A GUIDE TO WRITING

INSPECTION, OPERATION AND MAINTENANCE PLANS

Prepared by the Wisconsin Department of Natural Resources

Dam Safety/Floodplain Management

WISCONSIN
DEPT. OF NATURAL RESOURCES

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This guidance was created by the Department of Natural Resources for the benefit and convenience of dam owners. Because of differences in the location, size, construction and downstream development of each dam, the dam owner may wish to consult his or her own risk manager and/or engineering consultant if modifications are considered necessary to the attached template.

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Copies of *A Guide to Writing Inspection, Operation and Maintenance Plans* and the *Inspection, Operation and Maintenance Plans Template* can be downloaded in PDF format from: *http://dnr.wi.gov/topic/Dams/documents.html.*

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There are over 3,500 dams in the State of Wisconsin. Many of these dams have the potential to cause the loss of life and considerable property damage if they were to fail. The best method of avoiding a dam emergency is proper inspection, operation and maintenance. An Inspection, Operation and Maintenance Plan (IOM) is an important step a dam owner can take to maintain the structural integrity and operational status of a dam as well as protect upstream and downstream lives and property, protect his/her investment and reduce liability.

All owners of large dams are required to develop an adequate IOM for each dam they own under Chapter NR 333, Wisconsin Administrative Code, *Dam Design and Construction*. Because ch. NR 333.07(3)(a) does not specify the components of an IOM, the Wisconsin Department of Natural Resources (Department) has developed this guidebook and template to assist dam owners in writing a plan which meets an accepted minimum standard.

The *Guide* is designed to help the typical Wisconsin dam owner (someone who owns and operates a dam by himself or with one operator) easily and quickly develop a compliant IOM. Dam owners with more complex organizational structures will require IOMs which include additional language and more customization.

Each IOM must be tailored to site specific conditions and the requirements of the owner, agency or organization that operates the dam. Once the draft IOM is written, it must be sent to the Department Regional Water Management Engineer responsible for the county in which the dam is located for review and approval. Contact information for the Department Regional Water Management Engineers can be found at: *http://dnr.wi.gov/topic/dams/regionalContacts.html*.

As with any plan, an IOM should be reviewed annually to ensure the documents still meets the needs of the dam and the owner. The IOM should be updated as necessary to reflect changes in the dam's structure, its operation or ownership.

INTRODUCTION/GENERAL RESPONSIBILITIES

Description of Dam

The first step in writing an IOM is developing a description of the dam including location map and contact information. The description of the dam

should include the type of dam, gates and other components as well as the hazard rating, type of warning system, signage and surrounding land use. It is also helpful to include the use of the dam along with listing of any upstream or downstream dams. The description may also include information regarding the drainage area, height, storage volume, pool elevation and embankment elevation.

The Department's field file number and dam key sequence number should be included in the IOM on the cover page to ensure the plan can be linked to existing Department files. The cover page should also include all the necessary contact information for the owner, the operator if applicable and the plan preparer. If the IOM is prepared by the dam owner then his/her information should be included where needed.

Information on dams including hazard ratings, height, field files numbers, key sequence numbers can be obtained from the Department Dam Safety database at *http://dnr.wi.gov/topic/Dams/damSearch.html*. To obtain a report on a specific dam choose "Individual Dam Search". Enter the name of the dam and choose "Search". Next choose "View Dam" and then "Report". The report can then be exported to either Excel or Acrobat (PDF) and printed.

A Location Map is recommended because the individuals responsible for the inspection, operation, or maintenance of the dam may be someone other than the dam owner. To ensure others can access the dam when needed, the Location Map should clearly point out the location of the dam and the name and location of the dam access road. If access to the dam is by some means other than a road, the means of access should be clearly described and marked on the map.

Key Personnel and Their Responsibilities

The next step is a brief description of all key personnel and their responsibilities. For many dams, the dam owner is responsible for all routine inspections, dam operation and any needed maintenance. Because each IOM is tailored to dam's specific conditions and the requirements of the owner, agency or organization that operates the dam, the text used in this section may be brief.

The Key Personnel and Their Responsibilities section should include who is responsible for operating and monitoring the dam during both normal and

high flow conditions as well as routine and preventative maintenance. It should also include who is responsible for routine inspections; any Department required inspections as well as inspections during unusual events. All routine inspections should be performed by properly trained persons. All detailed inspections must be performed by a professional engineer licensed in Wisconsin. Information regarding the Department's Owner Responsible Inspection Program can be found at: *http://dnr.wi.gov/topic/Dams/inspections.html*.

The contact information for key personnel should consist of the individual's name, title and a means of contact both during and outside of typical office hours. For some dams, it may be useful to include where key personnel are located under normal conditions. While a simple list of names and telephone numbers should be sufficient, it could be useful to have a chart with each person's responsibilities outlined. This could be the same list as the list developed as part of the Emergency Action Plan for the dam.

INSPECTIONS

Inspections are a necessary part of owning and operating a dam since early detection of gradual changes can minimize problems and reduce maintenance costs. Routine inspections provide a way to monitor a dam's performance. Routine inspections are also an opportunity to note any vandalism which may have occurred. Detailed inspections provide an opportunity to have the dam be closely reviewed by a licensed professional engineer. Figure 1 below depicts the various deficiencies that may be found during an inspection.

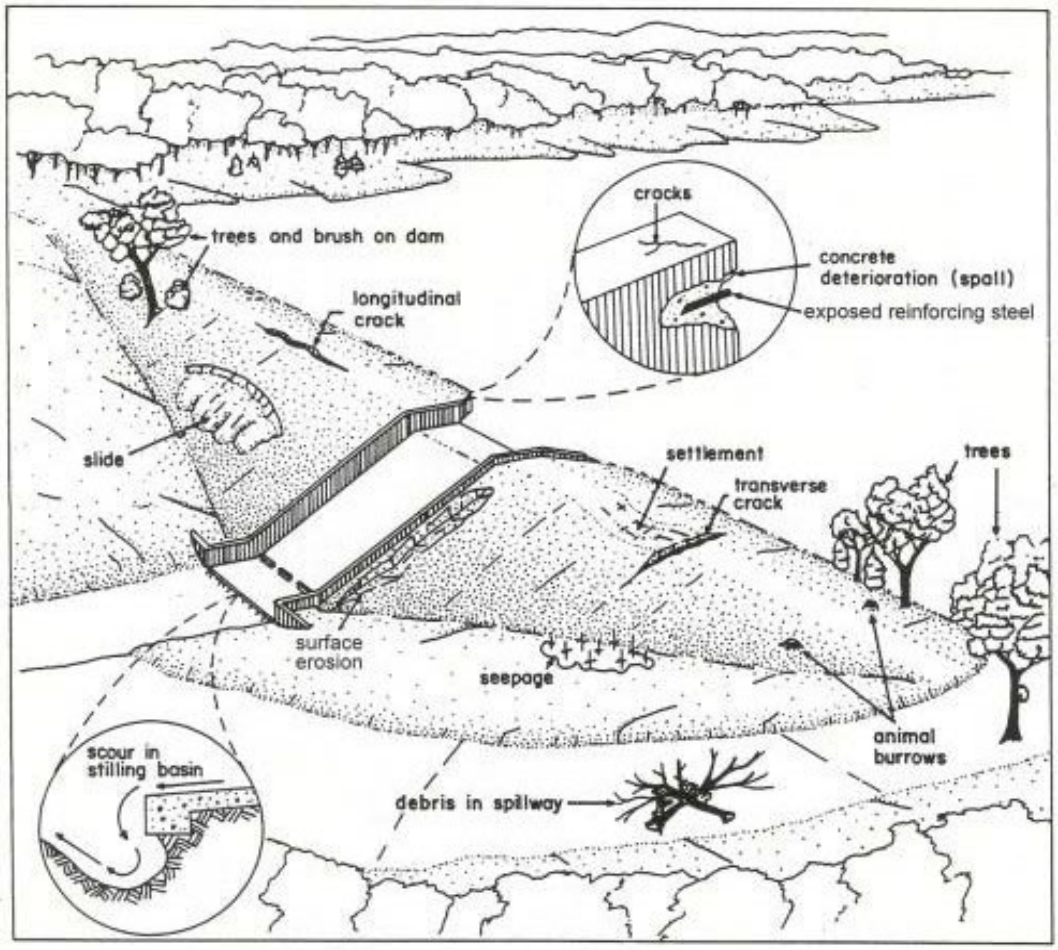

Figure 1. Typical Deficiencies

The Inspection portion of the IOM should include a list the routine inspections to be conducted, who is responsible for the inspections and where any needed documentation will be maintained. Because each IOM is tailored to dam's specific conditions and the requirements of the owner, agency or organization that operates the dam, the text used in this section may be brief.

All routine inspections should be performed by properly trained persons. All detailed inspections must be performed by a professional engineer licensed in Wisconsin. Listed below are the several categories of recommended routine inspections and required detailed inspections:

- Routine Inspections
  - Daily/Weekly
    - River flow observations
    - Precipitation records
    - Water level readings
    - Gate operation
    - Seepage monitoring (if present)
  - Monthly
    - Operating equipment
    - Safety equipment
    - Performance and superficial structure
  - Annual or after a flooding event
    - Structural
    - Operating and safety equipment
- Detailed Inspections
  - Department of Natural Resources required inspections
  - After emergencies as per the Emergency Action Plan

The routine inspection categories are based on the time needed to complete and overall complexity. Daily/weekly and monthly inspections generally require little time to perform. These inspections provide insight on how the dam is operating under current weather conditions. They also help determine if the dam is mechanically operable *during* emergencies. While vandalism to a dam is not a frequent occurrence, routine inspections will reduce the likelihood of it causing major damage. River flow conditions should also be regularly monitored. A water depth gauge on the upstream side of the dam provides the easiest way to consistently monitor water levels. Water levels and gate operating positions should be recorded and maintained in a consistent manner.

Annual inspections are designed to evaluate how the dam performed throughout the year and the overall condition of the dam. This inspection evaluates how the dam has changed from its original as-built plan condition or from the previous thorough annual inspection. Detailed photo

documentation provides a permanent record of changing conditions such as seepage. Cracking conditions can be carefully monitored by placing a ruler within the photo. Larger scale repair and maintenance items should be identified for correction. These inspections are best performed mid-year after the higher spring flows have subsided. When an annual inspection is conducted, a copy of the inspection report should be submitted to the Department.

All dams should be inspected after a flooding event. The owner/operator should evaluate the dam to ensure there has been no structural damage and that all valves or gates are operating correctly. For example, even dams designed for submergence can be susceptible to damage during high flow conditions. Such dams should have the following key elements inspected after storm flows have subsided:

- vegetation (high flow damage);
- earthen fill (slope, riprap, and abutment stability, seepage);
- tainter gates (operation);
- flashboard bays (board damage); and
- gate openings (deposited debris).

If damage is found during the post-flooding inspection, the dam owner/operator must contact his consulting engineer and the Department Regional Water Management Engineer. Contact information by county for the Department Regional Water Management Engineers can be found at: *http://dnr.wi.gov/topic/dams/regionalContacts.html*.

Detailed inspections include Owner-Responsible Inspections required under Ch. 31.19 (2) (ag), State Statutes, inspections done during construction or reconstruction of the dam and inspections conducted after an emergency. The Department conducts decennial (10 year) inspections of high and significant hazard dams. Under ch. 31.19 (2) (ag), owners are required to hire professional engineers licensed in Wisconsin to inspect their high hazard dams every 2 years, significant hazard dams every 3-4 years and low hazard dams every 10 years. Owners of small dams have no statutory detailed inspection requirements, but such dams should be inspected periodically as well.

Dam inspection schedules can be found in the Dam Safety Database at: *http://dnr.wi.gov/topic/Dams/damSearch.html.* Two search options have

been developed to help determine the inspection schedules for state regulated, large dams and to provide selected database information for all dams in the dam inventory.

The *Individual Dam Search* option can be used to view any dam's inspection schedule and to export a report of selected database information for the dam. The search can be done in various ways such as by using the dam's common name, key sequence number or field file number. If dam specific information is unavailable or a broader search is needed, a search can be done by county.

The *Inspection Schedule by Year* option can be used to get a list of all dams scheduled for owner responsible inspections for any year, either state–wide or by county. The data returned can be sorted by column headings or exported to an Excel spreadsheet. A report of selected database information for any dam listed in the search can be viewed or exported to a PDF or Excel format.

A detailed inspection thoroughly details, at minimum, the following:

- structural integrity (concrete, piling, erosion, up/downstream embankment conditions);
- dam equipment operation (gate operators, winches, stoplog condition, vehicles); and
- dam safety equipment operation (fences, signage, buoys, restraints).

Post emergency inspections must be made by a professional engineer licensed in Wisconsin as soon as the emergency has been resolved. The inspection should cover all components of the dam affected by the emergency as well as any operational damage identified during a post-flood inspection.

The dam operator and qualified inspectors should be adequately equipped for inspection. The items listed below will help ensure that the data collected during the inspection is usable and that the individuals conducting the inspection are safe. The following are recommended inspection related equipment items:

- Camera with flash;
- Ruler with gradations large enough to be identified on photos;
- Knives for prying cracks and removing materials;

- Copy of site map to note locations of problems and changing conditions;
- Life jacket;
- Radio;
- Crack gauges;
- Inspection forms; and
- Other tools or equipment specifically needed to inspect dam.

A variety of sample forms can be found in the appendices of the IOM Template. The forms used for routine and detailed inspections should be appropriate for the type of dam and inspection. More information on how to perform an inspection, hire a consultant and an inspection checklist for large dams can be found at: *http://dnr.wi.gov/topic/Dams/inspections.html.*

Any inspection should be conducted in a methodical, careful manner using the same pattern each time to ensure a thorough review. Inspection checklists should be filled out as the inspection is conducted and any photos should be noted. Digital and hard copies of photos should be included in the inspection report. Information on the type and number of photos needed along with labeling and submittal requirements can be found at: *http://dnr.wi.gov/topic/Dams/inspections.html.*

Any inspection performed by a professional engineer should be submitted to the Department. Inspections submitted to the Department will be noted in the Dam Safety database, prompting staff to communicate with the owner and provide technical assistance if necessary. Dam owners should maintain copies of all inspection reports for a dam in order to provide information for mandatory inspections as well as give insight to any evolving questions concerning the structure.

OPERATIONS

Dams are part of a dynamic system composed of the river, the dam and precipitation. In order to operate a dam correctly, a dam owner/operator needs to monitor flow conditions and precipitation rates. Under certain conditions some dam owners will need to notify downstream dams of changes in operation.

The operation of a dam can include activities such as:

- adjusting reservoir levels;
- opening and closing valves and gates;
- coordination of activities with any dams upstream and/or downstream;
- maintaining water levels within the authorized permitted range and applicable state statutes (minimum and maximum levels);
- maintaining minimum flows; and
- controlling debris and litter.

A dam operator is also responsible for ensuring the dam is operated correctly during an emergency. The Operations section of an IOM should include a description of the general surveillance procedures along with the components of the dam and how they function.

Each dam has different components and is operated in a way specific to its design and location. Because each IOM is tailored to a dam's specific conditions and the requirements of the owner, agency or organization that operates the dam, the text used in this section may be brief. However, there are some aspects that are the same for all dams. Some of the typical components and operating procedures are described below.

Maintenance of Levels and Minimum Flows

Many dams have ordered operations for maximum, minimum, normal levels or all three. The required levels may also vary by season. Most dams are also required to pass a minimum flow at all times to protect the riverine resources downstream.

If a dam has required levels, the operator needs some means to easily check levels in the impoundment. The usual method is the placement of a staff gage near the upstream side of the outlet structure.

The Water Management Engineer for the county in which a dam is located

can help in explaining required levels and flows for a dam. Contact information for Water Management Engineers can be found at: *http://dnr.wi.gov/topic/dams/regionalContacts.html.*

Gates

In Wisconsin, gates in dams are generally either lift, stoplog or radial type gates. A lift gate is a vertical plate(s) with movable, or re-movable, sections. Movable sections can be lifted to allow water to pass underneath (as in a sluice gate) and over the top of the structure. Radial gates consist of cylindrical sections which rotate vertically (as in a Tainter gate).

Gates must always be operable in order to maintain pool levels, pass high flows or drain the impoundment to allow for maintenance. It is recommended that gates be operated at least once a year. For a dam with multiple gates, each gate should be opened to the fullest extent possible in sequence. However, this may not be possible for a dam with only one gate. For a dam with only one gate, the level of operation should be the minimum necessary to ensure the gate is on good operating condition. Also, any operations procedures should be reviewed for clarity and accessibility.

Lake Drains

A lake drain is a device to permit the draining of a reservoir for emergencies, maintenance and winter drawdown. Common types of drains include:

- a valve located in the spillway riser;
- a conduit through the dam with a valve at either the upstream or downstream end of the conduit;
- a siphon system;
- a gate valve or stoplogs located in a drain control tower; and
- stoplogs in a whistle tube (prefabricated CMP outlets/spillways).

Lake drains must always be operable in order that the pool level can be drawn down in a safe manner during an emergency or for necessary repairs. It is recommended that a drain be operated at least twice a year to prevent the inlet from clogging with sediment and debris, and to keep all moveable parts working easily. All valves and gates should be operated during the operations test to assure they are not blocked and to obtain a proper seal. Care must be taken in operating the gate if the gate has not been operated regularly to insure it will close once opened. The operator should open the gate several inches and then close. This action should be repeated until the gate is opened to a level the operator is confident it will open any remaining

amount and still close properly. Any operations procedures should be reviewed for clarity and accessibility.

Dams which use stoplogs in whistle tubes as lake drains should be treated differently as operation of the drain would result in the impoundment being drained. This type of lake drain could be checked when the impoundment is drawn down for other purposes. Sediment sampling tools such as core samplers can be used to check sediment accumulation around low level stop logs without a draw down.

Mechanical Equipment and Vehicles

A dam may have a wide variety of mechanical and electrical equipment associated with its operation. These can include valves, siphons, sump pumps, lights, generators and security systems. Dams may also have vehicles for maintenance, repair and emergency response. It is recommended that all mechanical and electrical equipment and vehicles be tested at least once per year to ensure they are operable, particularly under emergency situations. Any operations procedures including those for vehicles should be reviewed for clarity and accessibility.

If any equipment or system has an operation and maintenance manual, a copy of the manual including any diagrams should be included as an appendix to the IOM.

Warning Systems

Dams may have a variety of warning systems such as reverse 911 call systems or warning sirens and signs. Some remote high hazard dams may have automated gauges and call systems to ensure notification of downstream communities or dams in case of a rapid rise in pool elevation or tailwater elevation. All warning systems should be inspected and tested at least once a year. It is also recommended that a dam operator/owner test the warning system in conjunction with the annual review of a dam's Emergency Action Plan.

Coordination of Flows

The flow of water between dams as well as the flow of water from dams must be coordinated to reduce the risk of damage to the dams, any nearby buildings, infrastructure and property. Dams may need to release water from their reservoirs in anticipation of high water, in order to meet required water levels downstream or to provide access to portions of the dam

normally submerged. Dam operators should have a process in place which will ensure downstream dams are aware of any planned releases and are able either hold or pass through the higher flows. The process should also include a method of notifying downstream communities and property owners of any proposed releases. Sufficient time should be included in the notification process for preparation and response from those affected downstream. The flow release process should be reviewed annually to confirm contact information, the operating status of downstream dams and any other changes.

Winter Drawdown

Some dams have ordered operation ranges that vary between warm weather months and winter. If a drawdown to winter levels is required the drawdown should be coordinated with downstream dams and property owners as well as any property owners on the reservoir. The process for drawing down the reservoir and notification of all affected property owners and downstream dams should be reviewed annually and include a description of any planned inspections. All drawdowns not authorized by established water level orders must be coordinated with your area Water Management Specialist. Contact information for WMS can be found at: *http://dnr.wi.gov/topic/waterways/about_us/county_contacts.html.*

Record Keeping

The operation of a dam should include keeping accurate records of any observations, maintenance, gate operations, rainfall, pool levels, drawdowns or inspections. The records may include reports, photos or forms. A dam operator should annually update all forms. Maintenance of records is important to document historic operation of the dam and provide the background data for future inspections or proposed modifications.

MAINTENANCE

Maintenance of a dam should be performed regularly. Routine, annual and post emergency inspections will determine how often and what degree of maintenance is required. The type of dam will also determine what type of maintenance needs to be performed. Figure 1 on page 5 depicts the various deficiencies that may be found during an inspection and would require maintenance.

Typical maintenance tasks can include:

- mowing embankments;
- controlling livestock damage;
- controlling burrowing animal damage;
- removal of trees and woody vegetation;
- removal of floating debris from outlet works;
- clearing toe drains;
- painting and greasing of metal components;
- grouting or sealing concrete joints and cracks;
- repair and replacement of safety signs and barriers;
- controlling upstream slope erosion; and
- replacing gate seals.

Since dams hold back water under pressure, repairs often need to done differently than at other types of structures. When repairs are proposed, a dam owner should seek advice from engineering consultants and contractors familiar with dam design and construction.

Dam owners and operators must contact the Water Management Engineer for the county in which the dam is located prior to doing any work on a dam in order to determine if the work in question is maintenance/repair or reconstruction. Contact information for Water Management Engineers can be found at: *http://dnr.wi.gov/topic/dams/regionalContacts.html.*

For more detailed information on maintenance issues for dams, go to Appendix B of this Guide. A sample Maintenance Log form can be found in Appendix E of the IOM Template.

APPENDIX A

Glossary of Terms

Abutment – That part of the valley side or concrete walls against which the dam is constructed. An artificial abutment is sometimes constructed where there is no suitable natural abutment. Right and left abutments are those on respective sides of an observer when viewed looking downstream. The wall between a spillway or gate structure and the embankment can also be referred to as an abutment.

Alterations – Such changes in the design of the dam as may directly affect the integrity of the dam and thereby affect the safety of persons, property or natural resources.

Appurtenant Structures – The structures or machinery auxiliary to dams which are built to operate and maintain dams; such as outlet works, spillway, powerhouse, tunnels, etc.

Auxiliary Gate – A stand by or reserve gate used only when the normal means of water control is not available or at capacity.

Auxiliary Spillway (Emergency Spillway) – A secondary spillway designed to operate only during exceptionally large floods.

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.

Boil – An upward disturbance in the surface layer of soil caused by water escaping under pressure from behind or under a water-retaining structure such as a dam or a levee. The boil may be accompanied by deposition of soil particles (usually silt) 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. Dams can be breached intentionally to render them incapable of impounding water.

Conduit – A closed channel to convey the discharge of water through or under a dam.

APPENDIX A

Core – A zone of material of low permeability in an embankment dam.

Corewall - A wall built of impervious material, usually of concrete or asphaltic concrete in the body of an embankment dam to prevent leakage.

Crest of Dam – The crown of an overflow section of the dam. In the United States, the term "crest of dam" is often used when "top of dam" is intended. To avoid confusion, the terms crest of spillway and top of dam should be used in referring to the overflow section and dam proper, respectively.

Cutoff Wall – A wall of impervious material (e.g., concrete, asphaltic concrete, steel sheet piling) built into the foundation to reduce seepage under the dam.

Dam – A barrier built for impounding or diverting the flow of water.

Dike (Levee) – An embankment, usually applied to embankments or structures built to protect land from flooding.

Drain, Layer or Blanket – A layer of pervious material in a dam to facilitate drainage. Includes toe drain, weephole and chimney drain.

Drawdown – The resultant lowering of water surface level due to release of water from the impoundment.

Embankment – Fill material, usually earth or rock, placed with sloping sides.

Embankment Dam (Earth Dam / Earthfill Dam) - Any dam constructed of excavated natural materials, usually earth or rock, placed with sloping sides.

Emergency Action Plan – A predetermined plan of action to be taken to reduce the potential for property damage and loss of lives.

Energy Dissipater – Any device constructed in a waterway to reduce or destroy the energy of fast-flowing water.

APPENDIX A

Engineer/Consultant – A licensed or registered engineer in a given state; offers experience and expertise in the design and inspection of dams.

Failure – An incident resulting in the uncontrolled release of water from a dam.

Foundation of Dam - The natural material on which the dam structure is placed.

Freeboard – The vertical distance between a stated water level and the top of a dam.

Gate or Valve – In general, a device in which a leaf or member is moved across the waterway to control or stop the flow.

Gravity Dam – A dam constructed of concrete and/or masonry that relies on its weight for stability.

Groin – That area along the contact (or intersection) of the face of a dam with the abutments.

Height of Dam – The vertical measurement expressed in feet as measured from the downstream toe of the dam at its lowest point to the elevation of the top of the dam.

Hydraulic Shadow Map – A map delineating the area that would be inundated in the event of a dam failure.

Impoundment – Water or wastewater held back by a dam.

Maintenance – The upkeep necessary for efficient operation of dams and their appurtenance works. It involves labor and materials, but is not to be confused with alterations or repairs.

Masonry Dam - Any dam constructed mainly of stone, brick, or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

Ogee Spillway (Ogee Section) – An overflow weir in which in cross section the crest, downstream slope, and bucket have an "S" or ogee form

of curve. The shape is intended to match the underside of the nappe at its upper extremities.

One percent/One Hundred Year (100-YEAR) Flood – The flood magnitude expected to be equaled or exceeded on the average of once in 100 years. It may also be expressed as an exceedance frequency with a 1% chance of being exceeded in any given year.

Operator – The owner, or an agent or employee of the owner.

Outlet – An opening through which water can freely discharge for a particular purpose from an impoundment.

Owner – Any person who owns, leases, controls, operates, maintains or manages a dam or impoundment.

Phreatic Surface – The upper surface of saturation in an embankment.

Piping – The progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

Plunge Pool – A natural or sometimes artificially created pool that dissipates the energy of free-falling water. The pool is located at a safe distance downstream of the structure from which water is being released.

Primary Spillway (Principal Spillway) – The principal or first used spillway during flood flows.

Repair – To essentially restore a dam to its approved design condition.

Reconstruction – Alteration of an existing dam in a manner which affects its hydraulic capacity or structural integrity

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

Scarp – The nearly vertical, exposed earth surface created at the upper edge of a slide or a breached area along the upstream slope of an earthen embankment.

Seepage – - The movement of water that may take place through the dam, its foundations, or its abutments.

Slide – The movement of a mass of earth fill down a slope. In embankments and abutments, this involves the separation of a portion of the slope from the surrounding material.

Slump Area – A portion of earth embankment which moves downslope, sometimes suddenly, often with cracks developing.

Spillway – A structure over or through which flood flows are discharged. If the flow is controlled by gates, it is considered a controlled spillway; if the elevation of the spillway crest is the only control, it is considered an uncontrolled spillway.

Spillway Channel – - A channel conveying water from the spillway crest to the river downstream.

Stilling Basin – A basin constructed to dissipate the energy of fast-flowing water, eg. from a spillway or bottom outlet, and to protect the river bed from erosion.

Stoplogs – Logs or timbers, steel or concrete beams placed on top of each other with their ends held in guides on each side of a channel or conduit.

Storage – The retention of water or delay in runoff either by planned operation, as in a reservoir, or by temporarily filling the overflow areas, as in the progression of a flood crest through a natural stream channel.

Tailwater Level – The level of water in the discharge channel immediately downstream of the dam.

Toe of Dam – The junction of the downstream face of a dam with the ground surface. Also referred to as the downstream toe. For an embankment dam, the junction of the upstream face with the ground surface is called the upstream toe.

Toe of Embankment – The junction of the face of the dam with the ground surface.

Top of Dam – The elevation of the uppermost surface of a dam, usually a road or walkway, excluding parapet wall, railings, etc.

Trash Rack – A structure of metal or concrete bars located in the waterway at an intake to prevent the entry of floating or submerged debris.

Valve – In general, a device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway so as to control or stop the flow.

Weir – A low dam or wall built across a stream to raise the upstream water level. Termed fixed-crest weir when uncontrolled. A structure built across a stream or channel for the purpose of measuring flow. Sometimes described as a measuring weir or gauging weir. Types of weirs include broadcrested weirs, sharpcrested weirs, ogee weirs, and V-notched weirs.

Whistle tube – A pipe outlet/spillway using either full circle or half circle risers installed through an earthen embankment. It always consists of a vertical riser and a horizontal outlet.

APPENDIX B

VEGETATION ON DAMS

Problems with Trees and Brush near Dams
While trees and brush may be aesthetically pleasing, give off oxygen, and provide cooling shade, the growth of woody vegetation on and near dams, including the downstream toe area, can lead to serious problems. Sudden uprooting of trees by strong winds can result in the displacement of a relatively large amount of embankment material. This in turn can lower the crest of the dam, reduce the effective width of the dam, and facilitate seepage. Falling trees can also cause structural damage to concrete, steel, stone, or timber structures.

The root systems of trees can be a potential hazard by allowing seepage pathways to develop through a dam. Trees eventually die and their roots decay and rot. The root cavity leaves a void within the dam through which water can enter and flow. This can ultimately lead to failure of the dam by piping (internal erosion). Tree roots can also penetrate concrete, stone and timber structures causing cracks and leading to structural failure.

Brush and woody vegetation can also hinder the visual inspection of dam surfaces. Sinkholes, animal burrows, seeps, and other irregularities can be obscured by trees and brush. Woody vegetation can also cause excessive shade which in turn can hinder the growth of a sturdy, dense grass coverage. These affected areas are more prone to surface erosion.

Erosion Control
Grass cover is a very effective and inexpensive means to prevent the erosion of embankment surfaces. The stems and root systems of grasses tend to trap fine particles of soil, thus inhibiting the migration of these particles. A good grass cover provides an excellent means against erosion due to runoff caused by rains, and can protect the embankment during limited overtopping.

Maintenance
Grass cover should be routinely cut to provide a surface that can be easily inspected. Trees and brush should never be allowed to grow on or very near a dam. Many older dams have very large trees growing on or near them. Removal of trees, roots, and brush should be done under the direction of a qualified professional engineer knowledgeable in dam safety and maintenance.

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BURROWING ANIMALS AND DAMS

Rodents such as beavers, groundhogs, and muskrats are naturally attracted to areas of ponded water such as dams and reservoirs. Earth dams are most susceptible to the problems caused by these rodents. The burrowing nature of these animals can be quite dangerous to the structural integrity and performance of a dam. The tunnels these rodents construct can serve as pathways for seepage. It is essential that these animals and their activities be controlled to insure proper functioning of a dam.

Beaver

Beavers will instinctively try to block spillways and intake structures. Such actions can raise the water level in a reservoir, reduce the spillway discharge capacity, or produce sudden high outflows from the dam should the beaver structure suddenly fail. Beaver activity upstream of a dam may reduce or even halt the flow of water to the dam. Upstream beaver dams can also generate large quantities of floating debris that can clog a dam's intake and outlet structures. Beaver activity downstream can raise the tailwater elevation, which in turn can reduce the discharge from the dam or erode the downstream toe of the dam. Beavers have also been known to burrow into the upstream face of embankment dams, below the waterline.

- Beaver lodge

Periodic maintenance is the most basic way to insure against the adverse effects of floating beaver debris. Periodic maintenance may also discourage subsequent beaver activity in the general vicinity of the dam.

Groundhog

Groundhogs (woodchucks) burrow into the downstream face of a dam. Their burrows are usually a network of tunnels and chambers with multiple entrances. Groundhogs excavate above the phreatic surface (upper surface of seepage or saturation) in order to stay dry. Active groundhog burrows can be easily identified by mounds of fresh dirt located at the burrow entrances. Other telltale signs of groundhog activity are paths connecting the burrow to nearby fields and clawed or girdled trees and shrubs.

Groundhogs can be discouraged from inhabiting an embankment if the vegetation cover, which camouflages them from predators, is properly maintained.

Muskrat

Muskrats burrow into a dam's upstream face. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upwards slant. A dry chamber is constructed up to 15 feet from the entrance. If the water level of the dam rises, the muskrat will dig higher into the embankment in order to excavate a new dry chamber. Muskrat habitation can be discouraged by eliminating vegetation in and along the shoreline. A properly constructed riprap and sand/gravel filter, extending at least 3 feet below the water surface, may also discourage muskrat activity.

- Muskrat burrow

Eliminating a Burrow

The backfilling of burrows is a relatively easy and inexpensive way to insure proper operation of a dam. Dens should be eliminated immediately because damage from just one hole can lead to failure of the dam. The burrow should be excavated to eliminate all voids. The backfill should be placed in 4 inch to 6 inch loose lifts and well compacted by a heavy hand or mechanical tamper. The top surface of each compacted lift should be scarified (loosed to a depth of 1 inch to 2 inches) before the next lift of material is placed. After all voids and entrances are backfilled, vegetation should be reestablished.

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Hunting and Trapping Regulations

Under Wisconsin law, the control or extermination of beaver, groundhog, or muskrat is subject to certain restrictions. Prior to taking any action against these rodents, the dam owner/operator is advised to contact the local wildlife conservation officer or the wildlife manager the local office of the Wisconsin Department of Natural Resources.

APPENDIX B

INTERNAL EROSION OF EARTHEN DAMS

What is Internal Erosion?

Internal erosion is one of the most common causes of earthen dam failures. It is the removal of soil particles from the embankment, foundation or abutments of a dam by water seeping through the dam. If the seepage that discharges at the downstream side of the dam carries particles of soil, an elongated cavity or "pipe" may be eroded backward toward the reservoir through the embankment, foundation or an abutment. When a backward-eroding pipe reaches the reservoir, a catastrophic breaching of the dam will almost certainly occur.

Internal erosion is exceptionally dangerous because it can occur with little or no external evidence that it is occurring. A dam may breach within a few hours after evidence the internal erosion becomes evident.

What can cause Internal Erosion?

Internal erosion failures are often the result of physical structures which penetrate a dam such as outlet pipes buried in embankments or concrete spillways that cross the embankment. Other causes of internal erosion are tree roots and animal burrows. Decaying tree roots leave voids within the dam creating paths for water to enter and flow. Rodents such as beavers, groundhogs, and muskrats are naturally attracted to areas of ponded water such as dams and reservoirs. The tunnels these rodents construct can serve as pathways for seepage.

- Animal burrow

What are the signs of Internal Erosion?

An experienced dam engineer should be able to detect the subtle signs of internal erosion during required inspections, but dam owners/operators should be aware of what signs to look for during more routine inspections. If signs of internal erosion are observed, contact an experienced dam engineer as well as the DNR Regional Water Management Engineer (WME) responsible for the county in which the dam is located. Contact information for DNR Regional WMEs can be found at: *http://dnr.wi.gov/topic/Dams/contactInformation.html*.

Signs of Imminent Danger (*Call 911 and activate the Emergency Action Plan.*)

- Muddy water or a large flow of clear water discharging from the downstream side of a dam or next to a drain, low-level outlet pipe or spillway that penetrates the embankments or abutments.
- Large new sinkholes (more than 8 inches in diameter) or subsidence anywhere on the embankment or an abutment.
- Water flowing into a sinkhole below the reservoir surface on the upstream slope of the dam as evidenced by a whirlpool in the impoundment.

- Uncontrolled seepage/piping

- Slope failure

- Sinkhole in reservoir

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Signs of Potential Danger (*Contact an experienced dam engineer as well as the DNR WME responsible for the county in which the dam is located.*)

- Water discharging on the downstream slope of an earth dam or within a few hundred feet downstream from the dam, possibly with the accumulation of sediment.
- Clear water flowing along the outside of a pipe, concrete spillway, or other structure that penetrates the embankment.
- Corrosion or deterioration of the visible portion of a low-level outlet pipe or other structure that penetrates the embankment.
- Uprooted trees on the embankment or abutments or within a few hundred feet downstream from the dam.
- Dead trees on the embankment or abutments or in the valley bottom immediately downstream from the embankment.
- New sinkhole (less than 8 inches in diameter), animal burrows or an old sinkhole or subsidence on the embankment or abutments.

- Uncontrolled seepage

- Corroded outlet

- Trees on embankment

Can Internal Erosion be prevented?

Internal erosion on an earthen dam cannot be completely prevented. However, the damage caused by internal erosion can be limited by frequent, thorough inspections and prompt maintenance. Damage to earthen dams can also be limited by ensuring anyone involved in inspection of the dam knows the signs and causes of internal erosion.

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EMERGENCY ACTION PLANS

What is an EAP?
An Emergency Action Plan (EAP) is a major step an owner can take to protect downstream lives and property, protect his/her investment and reduce potential liability. It is a formal document that identifies potential emergency conditions at a dam and prescribes procedures to be followed to reduce the likelihood of the loss of life and to minimize property damage as a result of failure or mis-operation of a dam. The best method of avoiding an emergency response is proper operation, maintenance and inspection. Emergency Action Plans (EAP) cannot be a replacement for proper maintenance or remedial construction.

Each EAP must be tailored to site specific conditions, the requirements of the owner, agency or organization that operates or regulates the use of the dam and to the emergency response organizations that will implement the EAP. Once the draft EAP is written, it must be sent to the DNR Regional Water Management Engineer (WME) responsible for the county in which the dam is located for review and approval. Contact information for DNR Regional WMEs can be found at:
http://dnr.wi.gov/topic/Dams/contactInformation.html.

Why is an EAP needed?
An EAP is needed for three reasons:

- In Wisconsin, "It's the law!" Chapter NR 335.07, Wis. Admin. Code, requires an adequate emergency action plan for all new and existing dams which meet the large dam criteria or pose a threat to life or property.
- To plan the coordination of necessary actions by the dam owner and the responsible local, state, and federal emergency organizations and provide for timely notification, warning, and evacuation in the event of an emergency at the dam.
- To eliminate the loss of life and reduce the risk of property damage in downstream areas which may result from a dam failure. Unique situations do sometimes develop that might result in dam failure. Therefore, it is necessary for a dam owner's engineer to identify conditions which could lead to a failure and recommend emergency measures that could prevent or minimize the consequences to life and property.

The purpose of an EAP is to provide the owner/operator of a dam, especially those with a high potential to threaten life or property with a clear plan of action when any emergency arises. An emergency in terms of dam operation is identified as any condition which:

- develops unexpectedly;
- endangers the structural integrity of the dam; and
- could result in the dam's failure producing downstream flooding, requiring immediate action.

A well written EAP will identify the various parties involved in responding to a dam emergency, outline each party's responsibilities and tasks and lay out the appropriate lines of communication. An EAP should also outline levels of response based on the severity of the emergency.

Key points about EAPs

- An EAP must clearly specify the dam owner's responsibilities to ensure timely and effective action. Responsibilities of dam owners include: surveillance (monitoring the condition of the dam) and notification (phoning local or state emergency management agency officials in charge of emergency response).

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- EAPs are developed by dam owners working in coordination with local emergency response managers, dam safety engineers and state dam safety officials.
- The local emergency response manager or other local official is the link between dam owners and emergency responders. The owner can also contact the state dam safety official to initiate emergency action.
- Dam owners and local emergency responders are primary users of EAPs.
- Public awareness is a critical component of emergency planning.
- The EAP defines events that trigger emergency actions.
- Inundation maps show areas that may have to be evacuated.
- An EAP includes a notification flowchart with names and numbers of who will call whom and in what priority.
- EAPs are regularly updated to include new information.
- Emergency events at dams are infrequent. Training and exercises of EAPs help maintain readiness.

Who is responsible?
Dam owners are not responsible for implementing all aspects of an EAP during an emergency. Responsibilities are split between the dam owner/operator, local emergency managers and responders and state emergency management officials.

Dam Owners/Operators	Local Emergency Management/Responders	State Emergency Management
• Identification of emergency at dam • Initial notifications • Implementation of repairs • Security and technical assistance on site	• Public warning • Possible evacuation • Shelter plan activated • Rescue plan activated • Rescue and recovery • State of Emergency Declaration • Termination of Emergency Status	• Provide assistance to affected area when requested • Coordinate specialized assistance • Notify appropriate state or federal agencies

Assistance in writing an EAP
The WDNR Dam Safety Program has developed a guide and template to assist dam owners in writing an EAP appropriate for their dam. *A Guide to Writing Emergency Action Plans* and a template EAP can be downloaded in pdf format at: *http://dnr.wi.gov/topic/Dams/documents.html.* To obtain a copy of the *Guide* and EAP template in a different format, send an email request to damsafety@wisconsin.gov and enter “EAP” in the subject line.

APPENDIX B

HIRING AN ENGINEER

Note: *This fact sheet is not intended to provide any advice, counsel or directive to dam owners, nor should it be construed as advocating or requiring that a certain course of action be taken with respect to hiring an engineer.*

Why should I hire an engineer?
Ch. 31 of the Wisconsin State Statutes was revised in July, 2009. The changes give dam owners greater responsibility for inspection of their dams. Under ch. 31.19 (2)(ag), owners of low-hazard large dams are required to have a professional engineer licensed in Wisconsin perform a detailed dam once every ten (10) years. Owners of significant- and high-hazard large dams will be required to have a professional engineer licensed in Wisconsin perform a detailed dam safety inspection every 2-4 years, depending on the assigned hazard rating.

The DNR Dam Safety Database (*http://dnr.wi.gov/topic/Dams/damSearch.html*) includes inspection schedules for state regulated large dams. A search can be done in various ways such as by using the dam's common name, key sequence number or field file number. If dam specific information is unavailable or a broader search is needed, a search can be done by county.

Because most dam owners in Wisconsin have not regularly hired consultants for inspections, this fact sheet provides owners with helpful information on contacting, interviewing, reviewing references and experience, and hiring a consulting engineer to perform a dam safety inspection.

Why kind of engineer should I hire?
As a dam owner, you will need to hire a professional engineer who is licensed to practice in the State of Wisconsin, has experience with dams and dam safety, inspection of existing dams, the deficiencies common to the type of dams in the state and knowledge of the rules and regulations governing dams in Wisconsin. In addition, you will want someone who can provide a written report for you to submit to the Department with recommendations for repair, monitoring or reconstruction, and if you choose not to do your own, who can develop an Inspection, Operation and Maintenance Plan (IOM) and an Emergency Action Plan (EAP) specific to your dam.

How do I hire an engineer?
While the process of hiring an engineer is similar to hiring other contractors, using a Qualification Based (QB) selection strategy is the recommended by the Wisconsin DNR Dam Safety Program. A QB selection means that the knowledge, experience and ingenuity of the engineer are the determining factors in making the selection rather than just the fee. When a QB selection is used, the dam owner solicits several engineering firms to submit their technical qualifications, experience with similar projects, references and other factors related to the proposed project. Based on the submittals, the owner then selects the three most qualified firms to make brief presentations for the project. Based on the presentations, the owner then chooses the most qualified firm to develop a scope of work and negotiates the fee. During the selection process there are a few key elements that you may wish to pay particular attention to:

- Contacting an engineer: Wisconsin DNR Dam Safety maintains a directory of consulting engineers on its website *http://dnr.wi.gov/topic/Dams/documents/consultants.pdf*. It is a limited listing of credible engineers/contractors for dam inspections, maintenance and repairs, and hydrology and hydraulic analyses. The listed firms have provided a Consultant Background Information Form to DNR. The consultants' background information is also available on the website. The directory is not all-inclusive and does not represent DNR recommendations of engineering firms.

  In addition to the DNR directory, the American Council of Engineering Companies, Wisconsin branch (ACECWI) maintains a website (*www.ACECWI.org*) with information about Qualifications-Based Selection of engineering consultants.

Also, the Association of State Dam Safety Officials (ASDSO) has an extensive online library of resources, including a downloadable document on procuring the services of a registered professional engineer, available to the public at *www.damsafety.org*.

- Interviewing an engineer: Once you have contacted an engineer or firm, you should meet and talk with the engineer prior to hiring. The engineer can and should provide a list of references for work that he or she has done with other dam owners and the types of services (inspection, plan preparation, construction oversight, etc.) provided to the owners. You can inquire if the firm has submitted a qualifications document (Consultant Background Information Form) to the Department or request a copy of that form from the firm.
- Checking references: This is an important step in the process. Call other dam owners and communities with which the engineer has worked. Ask if they had any issues working with the individual. Ask if they completed the work on time, within budget and according to the approved plans. References are also part of the qualifications (Consultant Background Information Form) that firms can submit to the Department.
- Hire your engineer: After you have contacted an engineer and checked references, the next step is to get a written estimate for the required work. If you are satisfied with this engineer, you may hire him or her; if not, you can of course "seek a second opinion" and discuss your needs with another engineer or firm, check references, and obtain a written estimate. ***Note****: If you have an engineer on staff that has dam inspection experience, you may be able to forego the hiring process. Please contact the Wisconsin DNR Dam Safety staff to verify the qualifications.*

If you have questions about the ch. 31.19 requirements or need further assistance – contact the Water Management Engineer (WME) for the county in which your dam is located. A list of WMEs by county can be found at *http://dnr.wi.gov/topic/dams/regionalcontacts.html*.