Classification and Inflow Design Flood Criteria

Technical Bulletin

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The Lakes and Rivers Improvement Act (LRIA) provides the Minister of Natural Resources with the legislative authority to govern the design, construction, operation, maintenance and safety of dams in Ontario. The Lakes and Rivers Improvement Act Administrative Guide and supporting technical bulletins have been prepared to provide direction to Ministry of Natural Resources staff responsible for application review and approval and guidance to applicants who are seeking approval under Section 14, 16 and 17.2 of the LRIA. All technical bulletins in this series must be read in conjunction with the overarching Lakes and Rivers Improvement Act Administrative Guide (2011).

Classification and Inflow Design Flood Criteria

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1.0 General

This technical bulletin has been prepared to provide direction to Ministry of Natural Resources (MNR) staff and guidance to dam owners in determining the Hazard Potential Classification (HPC) and Inflow Design Flood (IDF) for dams and is to be used when considering applications submitted for approval under Sections 14, 16, and 17.2 of the Lakes and Rivers Improvement Act (LRIA).

The standards and criteria outlined within this technical bulletin are intended to apply to dams (including the control structure and all appurtenant facilities) that hold back water in a river, lake, pond or stream to raise the water level, create a reservoir to control flooding or divert the flow of water; and are not intended to apply to other works subject to LRIA approval such as water crossings, channelizations, enclosures, pipelines and cables.

In many cases, several dams (including block or saddle dams) may be required to contain the stored contents of a reservoir. Dams must be identified as individual structures where they are separated by undisturbed parent material such as earth or rock. These dams can be separated by a significant distance or be adjacent to each other. Each of these dams must be separately classified and appropriately managed in a safe manner as required under the LRIA.

This technical bulletin must be read in conjunction with the Lakes and Rivers Improvement Act Administrative Guide (2011).

2.0 Classification of Dams

2.1 General

In Ontario, dams are classified using the Hazard Potential Classification (HPC) system. The HPC system categorizes dams according to the potential hazards presented by the dam. The hazard potential is determined through an assessment of the greatest incremental losses that could result from an uncontrolled release of the reservoir due to the failure of a dam or its appurtenances. Potential incremental losses are to be assessed with respect to life, property, the environment and cultural - built heritage sites at the dam site, upstream, downstream, or at other areas influenced by the dam.

The dam's HPC is used to provide guidance on the expectations on dam owners and their designers in identifying additional requirements of the dam safety program for the structure (e.g. standards for dam design, construction, operation, maintenance, surveillance, inspection and emergency preparedness planning).

2.2 Ontario's Dam Classification System

The HPC assigned to a dam is a measure of the greatest incremental losses that could result from the uncontrolled release of water or stored contents behind a dam due to the failure of the dam or its appurtenances based on the worst-case but realistic failure

condition. Incremental losses refer to losses from dam failures which are above and beyond those which may be expected to occur under the same natural conditions (flood, earthquake or other event) with the dam in place, but without failure of the dam. The classification of the dam is assessed based only on incremental losses from potential dam failure regardless of the condition of the dam or the existence of an advanced dam safety program.

Evaluation of the hazard potential must be based on both present land use and on anticipated development as outlined in the pertinent official planning documents (e.g. Official Plan). In the absence of an approved Official Plan the HPC should be based on expected development within the foreseeable future.

Ontario's dam classification system is based on four (4) classification categories: Low, Moderate, High and Very High that define incremental losses due to dam failure on the basis of an increasing level of magnitude.

Table 1 outlines the criteria for determining the HPC for individual dams.

Table 1 - Hazard Potential Classification

	Hazard Categories – Incremental Losses[1]			
Hazard Potential	**Life Safety[2]**	**Property Losses[3]**	**Environmental Losses**	**Cultural – Built Heritage Losses**
Low	No potential loss of life.	Minimal damage to property with estimated losses not to exceed $300,000.	Minimal loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a very low likelihood of negatively affecting the status of the population.	Reversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act.
Moderate	No potential loss of life.	Moderate damage with estimated losses not to exceed $3 million, to agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, other dams or structures not for human habitation, infrastructure and services including local roads and railway lines. The inundation zone is typically undeveloped or predominantly rural or agricultural, or it is managed so that the land usage is for transient activities such as with day-use facilities. Minimal damage to residential, commercial, and industrial areas, or land identified as designated growth areas as shown in official plans.	Moderate loss or deterioration of fish and/or wildlife habitat with moderate capability of natural restoration resulting in a low likelihood of negatively affecting the status of the population.	Irreversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act. Reversible damage to provincially designated cultural heritage sites under the Ontario Heritage Act or nationally recognized heritage sites.

High	Potential loss of life of 1-10 persons	Appreciable damage with estimated losses not to exceed $30 million, to agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, other dams or residential, commercial, industrial areas, infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes regional roads, railway lines, or municipal water and wastewater treatment facilities and publicly-owned utilities.	Appreciable loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with reasonable likelihood of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a portion of the population of a species classified under the Ontario Endangered Species Act as Extirpated, Threatened or Endangered, or reversible damage to the habitat of that species.	Irreversible damage to provincially designated cultural heritage sites under the Ontario Heritage Act or damage to nationally recognized heritage sites.
Very High	Potential loss of life of 11 or more persons.	Extensive damage, estimated losses in excess of $30 million, to buildings, agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, infrastructure and services. Typically includes destruction of, or extensive damage to, large residential, institutional, concentrated commercial and industrial areas and major infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes highways, railway lines or municipal water and wastewater treatment facilities and publicly-owned utilities.	Extensive loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with very little or no feasibility of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a viable portion of the population of a species classified under the Ontario Endangered Species Act as Extirpated, Threatened or Endangered or irreversible damage to the habitat of that species.	

Notes

1. Incremental losses are those losses resulting from dam failure above those which would occur under the same conditions (flood, earthquake or other event) with the dam in place but without failure of the dam.
2. Life safety. Refer to Technical Guide – River and Streams Systems: Flooding Hazard Limits, Ontario Ministry of Natural Resources, 2002, for definition of 2 x 2 rule. The 2 x 2 rule defines that people would be at risk if the product of the velocity and the depth exceeded 0.37 square metres per second or if velocity exceeds 1.7 metres per second or if depth of water exceeds 0.8 metres. For dam failures under flood conditions the potential for loss of life is assessed based on permanent dwellings (including habitable buildings and trailer parks) only. For dam failures under normal (sunny day) conditions the potential for loss of life is assessed based on both permanent dwellings (including habitable dwellings, trailer parks and seasonal campgrounds) and transient persons.

3. Property losses refer to all direct losses to third parties; they do not include losses to the owner, such as loss of the dam, or revenue. The dollar losses, where identified, are indexed to Statistics Canada values Year 2000.
4. An HPC must be developed under both flood and normal (sunny day) conditions.
5. Evaluation of the hazard potential is based on both present land use and on anticipated development as outlined in the pertinent official planning documents (e.g. Official Plan). In the absence of an approved Official Plan the HPC should be based on expected development within the foreseeable future. Under the Provincial Policy Statement, '*designated growth areas*' means lands within *settlement areas* designated in an official plan for growth over the long-term planning horizon (specifies normal time horizon of up to 20 years), but which have not yet been fully developed. *Designated growth areas* include lands which are *designated and available* for residential growth in accordance with the policy, as well as lands required for employment and other uses (Italicized terms as defined in the PPS, 2005).
6. Where several dams are situated along the same watercourse, consideration must be given to the cascade effect of failures when classifying the structures, such that if failure of an upstream dam could contribute to failure of a downstream dam, then the HPC of the upstream dam must be the same as or greater than that of the downstream structure.
7. The HPC is determined by the highest potential consequences, whether life safety, property losses, environmental losses, or cultural-built heritage losses.

2.2.1 Low Hazard Potential

Dams classified as having a *Low Hazard Potential* are those dams where one or more of the following incremental losses may occur:

Life Safety: there is no potential loss of life as no persons are exposed to water velocities and depths greater than the 2 x 2 rule (Technical Guide – River and Streams Systems: Flooding Hazard Limits, 2002).

Property Losses: minimal damage limited to third party losses of not more than 300,000 dollars (indexed to Statistics Canada values year 2000). Damages would be principally limited to the dam owner's property and in the immediate vicinity of the dam.

Environmental Losses: habitat losses would be minimal with a high capability of natural restoration. There would be no measurable reduction in the status of fish and wildlife populations after restoration.

Cultural - Built Heritage Losses: reversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act. Losses to contents of cultural – built heritage structures must be included in the above property losses limit.

2.2.2 Moderate Hazard Potential:

Dams classified as having a *Moderate Hazard Potential* are those dams where one or more of the following incremental losses may occur.

Life Safety: there is no potential loss of life as no persons are exposed to water velocities and depths greater than the 2 x 2 rule (Technical Guide – River and Streams Systems: Flooding Hazard Limits, 2002).

Property Losses: moderate property damage limited to third party losses of not more than 3 million dollars (indexed to Statistics Canada values year 2000). The inundation

zone is undeveloped with the exception of forestry, mineral, aggregate, mining and petroleum resource extraction or harvesting operations occurring, or it is predominantly rural or agricultural. In addition, it includes dams and other structures not for human habitation and infrastructure and services associated with this land use such as local roads and railways. Some minimal damage may occur to residential, commercial or industrial lands in the dam failure inundation zone and lands identified as designated growth areas in official plans.

Environmental Losses: moderate loss or deterioration of fish and/ or wildlife habitat with moderate capability of natural restoration resulting in a low likelihood of negatively affecting the long term status of fish and wildlife populations.

Cultural - Built Heritage: irreversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act or reversible damage to either provincially designated cultural heritage sites under the Ontario Heritage Act or nationally recognized heritage sites. Losses to contents of cultural heritage structures must be included in the above property losses limit.

2.2.3 High Hazard Potential

Dams classified as having a *High Hazard Potential* are those dams where one or more of the following incremental losses may occur:

Life Safety: there is a potential for loss of life of 1 to 10 person(s) based on their exposure to water velocities and depths greater than the 2 x 2 rule (Technical Guide – River and Streams Systems: Flooding Hazard Limits, 2002).

Property Losses*:* appreciable property damage limited to third party losses of not more than 30 million dollars (indexed to Statistics Canada values year 2000). The inundation zone can contain agricultural, forestry, mineral, aggregate, mining and petroleum resource operations or other dams or residential, commercial or industrial areas, and services and infrastructure associated with this land use including regional roads, railway lines or municipal water and wastewater treatment facilities, publicly-owned utilities or lands identified as designated growth areas in official plans.

Environmental Losses: appreciable loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with reasonable likelihood of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a portion of the population of a species classified under the Ontario Endangered Species Act (ESA) as Extirpated, Threatened or Endangered or reversible damage to the habitat of that species.

Cultural - Built Heritage Losses: irreversible damage to provincially designated cultural heritage sites under the Ontario Heritage Act or damage to nationally recognized heritage sites*.* Losses to contents of cultural heritage structures must be included in the above property losses limit.

2.2.4 Very High Hazard Potential

Dams classified as having a *Very High Hazard Potential* are those dams where one or more of the following incremental losses may occur:

Life Safety*:* there is a potential loss of life of 11 or more persons based on their exposure to water velocities and depths greater than the 2 x 2 rule (Technical Guide – River and Streams Systems: Flooding Hazard Limits, 2002).

Property Losses: extensive damage with third party losses exceeding 30 million dollars (indexed to Statistics Canada values year 2000). The inundation zone typically includes destruction of, or extensive damage to, large residential, institutional, concentrated commercial and industrial areas and major infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes highways, railway lines or municipal water and wastewater treatment facilities and publicly-owned utilities.

Environmental Losses: extensive loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with very little or no feasibility of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a viable portion of the population of a species classified under the Ontario Endangered Species Act (ESA) as Extirpated, Threatened or Endangered or reversible damage to the habitat of that species.

Cultural - Built Heritage Losses: dams cannot be classified as having a *Very High Hazard Potential* based on Cultural – Built Heritage losses.

2.3 Determining the Hazard Potential Classification

Dams require two HPCs – one based on dam failure under flood conditions and a second based on dam failure during normal (sunny day) conditions. The HPC under flood conditions must be used as a starting point for determining the Inflow Design Flood (IDF), while the HPC under normal (sunny day) conditions is used to determine the Maximum Design Earthquake (MDE). The higher classification between the flood and normal (sunny day) dam failure scenarios should be used to identify additional requirements of the dam safety program for the structure (e.g. requirements for dam design, construction, operation, maintenance, surveillance, inspection and emergency preparedness planning).

The HPC must be based on the worst-case scenario of failure of the dam and at the worst possible time thereby resulting in the highest HPC of all realistic failure scenarios. The combination of a seismic event with a flood event is not considered for determining the HPC.

The HPC is assigned by aligning the category with the description of the highest potential hazard, whether life safety, property losses, environmental losses, or cultural-built heritage losses. Once the highest category of loss has been determined there is no further requirement to assess the losses within the other categories.

Separate dams on the same reservoir may have the same or different classifications depending on the losses and damages that could result from their failure.

It should be understood that in any classification system, all possibilities can not be defined in advance. All areas in the downstream inundation zone need to be assessed in the context of the historical pattern of use in determining the classification of the dam. Engineering judgment and common sense must ultimately be a part of any decision for assigning a HPC.

2.3.1 Assessing Life Safety

In the event of an uncontrolled release of stored water, there is always a possibility that a person(s) could be temporarily within the dam failure inundation zone. Although loss of life can occur within the dam failure inundation zone, a person(s) who is only temporarily in the inundation zone (i.e. occasional overnight or recreational user of the river and downstream lands or passer-by and persons working on or downstream of the dam), should not be included within the assessment of potential loss of life.

Application of the 2 x 2 rule (see Technical Guide – River and Streams Systems: Flooding Hazard Limits, 2002) or a recognized methodology that has been pre-approved by the Ministry is to be used in the assessment of potential loss of life. The 2 x 2 rule defines that people would be at risk if the product of the velocity and the depth exceeded 0.37 square metres per second or if velocity exceeds 1.7 metres per second or if depth of water exceeds 0.8 metres.

Assessing Life Safety under Flood Condition Scenarios

For dam failures under flood conditions the potential for loss of life is assessed based on permanent dwellings which include habitable buildings and trailer parks. Transient persons should not be included within the assessment of potential loss of life under flood conditions.

For the purposes of dam classification it is to be assumed that Emergency Preparedness Plans (EPP), if they exist, will not be activated and further, that warning time will be limited or will not exist. The purpose of an EPP is to reduce the adverse effects of the eventual dam failure wherever possible. The EPP cannot be used as support to lower the HPC however with appropriate warning time it may be possible to demonstrate that the potential loss of life is lower and therefore a reduced IDF may be considered.

Assessing Life Safety under Normal (Sunny Day) Condition Scenarios

For dam failure under normal (sunny day) conditions the potential for loss of life is assessed based on both permanent dwellings and transient persons. Permanent dwellings include habitable buildings and trailer parks as well as seasonal (summer through fall) campgrounds. The potential for occasional overnight camping along undesignated canoe routes or river parks with low usage should not be considered in the assessment of potential loss of life.

Where a significant number of persons are regularly engaged in transitory activities within the dam failure inundation zone on a seasonal basis (day-use facilities and recreational activities based on historical patterns) and would be exposed to water velocities and depths that exceed the 2 x 2 rule they should be included within the assessment of potential loss of life under normal (sunny day) conditions.

2.3.2 Assessing Property Damage

Property losses must assess only direct third party losses to physical buildings, property, other structures and municipal water and waste water treatment facilities and publicly-owned utilities and services, and contents of cultural heritage buildings.

It does not include indirect or ancillary costs associated with dam failure such as the inconvenience of being relocated from a place of residence as a result of dam failure, loss of the dam, loss of revenue, or the dollar value of cultural – built heritage losses (including contents) owned outright by the owner of the dam.

Losses must be based on both present land use and on anticipated development as outlined in the pertinent official planning documents (e.g. Official Plan). In the absence of an approved Official Plan the HPC should be based on expected development within the foreseeable future.

The dollar losses, where identified, are indexed to Statistics Canada values Year 2000.

2.3.3 Cascade Failure

Cascade Failure – Existing Dams

Potential failure of an existing dam upstream of the dam under study will not be considered in selecting the HPC.

Where the failure of the dam under study could contribute to the failure of a downstream dam, then the HPC of the upstream dam under study must be the same as or greater than that of the downstream structure.

Cascade Failure – New Dams

A proposed new dam should not increase the HPC of an existing upstream dam. The proposed new dam must be designed to eliminate any increase in the upstream dam's HPC.

Where a new dam is constructed upstream of an existing dam and could contribute to the failure of the existing downstream dam, the HPC of the upstream dam must be the same as or greater than that of the downstream existing dam.

2.3.4 Using the HPC to Determine the Maximum Design Earthquake

The HPC from a dam failure under normal (sunny day) conditions is to be used to determine the Maximum Design Earthquake (MDE).

2.3.5 Using the Hazard Potential Classification to Determine the Inflow Design Flood

The HPC from a dam failure under flood conditions is to be used as a starting point for determining the required Inflow Design Flood (IDF), notwithstanding the fact that the HPC of a failure under normal (sunny day) conditions might be higher. A reduction in the IDF based on a further analysis can not be used to change the HPC.

2.4 Hazard Potential Classification Changes Over Time

The HPC for a dam may change over time. Downstream development in the incremental flood zone, physical or operational alterations to a dam to change the storage or discharge capability, the finding of a species at risk (plant or animal), revisions to hydrology or hydraulic characteristics of the watershed or changes in the magnitude or frequency of flood events require a re-assessment of the HPC of the dam. Therefore the HPC should be reviewed and confirmed whenever major works requiring approval are being considered.

3.0 Inflow Design Floods

3.1 General

The Inflow Design Flood (IDF) is the most severe inflow flood (peak, volume, shape, duration, timing) for which a dam and its associated facilities are designed (CDA, 2007).

The IDF may be determined directly from Table 2 below or by assessing the most severe flood above which there would be no further incremental consequences.

3.1.1 Future Development Potential

Evaluation of losses, as well as the selection of hydrologic and hydraulic parameters to be used in the determination of IDF, should be determined on the basis of both present land use and on anticipated development as outlined in the pertinent official planning documents (e.g. Official Plan). In the absence of an approved Official Plan the Hazard Potential Classification (HPC) should be based on expected development within the foreseeable future. Note that, with respect to natural flooding hazards, provincial policy prohibits development within the 1:100 year or regional flood zone.

3.1.2 Determining the Inflow Design Flood

The degree of study required to define the incremental losses associated with dam failure will vary with the extent of existing and potential downstream development, the type of dam (size and shape of breach and breach time formation) and the available advanced warning time.

Property losses contained in the HPC Table are used to assist in the selection of the IDF within the range of protection provided in the IDF Table. For example, if the property loss of a moderate HPC dam was close to $3 million, then the IDF standard should be at the top of the IDF range.

Where there is a potential for loss of life, the IDF may be able to be reduced provided that a minimum of 12 hours advanced warning time is available from the time of dam failure until the arrival of the inundation wave. In order to reduce the IDF, the dam owner must be able to demonstrate that they have an Emergency Preparedness Plan which is integrated with authorities responsible for evacuations of the affected population, and that evacuations can be carried out within the time period.

The IDF will be determined by either statistical or event-based methodologies. See Section 3.4 Flood Flow Estimates for more detail.

3.2 Selecting the Inflow Design Flood

Table 2 identifies the range of minimum Inflow Design Floods (IDF) that corresponds with each of the four Hazard Potential Classifications (HPC).

Table 2 - Range of Minimum Inflow Design Floods[2]

<table>
<tr><th rowspan="2">Hazard Potential Classification</th><th colspan="4">Range of Minimum Inflow Design Floods[1]</th></tr>
<tr><th colspan="2">Life Safety[3]</th><th>Property and Environment</th><th>Cultural – Built Heritage</th></tr>
<tr><td>Low</td><td colspan="4">25 Year Flood to 100 Year Flood</td></tr>
<tr><td>Moderate</td><td colspan="4">100 Year Flood to 1000 year flood or Regulatory Flood whichever is greater</td></tr>
<tr><td>High</td><td>1-10</td><td>1/3 between the 1000 year Flood and PMF</td><td>1000 Year Flood or Regulatory Flood whichever is greater to 1/3 between the 1000 year flood and PMF</td><td>1000 Year Flood or Regulatory Flood whichever is greater</td></tr>
<tr><td rowspan="2">Very High</td><td>11-100</td><td>2/3 between the 1000 year Flood and PMF</td><td rowspan="2">1/3 between the 1000 Year Flood and PMF to PMF</td><td rowspan="2"></td></tr>
<tr><td>Greater than 100</td><td>PMF</td></tr>
</table>

Notes

1. The selection of the IDF within the range of flows provided should be commensurate with the hazard potential losses within the HPC Table. The degree of study required to define the hazard potential losses of dam failure will vary with the extent of existing and potential downstream development and the type of dam (size and shape of breach and breach time formation).

2. As an alternative to using the table the IDF can also be determined by an incremental analysis. Incremental analysis is a series of scenarios for various increasing flows, both with and without dam failure that is used to determine where there is no longer any significant additional threat to loss of life, property, environment and cultural – built heritage to select the appropriate IDF.

3. Where there is a potential for loss of life the IDF may be reduced provided that a minimum of 12 hours advanced warning time is available from the time of dam failure until the arrival of the inundation wave, provided that property, environment, or cultural – built heritage losses do not prescribe a higher IDF.

The methodology to compute the IDF hydrograph is as follows:

1 Compute the peak flow, total volume and hydrograph of the 1:1000 year Flood;
2 Compute the peak flow, total volume and hydrograph of the PMF;
3 Plot the 1:1000 year and the PMP hydrographs on one graph, adjusting the time origin of one flood so the peaks of the hydrograph coincide;
4 For each time step of the hydrographs compute the IDF discharge with equation (3.1)

Equation (3.1) Q (IDF) = Q (1:1000) + A x (Q(PMF) - Q(1000))

Where:

a. Q (IDF) is the discharge of the IDF for the selected time step of the hydrographs
b. Q (1:1000) is the discharge of the 1:1000 year flood for the selected time step of the hydrographs
c. A is a proportionality coefficient which is equal to 1/3 for the High HPC and 2/3 for the Very High HPC (life safety 11 to 100) when Life Safety poses the highest hazard potential. When the HPC is determined by Property Loss, the coefficient A can be determined as a proportionality factor based on the magnitude of loss with respect to the upper and lower bound for all classes except Very High. Selection of A for Very High class has to be guided by Note 2 above. Since Environmental and Cultural - Built Heritage Losses are defined only in a qualitative (descriptive) manner, a judgment based on magnitude of potential loss with respect to descriptors for the class has to be used in selection of coefficient A.
d. Q (PMF) is the discharge of the PMF for the selected time step of the hydrographs
e. The annual exceedance probability for the PMF is set to 1:1,000,000

The upper bound of the IDF in the Very High class for Property and Environment is set as the PMF with the understanding that such an IDF should be reserved for catastrophic losses only. Such understanding provides necessary flexibility in IDF selection in recognition that only exceptional environmental or economic loss can be considered in terms equivalent to the loss of life.

A dam owner may wish to select a higher IDF or MDE to protect the dam assets. An assessment of dam owner losses in the event of a dam failure might indicate that the risk cost of a dam failure justifies the adoption of higher standards than the minimum standards contained in this technical bulletin. These costs might include loss of revenue and costs to replace or repair damages to the dam.

In cases where the dam owner wishes to explore the possibility of selecting a lower magnitude IDF, an incremental analysis is performed using progressively higher magnitude, lower frequency, floods as the candidate IDF. The object is to find the smallest flood for which the incremental losses associated with dam failure during the flood event, or for any larger floods, are considered to be acceptable (do not create significant incremental increase in the threat to loss of life or damages to property, environment and cultural – built heritage sites). These 'incremental losses' include any losses that could occur within the dam breach area in the event of a dam failure, that would not occur if the dam does not fail.

The following steps are to be performed in order to properly assess the potential losses that could occur in the event of a dam failure:

1. Flood Flow Estimates;
2. Flood Routing;
3. Dam Break analysis, including documentation of and rational for:
    a. the Initial Conditions
    b. the Dam Breach Parameters;
4. Inundation mapping of each scenario with and without dam failure; and
5. Documentation of Incremental Losses.

The criteria given above are for permanent structures. Design floods for temporary structures (e.g. coffer dams) should be commensurate with the hazard and duration.

3.3 Flood and Erosion Impacts

The right to flood lands normally extends to the area flooded at the level of the IDF. Flooding rights may also be required to account for any backwater effects and potential upstream damages beyond the IDF level. Flooding of developed land (existing or future) or flooding extending for considerable distance upstream (streams with flat gradients) requires an assessment by backwater analysis. The need for reassessing flooding rights due to proposed works to a dam or a change in operations should be determined accordingly.

3.3.1 Upstream Flooding and Erosion Rights

No dam may cause flooding to lands owned by others, either directly or indirectly, by backwater effect over and above that which may be expected to occur under existing conditions, unless legal authority has been obtained to permit such activity to occur.

Legal Authority may take the form of:

1. A flood easement, right or zoning;
2. lease or acquisition of property subject to flooding; or
3. legal agreement to compensate for any flood damage caused by the dam.

For earthfill dams, it is generally assumed that the dam will fail if the water level exceeds the crest of the dam. To determine the upstream design flood level for this type of dam, the crest of the dam is selected at an elevation such that no upstream flood damage or flooding of land to be developed will occur. For concrete dams it is generally assumed that failure occurs at a water depth over the crest of the dam which varies with dam design and the erosion resistance of the foundation. To determine the upstream design flood level for this type of dam, the overtopping depth on the dam above which failure occurs is determined and the height or location of the dam is selected such that no upstream flood damage or flooding of land to be developed occurs at this overtopping level. Note that if a concrete dam is located on an erodible foundation, it should not be designed to be overtopped. If a backwater effect is created by a dam, this must be included and the upstream flood level for the dam lowered accordingly.

3.4 Flood Flow Estimates

Analyses should include estimates of peak flood flows and hydrographs for a range of flood frequencies up to and including the probable maximum flood (PMF). The flood flows at any given site are a function of watershed size and its hydrological characteristics (antecedent moisture conditions, soil and land cover conditions, basin shape and slope, the time to peak, etc), the storm volume, duration and distribution, the flood routing processes, the storage volume of the reservoir and the outlet capacity.

It should be noted that, in any given reservoir, the governing flood water level might be the result of short duration, high intensity summer storms or of high runoff volume from long-duration rainfall plus snowmelt events in spring. Establishing the critical storm period is an essential part of determining the appropriate flood inflows.

In performing the flood flow analyses, appropriate consideration must be given to seasonal variations that might affect the magnitude of the flood flows. The calculated flood flow is then compared with any available records of historical high water levels and flows. Various methods of estimating the flood flows (e.g. regional analysis and hydrologic modeling) should be investigated and the results from these summarized for comparison purposes.

3.4.1 Determining Flood Magnitudes

Hydrologic and hydraulic calculations should be undertaken in accordance with the Technical Guide – River and Streams Systems: Flooding Hazard Limits, Ontario Ministry of Natural Resources, 2002. Quantitative precipitation distribution for regulatory floods in Ontario are described in this publication.

The 1:1000 year flood is a flood having a .001 (or .1%) probability of occurrence being exceeded in any year. The 1:1000 year flood is estimated using a number of different methodologies. The preferred method to determine the 1:1000 year flood (peak flow and volume of runoff) is by interpolation between the 1:100 year flood and PMF where the annual exceedance probability for the PMF is set to 1:1,000,000. Details on determining the 1:1000 year flood by interpolation between the 1:100 year flood and PMF is contained in the document, “Guidelines on Extreme Flood Analysis”, Alberta Transportation, Transportation and Civil Engineering Division, Civil Projects Branch – November 2004. Where there is consistency in results between the methodologies judgment and conservatism are used to derive the estimated 1:1000 year flood. If there is no consistency between methods, the method that provides the most conservative estimate is to be used.

A probable maximum flood (PMF) must be determined if it is needed for use in the evaluation. If a previous PMF value is already available, it should be reviewed to determine if it needs to be re-assessed based on current meteorological observed data and flood events. The MNR is preparing documentation supporting the determination of the Probable Maximum Precipitation (PMP) and should be consulted before an owner embarks on a PMP study for the purpose of deriving the PMF.

Glossary of Terms

Appurtenant Facilities: Means structures and equipment on a dam site including, but not limited to, intake and outlet structures, powerhouse structures, tunnels, canals, penstocks, surge tanks and towers, gate hoist mechanisms and their supporting structures, spillways, mechanical and electrical equipments, water control and release facilities.

Dam: For the purpose of the administration of the LRIA, a dam is defined as a structure that is constructed which holds back water in a river, lake, pond, or stream to raise the water level, create a reservoir to control flooding or divert the flow of water.

Dam Owner: The owner of a dam, structure or work and includes the person constructing, maintaining, or operating the dam, structure or work; ("proprietaire").

Easement: A right or interest or use of passage of persons, vehicles and animals over another person's owned or leased property created through an express registered grant of easement.

Exceedance Probability: The probability that a specified level of ground motion or specified social or economic consequence of earthquake will be exceeded at a site or in a region during a specified exposure time.

Foundation: The soil or rock upon which the structure or embankment rests. An alternative definition is similar to footing.

Height: The height of a dam is the vertical distance between the lowest point of the natural surface of the ground at the downstream toe of the dam and the upper most point of the top of the dam.

Inflow Design Flood: the most severe inflow flood (peak, volume, shape, duration, timing) for which a dam and its associated facilities are designed.

Local Road: A road to residences, farms, and buildings not used as a main route.

Probable Maximum Flood (PMF): The largest possible flood based on an analysis of the maximum possible precipitation in a given area.

Probable Maximum Precipitation (PMP): The greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year.

Regional Flood: A specified flood on a watershed for various regions in Ontario.

Regulatory Flood: The Flooding Hazard Limit used in Ontario for the purpose of regulating land development.

List of Acronyms

EPP	Emergency Preparedness Plans
ESA	Endangered Species Act
HPC	Hazard Potential Classification
IDF	Inflow Design Flood
LRIA	Lakes and Rivers Improvement Act
MDE	Maximum Design Earthquake
MNR	Ministry of Natural Resources (provincial)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation

References

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Canadian Dam Association, 2007 Technical Bulletin: Flow Control Equipment for Dam Safety

Federal Emergency Management Agency, 2004 Federal Guidelines for Dam Safety – Selecting and Accommodating Inflow Design Floods for Dams, Appendix A

Ministry of Natural Resources, 2002 Natural Hazard Technical Guides – River and Streams Systems: Flooding Hazard Limits