintain a complete and up-to-date set of plans and specifications ("as-built" drawings) for the dam, which should show all changes made over time. Knowing how a dam, its spillways, and other appurtenances were constructed and/or modified is very helpful in diagnosing problems.

Left: Recording observations.

WINTERIZING TECHNIQUES AND PROBLEMS



Right: Walkway support pier displaced by ice pressure.

The pool level of a reservoir is often lowered for the winter months for various reasons: to facilitate repair of boat docks and other structures; to retard growth of aquatic vegetation; to provide additional spring flood storage; or to prevent ice damage. Rapid drawdown of the pool will leave the upstream slope saturated and without support, and could result in sloughs and slides. Unless there is an emergency, the maximum recommended rate of pool level drawdown is 1 foot per week for slopes of clay or silt material. This should allow time for the saturated soil to drain. If there is a question about the allowable drawdown rate, the design engineer should be contacted.

Ice can pose problems at spillways and around other structures. Ice formation can be prevented by heaters, aeration equipment, or forced movement of water. Ice in conduit outlets or stilling basins can impair their proper functioning. The owner should be aware of these potential problems and take appropriate action during extended periods of severe cold weather. Ice damage from impact can also occur during the spring thaw when large chunks of ice begin to break free.

Other winterizing activities may include:

1. Seeding bare areas so that vegetation is established before onset of winter.
2. Removing flashboards for storage.
3. Opening valves slightly to provide a small flow to prevent freezing.

VANDALISM

Vandalism is a common problem faced by all dam owners. Particularly susceptible to damage are the vegetated surfaces of the embankment, mechanical equipment, manhole covers, and rock riprap. Every precaution should be taken to limit access to the dam by unauthorized persons and vehicles.

Unauthorized Vehicles

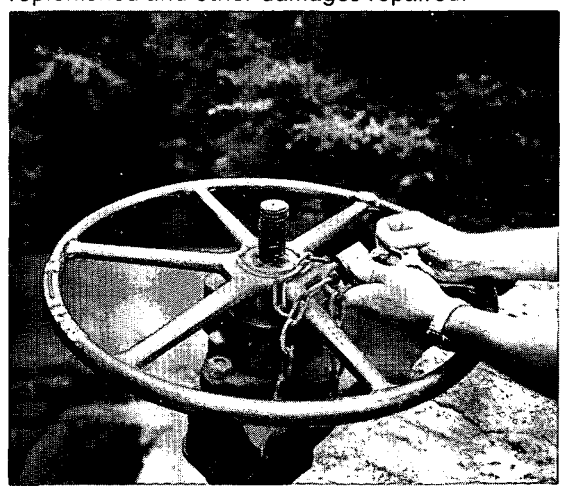
Dirt bikes (motorcycles) and four-wheel drive vehicles can severely damage the vegetation on embankments. Worn areas could lead to erosion and more serious problems. Constructed barriers such as fences, gates, and cables strung between poles are effective ways to limit access of these vehicles. A highway metal guardrail constructed immediately adjacent to the toe of the downstream slope is an excellent means for keeping vehicles off embankments. However, this may interfere with the operation of mowing equipment.

Mechanical Equipment

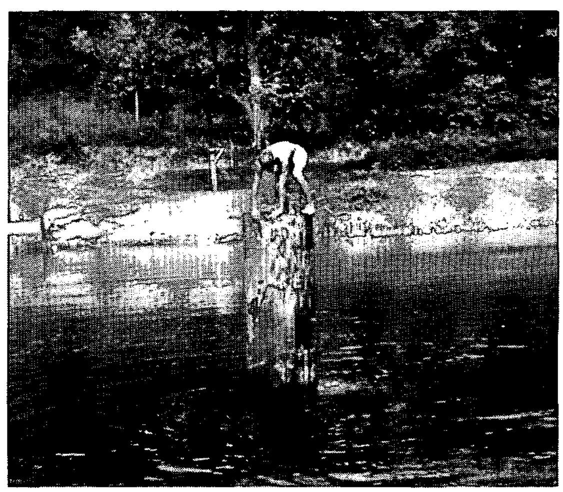
Mechanical equipment and its associated control mechanisms should be protected. Buildings housing mechanical equipment should be sturdy, have protected windows, have heavy-duty doors, and should be secured with deadbolt locks or padlocks. Detachable controls such as handles and wheels should be removed when not in use and stored inside. Other controls should be secured with locks and heavy chains, where possible. Manhole covers are also subject to removal and are often thrown into the lake or spillway by vandals.

Rock Riprap

Rock used as riprap around dams is often thrown into the lake, spillways, stilling basins, pipe spillway risers, and elsewhere. Riprap is often displaced by fishermen to form benches. The best way to prevent this abuse is to use rock too large and heavy to move easily or to slush grout the riprap. Otherwise, the rock must be constantly replenished and other damages repaired.



Locked control wheel.



Danger—Keep Off!!

Far left: Damage from four-wheel vehicles.

Public Safety

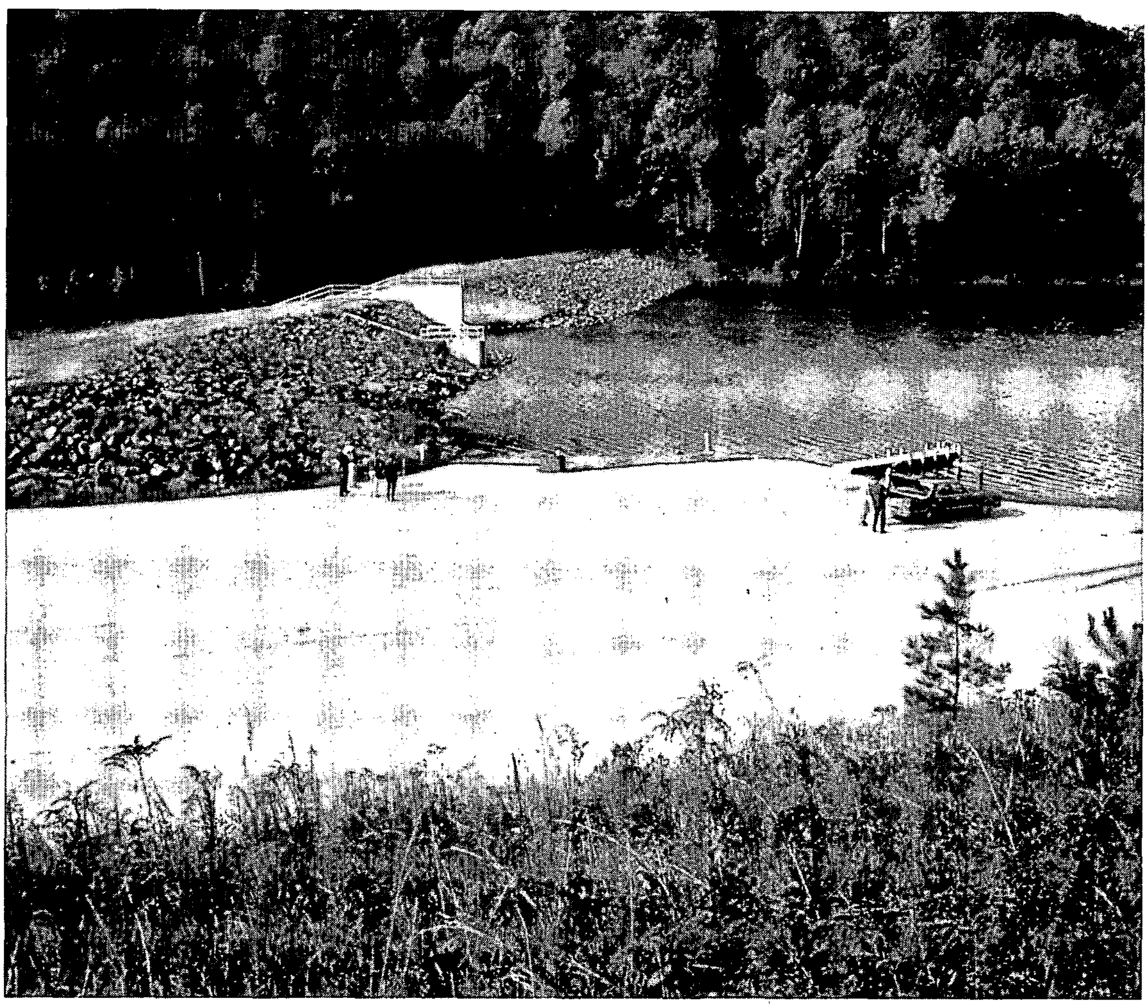
Owners should be aware of their responsibility for public safety, including the safety of people not authorized to use the facility. "No Trespassing" signs should be posted and fences and warning signs should be erected around dangerous areas. Liability insurance can be purchased to protect the owner in the event of accidents.

DESIGN MODIFICATIONS

Alteration of a dam or spillway without adequate engineering design and supervision could result in the spillway or dam being inadequate in capacity or function. This could lead to a costly repair or complete failure of the structure. In addition, approval by the Ohio Department of Natural Resources of any proposed changes is required by state law.

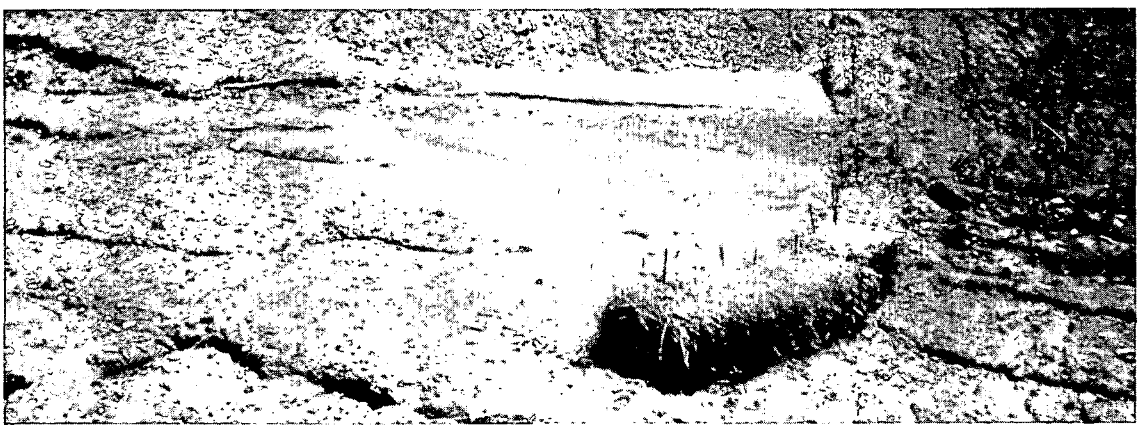
One of the more common "errors" made by dam owners is raising the normal pool elevation by permanently elevating the crest of the principal spillway. This action not only results in a decrease in storage available during a flood event but also reduces the capacity of the spillway by reducing the total depth available to "push" water through the spillway. Raising the normal pool will usually cause the emergency spillway to flow more frequently than its design allows, thus increasing its maintenance cost. Furthermore, raising the normal pool may be in violation of Ohio dam safety laws and associated administrative rules.

Emergency spillways usually are designed to flow only once every 10 to 100 years. Because the spillway flows so infrequently, owners are tempted to find other uses for it. Temporary uses such as parking or boat launching are acceptable. Permanent alteration of the spillway shape or construction of a building or other structure in the spillway could seriously affect the spillway's ability to function properly and should not be undertaken.



An emergency spillway being used as a parking lot and boat launching ramp.

SEDIMENTATION AND DREDGING



Sediment collected by straw bales used to slow the velocity of flowing water.

Erosion and sedimentation are natural processes in which soil particles are detached from the earth by raindrops or flowing water and carried away by streamflow. The velocity of the flowing stream carries the sediment load. When streams enter lakes, their velocities suddenly drop and the sediment load is deposited on the lake bottom. Typically, about 90 percent of the sediment load carried by incoming streams is deposited in a lake.

Sedimentation occurs in every lake, regardless of whether the lake is natural or created by a dam. Sedimentation rates vary widely and depend on many factors of the watershed areas. Among these are soil type, land cover, land slope, land use, stream slope, size of watershed, total annual precipitation, number and intensity of severe storm events, material in the streambed, and volume of the lake with respect to size of the drainage area. In Ohio most of the sediment enters lakes and reservoirs during a few large flood events that occur each year. Sediment deposits first become apparent when deltas build up at the mouths of streams entering the lake. Aquatic vegetation, such as cattails and lily pads, soon develops in the shallow water over these deltas. As sediment deposition continues, the delta will rise above the water surface.

The best way to avoid sedimentation problems is to reduce erosion in the watershed area. As most dam owners do not control the watershed land, other means must be found to minimize the effects of sedimentation. One way is by dredging. However, this is expensive and will eventually have to be repeated because the sedimentation process never stops. Disposal of the dredged material is often a problem. Under certain conditions, dredging and disposing of dredged material in a lake or adjacent to a stream requires a permit from the U.S. Army Corps of Engineers. Before undertaking such work, the owner should check with the appropriate District Office of the Corps.

One commonly used plan for dredging is to create a relatively narrow channel through the delta and into deeper water. Flow velocities in the narrow channel remain high enough to carry sediment particles into deeper water before they are deposited. The narrow channel is created by placing dredged material along the sides of the channel to build peninsulas. Location and shape of the peninsulas will depend on the configuration of the lake at the point the stream enters. This process will eventually have to be repeated as deposits build in the channel and new deposition area.

Another way to control sedimentation is to lower the lake level during the winter and early spring when many of the larger floods occur. Sediments will then be carried farther into the lake and deposited several feet below the normal pool. Periodically opening the drain valve will help keep sediment from obstructing or burying the drain inlet.

For ponds with smaller drainage areas, vegetated strips around the pond will act as filters and trap much of the sediment. These are especially effective for ponds where much of the runoff enters as sheet flow rather than in small streams.

Many private landowners ask if financial assistance is available for removing sediment from their lake. As of the date of this publication, no state or federal funds are available to private landowners for this purpose.

ACCESS ROADS

ACCESS ROADS

The safe operation of a dam depends on reliable and safe means of access. Usually this involves maintaining a road to the dam. The road should be of all-weather construction, suitable for the passage of automobiles and any required equipment for servicing the dam. Cut-and-fill slopes, both uphill and downhill from the road, should be stable under all conditions. The road surface should be located above the projected high-water elevations of any adjacent streams and the reservoir pool so access can be maintained at times of flooding.

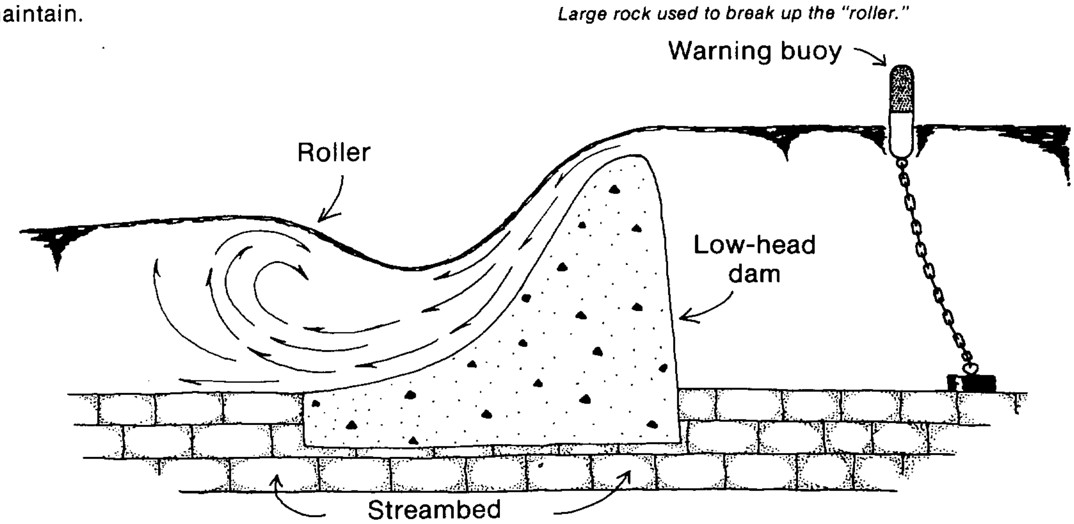
LOW-HEAD DAMS

LOW-HEAD DAMS

Owners of low-head dams should be aware these dams are potentially dangerous to boaters and canoeists. During high flow conditions the dam may appear as only a "bump" or ripple in the water surface. This tranquil scene is very deceptive and does not indicate the truly dangerous conditions that exist. If a canoe safely negotiates the "bump," backflow just downstream from the dam can act to pull the canoe into the dam and overturn it. The hydraulic action of water passing over the dam creates a "roller" that can trap the victims, continuously pulling them beneath the surface and preventing them from swimming downstream or to the banks.

Extremely large riprap (stones weighing 2 to 4 tons each) placed immediately downstream from three low-head dams in Columbus, Ohio has been effective in breaking up the "roller." A hydraulic engineer should be contacted to properly design any similar corrective measures. Warning buoys, signs, or cable with warning signs stretched across the stream can be effective in discouraging canoeists, but these are often ignored and are difficult to maintain.

Large rock used to break up the "roller."



CONTACTING A PROFESSIONAL ENGINEER

Solutions to many of the problems noted in this manual require the services of a registered professional engineer. Because dams and their associated works are complex structures, engineers who are fully experienced in the design, construction, and inspection of dams should be engaged. Several sources for locating professional engineers are listed below.

The State Board of Registration for Professional Engineers and Surveyors publishes a roster of registered professional engineers and surveyors of the State of Ohio. The roster can be obtained by calling or writing to:

State Board of Registration for
Professional Engineers and Surveyors
65 South Front Street, Room 302
Columbus, Ohio 43215
Telephone Number: (614) 466-3650

The Ohio Association of Consulting Engineers publishes a directory of member engineering firms. This directory lists firms by area and briefly describes the services each firm offers. The directory can be obtained by calling or writing to:

Ohio Association of Consulting Engineers
445 King Avenue
Columbus, Ohio 43201
Telephone Number: (614) 424-6648

The local county engineer may know of engineers or firms in the owner's immediate area who would be qualified to provide assistance.

Assistance in the form of technical advice can be provided by engineers within the Dam Inspection Section of the Ohio Department of Natural Resources. Contact by calling or writing:

Ohio Department of Natural Resources
Division of Water
Dam Inspection Section
Fountain Square, Building E-3
Columbus, Ohio 43224
Telephone Number: (614) 265-6731

STOCKING FISH

A popular recreational use of ponds and lakes in Ohio is fishing. The Ohio Department of Natural Resources, Division of Wildlife, offers free fish for stocking private ponds. However, pond owners are required to sign an agreement that provides they will allow free public fishing under their control; will post signs provided by the Division of Wildlife; and state fishing license laws will be in effect at the pond. Pond owners who do not need fish for stocking may also participate in the program. Pond owners who participate in this program are protected from liability associated with fishing by Sections 1533.18 and 1533.181 of the Ohio Revised Code.

To qualify for the program, the pond must be one-half acre or larger, and 25 percent of the pond must be at least 8 feet deep. The pond must be fenced from livestock. Ponds with existing populations of bass, bluegill and channel catfish are not eligible for stocking until rehabilitated. Fish provided for stocking are 2-inch largemouth bass (100 per acre), 1-inch bluegills (500 per acre) and 1-inch channel catfish (100 per acre). Ponds, five acres and over in area, receive the number of fish allocated for a five-acre pond. For additional information on this program, contact your local State Game Protector or any Division of Wildlife office.

If an owner does not want to participate in the state program, fish for stocking can be purchased from a number of private hatcheries throughout the state. A listing of these hatcheries can be obtained by requesting Publication 196 (Fish and Fish Food Propagators) from:

Ohio Department of Natural Resources
Publications Center
Fountain Square, Building B-1
Columbus, Ohio 43224
Telephone Number: (614) 265-6608

Ohio Pond Management (7), a publication on management of small impoundments for fishing and other recreational uses, is available from the U.S. Department of Agriculture, Cooperative Extension Service offices located in every county.

PART

INSPECTION, OPERATION AND MAINTENANCE CHECKLISTS

VI

Periodic inspection of dams is extremely important. Owners are encouraged to make a thorough visual inspection of their dams at least twice a year, once in the summer and once in the winter, and to have their dams inspected by a registered professional engineer at least once every 5 years. A closer inspection of the embankment surface can usually be made during the winter months when the vegetal cover is dormant and during the summer immediately after mowing. Throughout this manual, items to look for during inspection have been emphasized.

Included in this section are suggested forms to record inspection observations, and operation, maintenance, rainfall and pool level records. The inspection forms have been set up with common problems identified for each area inspected. Additional copies of these forms may be obtained from:

Ohio Department of Natural Resources
Division of Water, Dam Inspection Section
Fountain Square, Building E-3
Columbus, Ohio 43224
Telephone Number: (614) 265-6731

Four forms are provided on which to record inspection observations: one for embankments, dikes, or levees; one for spillways and drains or outlet works; one for miscellaneous items such as the watershed, lake shoreline, downstream area, monitoring devices, etc.; and a separate form for concrete dams. The form on page 59 is only used if the dam is concrete or has a concrete section. General instructions are provided on the back of each sheet. The fifth form is for recording operation, maintenance, rainfall, and pool level events.

These forms are used by the Dam Inspection Section of the Division of Water, Ohio Department of Natural Resources, and their use by dam owners is encouraged.

DAM INSPECTION CHECKLIST

Date ____________
Time ____________

NAME OF DAM ____________________
FILE NUMBER ____________ COUNTY ____________ CLASS ____________
WEATHER & SITE CONDITIONS ____________________
INSPECTORS ____________________
OTHERS ____________________

EMBANKMENT • DIKE • LEVEE

CHECK AREA AS INSPECTED ✓	✓	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
U/S SLOPE ☐	☐	vegetation/riprap				
	☐	beaching/slides/cracks				
	☐	undermining/erosion				
	☐					
CREST ☐	☐	ruts/erosion				
	☐	cracks/settlement				
	☐	poor alignment				
	☐					
D/S SLOPE ☐	☐	vegetation/erosion				
	☐	rodent burrows				
	☐	sloughs/slides/cracks				
	☐	seepage/wetness				
	☐					
GROINS ☐	☐	vegetation/riprap				
	☐	erosion				
	☐	seepage/wetness				
	☐					
ABUT-MENTS ☐	☐	vegetation/erosion				
	☐	sloughs/slides/cracks				
	☐	seepage/wetness				
	☐					
TOE ☐	☐	cracks/slumps				
	☐	embankment drains				
	☐	seepage/wetness				
	☐					

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

GENERAL INSTRUCTIONS

1. HEADING

File Number refers to the Dam Inspection Section, Ohio Department of Natural Resources inventory system for dams, dikes and levees and may be obtained from the Dam Inspection Section office.

Class refers to classification under Administrative Rule 1501:21-13-01. The classification (I, II, III, or IV) may be obtained from the Dam Inspection Section office.

Inspectors and Others should include names and affiliations.

Weather and Site Conditions should include weather conditions and the condition of the ground surface (wet, snow-covered, muddy, dry, etc.) at the time of the inspection.

2. CHECKLIST

Check the appropriate box along the left-hand side as that AREA is inspected. Check the appropriate box if that CONDITION/ITEM is noted and/or inspected. The specific item should be circled. Further description should be provided under OBSERVATIONS. Check the appropriate box for the required ACTION. Obvious problems will require repair. Monitoring will be recommended if there is potential for a problem to occur in the future. Investigation is necessary if the reason the problem is occurring is not obvious. More than one box can be checked.

3. OBSERVATIONS

A brief description of any noted irregularities, needed maintenance or problems for each CONDITION/ITEM checked or circled should be made. Use blank row for any ITEMS not listed. Abbreviations and short descriptions are recommended. Examples: VEGETATION - Dense brush and trees. SEEPAGE/WETNESS - 10 foot diameter area, at toe near left abut., cattails, no flowing water. EROSION - 3 feet deep gullies at both d/s groins. If more room is needed for a description, the bottom of the page may be used.

4. GENERAL COMMENTS, SKETCHES, AND FIELD MEASUREMENTS

Explanatory sketches, measurements of cracks, slides and settlement, and additional explanation of observations should be placed in this section.

Definitions
U/S - Upstream
D/S - Downstream
Gallery - Inspection/Access hall inside of concrete dam
Groin - Intersection of embankment face with the valley abutment

Additional copies of this form may be obtained from:

Ohio Department of Natural Resources
Division of Water
Dam Inspection Section
Fountain Square, Building E-3
Columbus, Ohio 43224
Telephone Number: (614) 265-6731

DAM INSPECTION CHECKLIST

Date ____________
Time ____________

NAME OF DAM ____________________
FILE NUMBER ____________ COUNTY ____________ CLASS ____________
WEATHER & SITE CONDITIONS ____________________
INSPECTORS ____________________
OTHERS ____________________

CONCRETE DAM TYPE ____________

CHECK AREA AS INSPECTED	✓	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
U/S FACE		deteriorated joints				
		cracking/spalling				
CREST		deteriorated joints				
		cracking/spalling				
		poor alignment				
D/S FACE		deteriorated joints				
		cracking/spalling				
		seepage				
ABUT-MENTS		vegetation/erosion				
		sloughs/slides/cracks				
		seepage/wetness				
TOE		erosion/undermining				
		seepage/wetness				
		foundation drains				
GAL-LERY		deteriorated joints				
		cracking/spalling				
		seepage				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

GENERAL INSTRUCTIONS

1. HEADING

File Number refers to the Dam Inspection Section, Ohio Department of Natural Resources inventory system for dams, dikes and levees and may be obtained from the Dam Inspection Section office.

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Inspectors and Others should include names and affiliations.

Weather and Site Conditions should include weather conditions and the condition of the ground surface (wet, snow-covered, muddy, dry, etc.) at the time of the inspection.

2. CHECKLIST

Check the appropriate box along the left-hand side as that AREA is inspected. Check the appropriate box if that CONDITION/ITEM is noted and/or inspected. The specific item should be circled. Further description should be provided under OBSERVATIONS. Check the appropriate box for the required ACTION. Obvious problems will require repair. Monitoring will be recommended if there is potential for a problem to occur in the future. Investigation is necessary if the reason the problem is occurring is not obvious. More than one box can be checked.

3. OBSERVATIONS

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4. GENERAL COMMENTS, SKETCHES, AND FIELD MEASUREMENTS

Explanatory sketches, measurements of cracks, slides and settlement, and additional explanation of observations should be placed in this section.

Definitions
U/S - Upstream
D/S - Downstream
Gallery - Inspection/Access hall inside of concrete dam
Groin - Intersection of embankment face with the valley abutment

Additional copies of this form may be obtained from:

Ohio Department of Natural Resources
Division of Water
Dam Inspection Section
Fountain Square, Building E-3
Columbus, Ohio 43224
Telephone Number: (614) 265-6731

DAM INSPECTION CHECKLIST

Date ______
Time ______

NAME OF DAM ______
FILE NUMBER ______ INSPECTORS ______

SPILLWAYS • DRAINS • OUTLETS

CHECK AREA AS INSPECTED	√	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
Principal Spillway			**Type:**			
INLET-RISER		trashrack/debris				
		gates/flashboards				
		cracks/deterioration				
FLOW-WAY		improper alignment				
		cracks/deterioration				
		joint deterioration				
STILLING BASIN/OUTLET		type				
		cracks/deterioration				
		seepage/piping				
		undercutting				
		erosion				
		debris				
Emergency Spillway			**Type:**			
ALL AREAS		vegetation/cover				
		erosion				
		obstructions				
Lake Drains/Other Outlets			**Type:**			
DRAINS, OUTLETS		gates/valves				
		joints/flow surface				
		inlet tower				
		outlet area				
		operability				
TOE DRAIN		flow amounts				
		flow clear/muddy				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

GENERAL INSTRUCTIONS

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Class refers to classification under Administrative Rule 1501:21-13-01. The classification (I, II, III, or IV) may be obtained from the Dam Inspection Section office.

Inspectors and Others should include names and affiliations.

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Time ____________

NAME OF DAM ____
FILE NUMBER ____________________ INSPECTORS ____________________

MISCELLANEOUS AREAS

CHECK AREA AS INSPECTED ✓	✓	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
MONI-TORING		piezometers				
		weirs				
		monuments				
GAGES		rainfall				
		pool level				
		stream				
POOL AND SHORELINE		erosion/ground cover				
		development				
		reservoir crossings				
		sedimentation				
		water quality				
WATER-SHED		slopes				
		land use				
		other impoundments				
D/S AREA		stream channel				
		channel crossings				
		flood plain				
		development				
EMERG. PLAN		notification list				
		evacuation plan				
		materials/equipment				
		access road to dam				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

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OPERATION, MAINTENANCE, RAINFALL & POOL LEVEL RECORDS	NAME OF DAM ______________ NORMAL POOL ELEVATION ______________

DATE	TIME	RAIN (inches)	POOL LEVEL	WEATHER CONDITIONS	GENERAL OBSERVATIONS OR COMMENTS	RECORDED BY

DATE	MAINTENANCE PERFORMED	COMMENTS	RECORDED BY

DATE	EQUIPMENT OPERATED	COMMENTS	RECORDED BY

	FLOW AMOUNTS				WEATHER & COMMENTS	RECORDED BY
DATE	Left Toe Drain	Right Toe Drain	Weirs	Other		

GENERAL INSTRUCTIONS

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Rainfall and Pool Level Records - Spaces have been provided for one month's records if daily readings and/or pool levels are made. As a minimum, rainfall and pool level records should be kept of significant (very large) rainfall events. Weather conditions should include rainfall duration and intensity estimates; temperatures; ice and snow cover; etc. General observations of the spillway performance and condition of the dam could be made.

Maintenance Performed, Equipment Operated - Operation of equipment and maintenance can be recorded under these headings. For example, if the lake drain is operated periodically, the date can be recorded here. Patching of spillway concrete or joint repairs would be significant maintenance items.

Flow Amounts - Records can be kept of any flows which are being periodically observed. Other could apply to seepage flow estimates of a certain area. Weather conditions during the observation are important to note.

REFERENCES

1. "Concrete Manual," eighth edition, Water and Power Resources Services (Bureau of Reclamation), Denver, Colorado, 1981.

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3. "Design of Small Dams," second edition, Bureau of Reclamation, Denver, Colorado, 1973.

4. "Earth and Rockfill Dams General Design and Construction Considerations," EM 1110-2-2300, Department of the Army, Corps of Engineers, Office of the Chief of Engineers, 10 May 1982.

5. "Guidelines for Maintenance and Inspection of Dams in Kentucky," Kentucky Department for Natural Resources and Environmental Protection, Division of Water Resources, Frankfort, Kentucky.

6. Jewell, G.K., A manual of maintenance procedures for dams, dikes, and levees: Report of G.K. Jewell and Associates, Consulting Engineers to the Ohio Division of Water, Columbus, Ohio, 1970.

7. "Ohio Pond Management," Bulletin No. 374, Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

8. "Principles of Water Rights Laws in Ohio," Ohio Department of Natural Resources, Division of Water, Columbus, Ohio, 1970.

9. "Safety Evaluation of Existing Dams," Water and Power Resources Service (Bureau of Reclamation), Denver, Colorado, 1980.

10. Waddell, Joseph J., "Concrete Construction Handbook," second edition, McGraw-Hill Book Company, New York, New York, 1974.

GLOSSARY

abutment - The valley wall that supports the end of a dam or embankment.

agricultural tire - Tires that have large, raised tread of a herringbone pattern generally used on farm tractors.

anti-seepage collar - A projecting collar of concrete or other material built around the outside of a tunnel or conduit, under an embankment dam, to reduce the seepage potential along the outer surface of the conduit.

appurtenances - The associated works of a dam other than the embankment or main impoundment structure.

as-built drawings - Plans or drawings portraying the actual dimensions and conditions of a dam, dike, or levee as it was built. Field conditions and material availability during construction often require changes from the original design drawings.

beaching - The removal by wave action of a portion of the upstream (reservoir) side of the embankment and the resultant deposition of this material farther down the slope. Such deposition creates a relatively flat beach area.

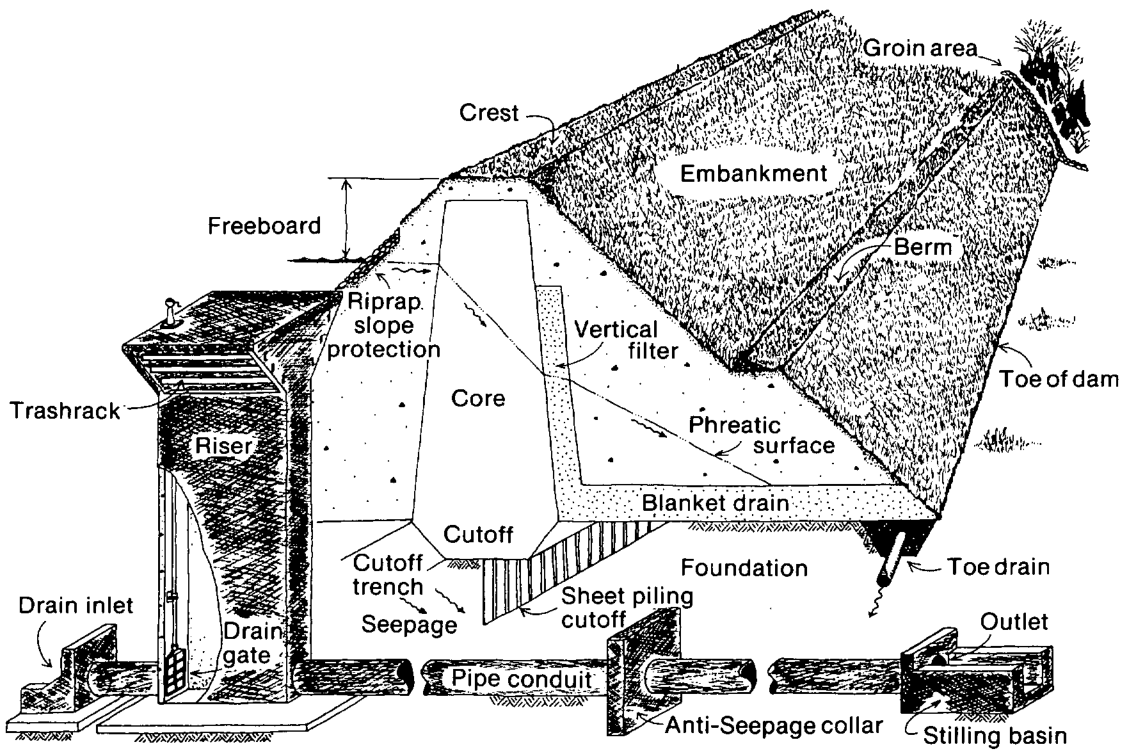
berm - A horizontal step in the slope of an embankment.

blanket drain - A drain that extends in a generally horizontal direction (much like a blanket) under a relatively large area of the downstream portion of the embankment, intercepts seepage through the embankment and the foundation, and prevents further saturation of the downstream toe.

boil - A disturbance in the surface layer of soil caused by water escaping under pressure from behind a water-retaining structure such as a dam or a levee. The boil may be accompanied by deposition of soil particles (usually sand) in the form of a ring (miniature volcano) around the area where the water escapes.

breach - An opening or a breakthrough of a dam sometimes caused by rapid erosion of a section of earth embankment by water.

cavitation - Wear on hydraulic structures where a high hydraulic gradient is present. Cavitation is caused by the abrupt change in direction and velocity of the water so the pressure at some points is reduced to the vapor pressure and vapor pockets are created. These pockets col-



lapse with great impact when they enter areas of higher pressure, producing very high impact pressures over small areas that eventually cause pits and holes in the surface. Noises and vibrations may be evident during high flows.

construction joint - The interface between two successive placings or pours of concrete where bonding, not permanent separation, is intended.

contraction joint - A joint constructed where shrinkage of the concrete would cause a crack.

core - The impervious or relatively impervious material forming the central part of a dam or embankment. Where a dam has a core, the outer zones are usually comprised of more pervious materials. Some dams are constructed entirely of a relatively homogeneous, impervious material with no distinct core. In this case, the entire dam is considered the core.

core wall - A wall of substantial thickness built of impervious materials, usually of concrete or asphaltic concrete, in the body of an embankment to prevent leakage.

corrosion - The chemical attack on a metal by its environment. Corrosion is a reaction in which metal is oxidized.

cutoff - A relatively impervious barrier of soil, concrete or steel constructed either to minimize the flow of water through pervious or weathered zones of the foundation, or to direct flow around such zones.

cutoff trench - The excavation later to be filled with impervious material so as to form the cutoff. The term is sometimes used incorrectly to describe the cutoff itself.

dam - An artificial barrier with appurtenant (or associated) works that does, or may, impound water or liquefied material. Dams may be constructed to retain normal runoff from streams and land surfaces; flood waters; brine; water pumped from a stream or a well; or wastes from industrial processes, chemical processes, and mining operations.

dike - see levee

distress - A condition of severe stress, strain, or deterioration indicating possible or potential failure.

drainage well or relief well - Vertical wells or boreholes downstream of, or in the downstream berm of, an embankment to collect and control seepage through or under the dam and so reduce water pressure. A line of such wells forms a drainage curtain.

embankment - Fill material, usually earth or rock, placed with sloping sides and usually with a length greater than its height. An "embankment" is a part of a dam.

filter - A mass of relatively pervious or porous material through which water or other liquid will pass, but will restrain or collect materials held in suspension in the water or other liquid. Filters and associated drains within an earthen embankment permit drainage or removal of liquids to avoid saturation of the downstream toe of the embankment and/or to control underseepage forces, while preventing the removal of finer-sized particles. Filters associated with erosion protection on slopes of dams or in channel linings prevent the removal of finer-sized particles by wave action or turbulence from beneath the larger-sized material (see blanket drain, and vertical or sloping filter).

flashboards - Lengths of timber, concrete, or steel placed on the crest of a spillway to raise the water level.

foundation of dam - The undisturbed material on which the dam structure is placed.

freeboard - The vertical dimension between the crest of the dam at its lowest point and the reservoir water surface.

gabion - A hollow cage or basket, usually of heavy wire, filled with stones or rock and used as a revetment or other protective device to sustain a wall or channel.

gravity dam - A dam constructed of concrete and/or masonry which relies on its weight for stability.

groin area - The area at the intersection of either the upstream or downstream slope of an embankment and the valley wall or abutment.

grout - A thin cement mortar used to fill voids, fractures, or joints in masonry, rock, sand and gravel, and other materials. As a verb it refers to filling voids with grout. Grout is usually applied under pressure.

homogeneous earthfill - An embankment-type construction of more or less uniform earth materials throughout, except for possible inclusion of internal drains or blanket drains. The term is used to differentiate from a zoned earthfill embankment.

hydraulic jump - The abrupt rise in water surface that may occur in an open channel or stilling basin when water flowing at high velocity is retarded or suddenly slowed down.

leaves - Thin metal strips used to help seat and seal valves and gates.

left abutment - The abutment on the left-hand side of an observer when looking downstream.

levee (or dike) - Any artificial barrier together with appurtenant works that will divert or restrain the flow of a stream or other body of water for the purpose of protecting an area from inundation by flood waters.

low-head dam - A dam of low height (usually less than 15 feet) made of timbers, stone, concrete, or some combination thereof that extends across a stream channel.

outlet - An opening through which water can be freely discharged from a reservoir to the stream.

phreatic surface - The upper surface of seepage in an embankment. All the soil below this surface will be saturated when the steady-state seepage condition has been reached.

pipe conduit - Any tube or hollow channel that conveys water to or from a reservoir.

piping - Progressive erosion and removal of soil by concentrated seepage flows through a dam, dike, or levee, its foundation, or its abutments. As material is eroded, the area of the "pipe" increases and the quantity and velocity of flow increase, which in turn erodes more material. The process continues at a progressively faster rate until controlled, or failure occurs.

pore pressure - The internal cellular pressure of a fluid (air and/or water) within the voids of a mass of soil, rock, or concrete.

reservoir - Any impoundment or potential impoundment created by a dam.

right abutment - The abutment on the right-hand side of an observer when looking downstream.

riprap - A layer of large uncoursed stones, broken rock, or precast blocks placed in random fashion on the upstream slope of an embankment dam, on a reservoir shore or in a channel as a protection against flows, wave and ice action.

scarp - The nearly vertical, exposed earth surface created at the upper edge of a slide or a beached area along the upstream slope.

seepage - The slow percolation (or oozing) of a fluid through a permeable material. A small amount of seepage will normally occur in any dam or embankment that retains water. The rate will depend on the relative permeability of the material in and under the structure, the depth of water behind the structure, and the length of the path the water must travel through or under the structure.

slide - The movement of a mass of earth and/or down a slope. In embankments and abutments, this involves the separation of a portion of the slope from the surrounding material.

slope protection - The protection of the embankment slope against wave action and erosion.

slough - The separation from the surrounding material and downhill movement of a small portion of the slope. Usually a slough refers to a shallow earth slide.

spalling - Breaking (or erosion) of small fragments from the surface of concrete masonry or stone under the action of weather or abrasive forces.

spillway - A passage to conduct excess water or other liquid safely through, over, or around a dam or other artificial barrier that impounds the liquid.

stilling basin - An energy-dissipating device located at the outlet of a spillway to dissipate the high velocity (energy) of the flowing water in order to protect the spillway structure and avoid serious erosion of the outlet channel and subsequent undermining.

stoplogs - Large logs, timbers or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit to provide an inexpensive and easily handled means of closure.

structural joint - A joint constructed where movement of a part of a structure, due to temperature or moisture variations, settlement, or any other cause, would result in harmful displacement of adjoining structural components.

toe of dam - The junction of a dam with the ground surface. Also referred to as "downstream toe."

trash rack - A structure of metal or reinforced concrete bars located at the intake of a waterway to prevent entrance of floating or submerged debris of a certain size and larger.

turf tires - Tires which have a pattern of closely spaced raised rectangular or circular areas and generally used on sod.

uplift - The upward pressure in the pores of a material (internal cellular pressure) or on the base of a structure.

upstream blanket - An impervious blanket placed on the reservoir floor upstream of a dam. In the case of an embankment, the blanket may be connected to the impermeable element.

vertical or sloping filter - A filter placed in a generally vertical direction that extends longitudinally through an embankment to intercept seepage flows and prevent these flows from removing fine soils from the embankment. Often placed with vertical or sloping drainage zones and connected to the blanket drain.

weir - A type of spillway in which flow is constricted and caused to fall over a crest. Sometimes specially designed weirs are used to measure flow amounts. Types of weirs include "broad-crested weir," "ogee weir," and "v-notch weir."

zoned earthfill - An earthfill type embankment, the cross-section of which is composed of zones of selected materials having different degrees of porosity, permeability, and density.

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Richard F. Celeste,
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