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Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners

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Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners

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Preface

This is the first edition of, "Development, Interpretation and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: A Guideline for Canadian Water Resources Practitioners". It was developed by the CSA IDF Working Group and is expected to be further updated and refined in a successive edition in the near future. This first edition contains important information that is otherwise difficult for water resources practitioners to locate. To submit comments and feedback, please send a message to Inquiries@csa.ca and include "Feedback" in the subject line.

EXECUTIVE SUMMARY

Introduction to this Guideline

Canada has significant investments in storm water, drainage, waste water, and flood management systems. Every day Canadians rely on this infrastructure to protect lives, property, and natural systems such as creeks, rivers, and lakes. In designing and managing these works, practicing professionals need to be concerned with the probability of occurrence of extreme amounts of rainfall, often for specific storm durations.

Rainfall intensity-duration-frequency (IDF) information describes the probability of occurrence of extreme rainfall events of various rates and durations. IDF values are a critical input to a number of analytical techniques routinely used in the design and management of water resources infrastructure.

This Guideline is intended to help ensure that rainfall IDF characteristics are properly considered in the planning, design, and management of water infrastructure, by making clear the assumptions contained within current IDF information, and addressing what the limitations of this information might be. The implications of climate change for the occurrence of extreme rainfall events and, therefore, the interpretation of existing IDF values are also addressed.

The Guideline has four main objectives, as follows:

(a) Take stock of how rainfall intensity-duration-frequency (IDF) information has traditionally been developed in Canada;

(b) Clarify assumptions embedded within current IDF information which may be of potential significance for water resources practitioners;

(c) Highlight from a scientific as well as a water resources practitioner perspective shortcomings in, and potential opportunities for, improving the quality and application of IDF information in Canada; and,

(d) Suggest what the implications of climate change might be for the development, interpretation, and use of rainfall IDF information.

Extreme rainfall — Meteorological aspects

In order to judge the applicability of existing IDF information for the design and management of infrastructure at a particular site, it is important to have a general understanding of the atmospheric processes driving the occurrence of extreme rainfall events at that site. An understanding of the dominant atmospheric processes forcing rainfall extremes is also important for designing rainfall data networks, for interpreting regional climate trend analyses and climate change guidance, and for designing regional

IDF and other extreme value analyses. For example, in regions where smaller scale convective processes dominate, site specific IDF values may underestimate the true risks of these events in a region and a denser network of rain gauges and IDF sites will be needed to capture the spatial and temporal variability of the rain events.

Four atmospheric processes, or combinations thereof, drive most extreme rainfall events and each is associated with certain characteristic extreme rainfall patterns. The four main atmospheric processes are:

(1) large scale and longer lasting *synoptic* storms;

(2) smaller scale and shorter duration *convective* events;

(3) *tropical* storms or remnants that operate at spatial and temporal scales approaching the synoptic; and

(4) regional *orographic* processes that are regionally or locally tied to topography and enhance extreme rainfall amounts.

Convective processes tend to influence extreme rainfall events of two to six hours and shorter durations, while synoptic events dominate rainfall extremes for durations of about 12 hours and longer. Combinations of synoptic and convective rainfall processes bridge the durations and spatial scales between the two.

The influence of different atmospheric processes on extreme rainfall varies across Canada. For example, while the Pacific coast of Canada typically experiences its longer duration extreme rainfall events from synoptic storm systems that originate over the Pacific Ocean or from southerly latitudes, on the Canadian Prairies extreme rainfall events of all IDF durations usually involve convective rainfall processes or synoptic systems with embedded convection.

Rainfall observations and networks

In Canada, rainfall data are collected by Environment Canada (Meteorological Service of Canada), provincial and territorial ministries, municipalities, and other organizations. They are collected using a variety of measuring instruments and to a variety of standards. Environment Canada's meteorological networks are intended to provide a long-term baseline of observational data for use in characterizing important aspects of Canada's climate and weather at regional scales. Environment Canada 's networks and individual monitoring stations are generally designed, located and operated in accordance with World Meteorological Organization (WMO) guidelines.

It is important to understand how observations used for Environment Canada IDF tables and graphs are collected so that their characteristics and any possible implications for applying IDF information are well documented. In addition, Environment Canada's approaches should be consulted by agencies interested in deploying their own local or regional networks to obtain observations for IDF purposes.

Rainfall observations used for Environment Canada IDF information are most often collected using an automated tipping bucket rain gauge. The data are checked, where possible, against records from co-located manually observed standard gauges, and are adjusted upward by different amounts depending on the "catch bias" of the particular tipping bucket gauge model (some of which are more accurate than others, see Chapter 3).

Quality control (QC) checks are performed when data are added to the Environment Canada data archive. The QC process focuses mainly on verifying that the values are realistic and that there is internal consistency amongst all the amounts abstracted from the daily rainfall recording chart. The QC software flags data if triggered by the checks. The data are corrected or denoted as missing in the record.

The siting of rain gauges can have a considerable impact on the accuracy of their measurements. Standard practice for tipping bucket gauges includes, for example, the avoidance of sites with nearby tall obstructions (such as trees or buildings), and the use of solid mountings, so as to prevent vibrations which can result in inaccurate measurements.

Rate-of-rainfall measurements taken from tipping bucket rain gauges in the Environment Canada data archives for the purpose of IDF calculations are resolved to the 0.1 mm level for the following time intervals: hourly; 5, 10, 15, and 30 minute intervals; and 1, 2, 6, and 12 hour intervals. Procedures involved in collecting data and conducting quality control should be of interest both to those who must interpret the resultant IDF values, as well as to those who may be interested in establishing or enhancing their own monitoring program.

A key issue related to the use of (point-based) IDF information in water infrastructure design and management is how large or small an area is accurately represented by existing IDF values may be. Understanding historical precipitation patterns can be a useful approach in reducing the uncertainty related to the applicable areal extent of point-based IDF values, and to determining if additional data and/or an expanded monitoring network should be developed for a particular area of concern. Various techniques can be used in this respect, including analyses of historical, site-specific data; analyses of radar data for the identification of precipitation processes at different scales; and the use of knowledge of dominant meteorological processes to discern whether distinctive precipitation zones and areas of influence may exist. If no existing IDF monitoring site is suitable for the design of water infrastructure at a particular location, a new monitoring site may be established in accordance with the technical requirements provided in Section 3.2.

Derivation and dissemination of IDF values

In order to properly interpret existing Environment Canada IDF information, or develop new IDF values independently, it is important to have some knowledge of the assumptions historically made with respect to how extreme rainfall values are typically distributed, and of how rainfall data are “fitted” in order to estimate the frequency of different rainfall amounts and durations.

The approach most commonly used to calculate the frequency or probability of occurrence of rainfall amounts corresponding to various durations is to fit an appropriate frequency distribution to data from observing sites. This allows for an estimation of the parameters of the distribution from which the various return levels are calculated. The Gumbel distribution is the extreme value distribution that has historically been used by Environment Canada. The Gumbel distribution is fitted to the annual maximum series (AMS) of each rainfall duration and used to calculate the return period for Environment Canada IDF tables and graphs.

Fitting the Gumbel distribution to the AMS is not the only means for estimating the frequency of extreme rainfall values. There are other distributions suitable for analyzing a series of independent peak events that exceed an established high threshold value — commonly referred to as partial duration series (PDS) or peak-over-threshold (POT) analyses — whose application may result in different return period values than those yielded by the AMS approach. The POT approach is typically of advantage for datasets of relatively short periods of record (i.e., < 15 to 20 years).

The term “return period” is commonly used to express the probability of occurrence of independent extreme values of rainfall. An event with a return period *T* has a 1/*T* probability of being equalled or exceeded in any given year. For instance, a 50-year return period event has a 1/50 or two percent chance of occurring or being exceeded each year. Alternately, 50 years is the average period between years in which a 50-year event occurs or is exceeded.

Further Considerations: Understanding return periods

- Since events are assumed independent, if a 50-year event occurs in one year, the probability remains the same (2%) that a 50-year event occurs in the next year. Having experienced an extreme event one year doesn't affect the probability of experiencing a similar event the next year.
- Since the IDF return levels are for single points, the probability of experiencing an extreme event such as a 100-year rainfall, over a wide area such as a municipality or regional catchment, is greater than the 1% probability at any single point in the area.
- The probability of experiencing an extreme event over longer periods should be considered. For instance, the probability of experiencing a 50-year event at a single point at least once in a 50-year period is 64%. And the probability of experiencing a 500-year event at least once in 50 years is almost 10%.

Each return level estimate has a confidence level associated with it. Confidence levels reflect the amount of statistical uncertainty associated with the use of data samples representing only a small portion of the entire "population of events." If a 95% confidence interval is attributed to a given return level, this means that there is a 95% probability that the true population return level lies within the interval of the return level of the sample data, plus or minus the confidence interval.

Environment Canada IDF tables and graphs provide the return level estimates for rainfall durations ranging from 5 minutes to 24 hours, for return periods from 2 to 100 years, along with 95% confidence intervals. The data in these files are calculated for each of the single 557 Environment Canada IDF stations across Canada.

Descriptions of Environment Canada IDF graphs and tables are provided in Sections 4.2.6 to 4.2.9. Important practical aspects for interpreting IDF values include:

- The return level estimates reflect the observational data and hence provide probability of occurrence data for a single location. The information does not directly relate to the probability of extreme rainfall occurring somewhere in a larger region or area in a year.
- Environment Canada IDF return levels quantify rainfall amounts and rates for a given duration and return period. They provide no additional information regarding the context of the individual events (e.g., antecedent rainfall).
- As an expression of uncertainty, the confidence interval is based only on sampling variability from a population assumed to be described, in this case, by the Gumbel distribution. The confidence interval does not account for other potentially significant sources of uncertainty (e.g., data measurements errors, archiving errors).

IDF values and climate change

Under climate change, scientists project that a warming climate will bring increases in the intensity and frequency of extreme precipitation. As a result, infrastructure designed using historical IDF values may be at greater risk of damage or failure. It is therefore important to understand how extreme precipitation and IDF values are changing in the current climate, and to take stock of our state of knowledge, uncertainties, and assumptions in projecting future change.

Scientific analysis of precipitation observations over the past century has found that, in general, Canada's climate is getting wetter. Total annual precipitation in southern Canada increased by an average of 12% from 1900 to 1998 or by 5% from 1950 to 1998. The greatest increases in annual precipitation since 1948 (up to 45%) have occurred in the high Arctic, while parts of southern and central Alberta and Saskatchewan have seen little change or a slight decrease.

Conclusive evidence of changes in *daily precipitation extremes* can be difficult to obtain, since the density and temporal data recording interval of climate stations may be insufficient to capture many extreme events. A number of studies have investigated trends in extreme daily Canadian precipitation using a special database of "adjusted" daily rain, snow, and total precipitation amounts from 495 long-term climate stations across Canada. These studies suggest there have been no consistent changes in extreme daily Canadian precipitation, rainfall, or snowfall, either in intensity or frequency, over the past 50 to 100 years. However, and in contrast, U.S. studies *have* shown statistically significant increasing trends in daily rainfall extremes, many of which have been observed in states directly bordering Canada. Differences in indicator threshold levels used for the studies, time periods investigated, and the density of observing networks may have had some bearing on the divergence between US and Canadian results.

Though trends in *short duration* rainfall intensities of less than 24 hours are important considerations for the planning, design, and management of many drainage and stormwater systems, most archived short duration rainfall data records are generally 40 years or less in length, as recorded in the Environment Canada National Climate Archive of Canada. The archived sub-daily (IDF) rainfall network is less dense spatially than the daily precipitation observation network. While this can make trend analysis difficult, some studies have been conducted on short-duration rainfall datasets from Ontario, Quebec, as well as the Greater Vancouver Regional District. Results indicate that trends in extreme short duration rainfall have varied with duration and regional location, and have included decreases as well as increases. A Toronto area analysis suggested a shift in seasonality of rainfall extremes, to earlier in the warm season.

Despite the difficulty to date in detecting trends in rainfall IDF characteristics in Canada, climate change science indicates that discernable future change is likely. Enhanced warming of future climate is projected to lead to changes in global atmospheric circulation and teleconnection patterns (e.g., El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO) and Pacific Decadal Oscillation (PDO)) including a poleward shift of several degrees of latitude in storm tracks and subsequent changes in intensities and numbers of cyclones. This could result in a decrease in the total number of mid-latitude storms, but an increase in the number of more intense storms. Accompanying these changes, the hydrological cycle is expected to intensify, leading to changes in timing, frequency, and intensity of precipitation extremes and an increase, on average, in total annual precipitation. Over North America in general, extreme precipitation events which currently occur once every 20 years are projected to occur once every 12 to 3 years by mid-century and once every 8 to 9 years by 2081 to 2100.

Currently, the level of spatial and temporal resolution of Global and Regional Climate Models is inadequate for the projection of future rainfall IDF characteristics applicable to individual localities and the development of individual projects. While IDF curves typically used in the design and management of water infrastructure require point-specific rainfall intensity information at sub-daily intervals of 5-, 10-, 15-, and 30-minutes, 1-, 2-, 6-, and 12-hours, in addition to 24-hours, the temporal resolution of Global Circulation Model (GCM) outputs is not below the daily time scale, and sub-daily Regional Climate Model (RCM) outputs are available only at 6- and, in some cases 1- or

2-hour intervals. Furthermore, the horizontal spatial grid resolution is a few hundred kilometres for GCMs, and 40 to 50 kilometres for RCMs, respectively.

In an effort to derive quantitative future short-duration rainfall estimates to better suit the needs of water resources practitioners, various statistical downscaling and analysis techniques have been developed. However, there is no standard or accepted research methodology to determine how future sub-daily extreme rainfall could change in intensity and frequency at point locations or over a small area in the future climate.

Applying IDF information: A practitioners' guide

Rainfall-runoff *directly* affects storm sewers, culverts, detention ponds, drainage pump stations, and roads, while wastewater management infrastructure, including separated sanitary sewers and sanitary lift stations, can be *indirectly* impacted by processes of inflow and infiltration, and sometimes by hydraulic connections resulting from flooded roadways. When designing or operating using IDF information that either deviates too greatly from actual conditions, or is improperly applied, these systems run the risk of being under-sized (resulting in additional flood risk), significantly over-sized (resulting in misallocation of capital), or experiencing reduced service life as the result of more frequent stresses.

Whether public or private, existing drainage, stormwater, flood management, and wastewater infrastructure can typically be classified as providing either flow conveyance or storage. Safely conveying peak flows resulting from extreme rainfall has historically been the primary focus of design for the stormwater and wastewater infrastructure currently in use across Canada. Despite the increasing prevalence of techniques for reducing runoff at source (i.e., commonly known as green infrastructure or low impact development) there will continue to be a need to safely control peak rainfall-runoff, especially for relatively high-return period conditions. Design standards associated with conveyance infrastructure vary across Canada, depending upon local factors such as land use zoning, but mandated rainfall design return periods for storm sewers and culverts, often known as the minor system, typically range from the 5-year to the 100-year event. There is also often an allowance for an overland flow route, commonly known as the "major" flow path, to safely manage flows which exceed the capacity of the minor system.

Temporary storage of rainfall runoff can play an important role in the management of stormwater, by reducing downstream peak loading and corresponding infrastructure needs. Infrastructure used for temporary wet weather storage can be particularly important when mitigating the effects of urbanization, since urban land uses often lead to higher and more rapidly varying peak flows. Some ponds may play a role in improving stormwater quality by ensuring sufficient retention time for a desired level of particle settling. Analysis for the design of storage facilities generally involves consideration of local design standards. Local standards tend to stipulate that the post-development peak flow for a specified return period must not exceed the pre-development flow peak for the same, or sometimes a lower, return period, and that an emergency overflow be provided for the safe discharge of extreme peak flows, often in the order of the 100-year event.

Common analytical techniques

Storage and conveyance infrastructure is typically designed and managed by applying a variety of analytical techniques, most of which use IDF information as a critical input.

1. The **rational method** (RM) is the most direct application of IDF curves currently in use in hydrologic engineering, the purpose of which is to estimate the highest peak flow for a given return period. Application of the RM formula involves:
    - measuring the applicable drainage area;
    - using the IDF information to obtain the rainfall intensity; and
    - selecting or deriving the appropriate runoff coefficient for the area.

Obtaining rainfall intensity requires that the user select an appropriate return period frequency and rainfall duration. The frequency is generally dictated by the purpose of the calculation. The duration is obtained by calculating the “time of concentration,” or the time it takes for a hypothetical drop of water from the furthest point in the drainage area to reach the outlet (i.e., the point for which the peak flow is calculated).

The RM has a number of limitations:

- In its original form, the RM produces only a peak flow estimate. Hence, it cannot be used for applications that require a hydrograph and consideration of temporal factors.
- The RM can only be used with relative confidence for small areas, generally understood to be 20 hectares or less, largely because it assumes uniformity of rainfall over the entire drainage area.
- There are wide variations in the “standard” values of the runoff coefficient, *C*, for given land uses. Hence, resulting peak flows can vary considerably depending upon the selected *C* value.
- Methods of estimating time of concentration vary considerably. Hence, the estimated rainfall intensity for a given area can vary as well, resulting in considerable variation in estimating peak flows.

This Guideline provides a hypothetical application of the RM (see Chapter 6).

2. The **modified rational method** (MRM) is most commonly used in the design of facilities for temporary storage of rainwater, such as detention ponds. A primary limitation of the RM is that it can only be used to compute an estimate of peak flow. The MRM was developed to overcome this restriction.

Various forms of the MRM can be used to estimate the storage required to control a peak flow to a specified value, or to develop a hydrograph. One common form assumes that the flow calculated by the RM for a given duration can be multiplied by the duration to obtain an estimated runoff volume. The difference between the runoff volume (inflow) and discharge volume (outflow) gives an estimate of the storage used over that duration. It is usually found that, as the assumed duration increases, the storage volume will reach a maximum and then start to decline. This is because the intensity of rainfall typically decreases with increased duration resulting in a diminishing rate of increase in runoff volume, whereas the discharge volume increases linearly with increased duration.

The main limitations of the MRM are as follows:

- The MRM requires successive application of the RM and, therefore, shares many of the RM's limitations.
- Specific assumptions are made about the form of the rainfall distribution (uniform), the inflow hydrograph (trapezoidal), and the discharge hydrograph (linear increase to rainfall duration), leading to uncertainties with respect to the estimation of actual storage requirements.
- There is one version of the MRM in circulation that treats the calculated "Runoff Rate" column as an inflow hydrograph rather than as a set of discrete approximate storage estimates for different rainfall durations. This approach is theoretically incorrect and should not be applied.

This Guideline provides a hypothetical application of the MRM (see Chapter 6).

3. **Hydrological modelling** aims to provide a thorough and comprehensive understanding of hydrologic response throughout an entire watershed. While the RM and MRM approaches can be useful in developing estimates of design flow or runoff volumes, they are typically useful only in analyzing relatively small individual sites. Given design storm information, computer-based hydrologic simulation models can produce a robust accounting of how runoff is generated in the form of a hydrograph, and how it moves through the landscape, via either man-made or natural conveyance systems. Most hydrologic models use one form or another of a "unit hydrograph" which represents the flow generated by the area in question in response to a unit of runoff. There are tools available (e.g., water balance model) to assist in incorporating green infrastructure techniques, or low impact development, into hydrograph development.

While continuous modelling does not typically require IDF information, in many cases the data required to comprehensively analyze the runoff characteristics of a watershed using this approach may not exist or may not be suitable for the relatively high-return periods normally associated with design. As such, despite their limitations, event-based models remain the most broadly used approach across Canada both for calibration purposes and analysis. Continuous modelling, where applied, is mostly used for calibration, such that an event-based model can then be used for design (i.e., to establish design flows, often significantly larger than anything in the continuous modelling record).

Event-based approaches often utilize local IDF information in the form of artificial "design storms." Design storms are typically developed by analyzing local historical rainfall distribution information and are intended as a representation of the percentage of rainfall distribution over various timeframes, typically developed for one, six, twelve, or twenty-four hour durations. This Guideline provides an example demonstrating the use of a unit hydrograph-based single event model with a design storm (see Chapter 6).

Challenges and recommendations relating to the use of IDF information

Common challenges associated with the use of IDF information may stem from a number of issues.

1. Difficulties in understanding the theoretical basis for applying IDF information:
    - IDF data are often used to construct synthetic design storm events based upon hypothetical rainfall distributions that use IDF data as an input, but do not necessarily reflect the history of actual rainfall within the particular watershed.
    - The relationship between return periods specified in IDF data and return periods in flood events is often confused. Watercourse discharge resulting from a modelled 100-year return period synthetic rainfall event (constructed using IDF data) tends too often to be equated with the 100-year flood. This assumption may be erroneous for any number of reasons.
    - Practitioners may erroneously assume that durations taken from IDF data reflect the full length of actual historic storms, whereas, in reality they may reflect periods of heavier rainfall occurring within storms of longer durations.
    - Further to the above, in general terms the effects of multiple consecutive events (e.g., antecedent conditions saturating ground prior to a design event) are not often considered.

2. Uncertainties in selecting IDF information:
    - IDF data is often transposed spatially, using simple correction factors, without a full understanding of the implications and limitations.
    - Point data may be highly influenced by either the absence or inclusion of a particular outlier, especially in areas where thunderstorms tend to influence the critical design criteria.
    - Confidence intervals are rarely directly accounted for when applying IDF data, though uncertainty may be substantial, particularly for longer return period events and where data records are short.

3. Techniques used to develop IDF information:
    - The main challenges for practitioners which stem from the techniques applied in developing IDF information are described in the Chapter 4.

4. The effects of seasonality, climate cycles, and climate change:

    - Most IDF information is based upon assumptions of a stationary climate, without significant long-term trends in the rainfall data. Due to the effects of anthropogenic climate change, these past climate conditions may no longer be a good indicator of future climate conditions.
    - IDF information does not normally account for differences in data collected during different natural cycles, such as the El Niño-Southern Oscillation or the Pacific Decadal Oscillation. As a result, data may be collected under only one phase of the cycle, leading to infrastructure designs that may function less well under other phases.
    - The effect of seasonality is not normally well-reflected in available IDF information. For instance, IDF data in some areas of Canada, especially for shorter duration events, may only reflect the warmer parts of the year, when convective activity tends to occur. This can lead to challenges when designing infrastructure intended to function across all seasons (e.g., most stormwater and wastewater infrastructure) and climate events (e.g., snowmelt plus rainfall runoff) and may result in overdesign, under-design, or poor operational management of facilities used to convey peak flows or manage runoff.

In order to proactively address these challenges, it is recommended that practitioners

- acquire a solid base of understanding relative to the unique characteristics (i.e. rainfall processes) of the particular watershed within which they are working;
- remain aware of the theoretical limitations associated with IDF information used in applying the analytical approaches described in Section 6.2;
- clearly state and consider the limitations involved in selecting IDF data for use in a particular analysis;
- clarify confidence intervals associated with the underlying IDF data;
- review the limitations of the data upon which IDF information for their location is based;
- consider whether the effect of seasonality or natural climate cycles on the IDF information requires attention when applying this information to infrastructure design; and
- use general strategies and techniques in order to consider the potential effects of anthropogenic climate change on rainfall IDF characteristics in their region and watershed.

Climate change strategies for infrastructure

Due to anthropogenic climate change, it is generally expected that in most areas of the country, design intensities will increase, especially for shorter storm durations. Further, it is also expected that events which are now considered extreme will become more frequent in occurrence.

In the case of existing sewers which are expected to be adversely affected (i.e., with a risk of exceeding original design capacity) by climate change, it may be possible to extend their lives by

- removing or diverting loading from the sewer (e.g., Low Impact Development or green infrastructure strategies, integrated resource management techniques, rehabilitating sewers to reduce inflow and infiltration, etc.);
- expanding or rerouting major flow path (i.e., the solution may not always be in the piped system); and
- re-evaluating appropriate levels of service under future climate scenarios (e.g., is the originally anticipated level of service still going to be practical and economic?).

General considerations for designing new infrastructure in the face of increasing uncertainty associated with climate change include:

- Capitalize on local knowledge and data;
- Carefully consider the anticipated service life of infrastructure;
- Consider an adaptation design increment when investing in larger, long-lived infrastructure;
- Allow for flexible designs that can accommodate future infrastructure upgrades (increase) where possible;
- Arrange for possible expansion of major flow path; and
- Consider green infrastructure and low impact development.

Table of Contents

1 INTRODUCTION TO THE GUIDELINE

CHAPTER SUMMARY

This Chapter introduces the Guideline. This Guideline has been designed for professionals with a role to play in the planning, design, management, inspection, and regulation of storm water, drainage, waste water, and flood management systems. It is not a design text book, but rather a resource for understanding the derivation, and application in water system planning and design, of climate information in the form of rainfall intensity-duration-frequency (IDF) information.

IDF information is meant to describe the frequency (probability of occurrence) of extreme rainfall events of various rates and durations. This Guideline is intended to equip the reader with the ability to ensure that rainfall IDF characteristics are properly considered in the planning and design of water infrastructure, through familiarization with the assumptions contained within current IDF information, and clarification on what the limitations of this information could be. The implications of climate change on the occurrence of extreme rainfall events are also addressed.

1.1 Background and objectives of this Guideline

Canada has significant investments in storm water, drainage, waste water, and flood management systems. Every day, Canadians rely on this infrastructure to protect lives, property, and natural systems such as creeks, rivers, and lakes. In designing and managing these works, practicing professionals need to be concerned with the probability of occurrence of extreme values of rainfall amounts, often for specific storm durations. Rainfall IDF information commonly forms a critical input when applying the analytical techniques routinely used by practitioners.

IDF information is meant to describe the frequency (in terms of probability of occurrence) of extreme rainfall events of various rates and durations. The demand for rainfall IDF information has increased across Canada over recent years for a number of reasons. First, as the spatial heterogeneity of extreme rainfall patterns becomes better understood and documented, a stronger case is made for the value of "locally relevant" IDF information. Second, Canada continues to become increasingly urbanized. As urban areas expand, making watersheds generally less permeable to rainfall and run-off, many older water