Climate Adaptation Tools: Extreme Rainfall Intensity-Duration-Frequency (IDF) Curves

Heather Auld
Principal Climate Scientist
Risk Sciences International
1. Evaluate trends in short and longer duration rainfall amounts in order to:
   • determine whether the existing IDF curve and extreme rainfall design values should be changed

2. Consider adaptation measures where updated IDF calculations show increases, AND

3. Options for cases where new updated IDF calculations show decreases.
Figure 1.1
Locations of Environment Canada intensity-duration-frequency (IDF) stations
Risk Management Tools for Extreme Rainfall Events: Outline of Workshop

• Extreme rainfall risks (i.e. < 1day) can be described using Rainfall Intensity-Duration-Frequency Tables and Curves
• Represent statistical probability treatment of extreme rainfall events
• Limitations to IDF calculations – frequently misused
• Climate change will alter rainfall extremes. How to adjust IDF values for design? Or, other practices?
Introducing an Extreme Rainfall Intensity-Duration-Frequency (IDF) Curve

Equation to interpolate to different durations

Caution/Sujet à caution:
- 95% Confidence Interval > ±25%
  Intervalle de confiance de 95% > ±25%

Return period estimates fit for each duration separately

Intensity (mm/h), Intensité (mm/h)

Duration

Frequency

Intensity vs. Duration/Durée

Return Periods/
Périodes de retour
Years / ans

Environment Canada

Canada

VINELAND STATION RCS
ON
6139148
(composite)
1963 – 2007
26 years / ans
Latitude
43° 11’N
Longitude
79° 24’W
Elevation / Altitude
79 m
What is a Rainfall IDF curve, table?

IDF stands for Intensity, Duration, Frequency Curve

- Rainfall **Intensity** (mm/hr) or rate of rainfall, 
  i.e. the amount of heavy or intense rain that falls over a period of time of interest. High rainfall intensity indicates that it’s raining hard.
- Rainfall **Duration** (how many hours it rained at that intensity) 
  i.e. the time of interest for water to potentially flood a “system, and
- Rainfall **Frequency** (how often that rain storm repeats itself) 
  i.e. the probability that an extreme rainstorm giving intense rainfall over a selected period of time will happen again, on average.

Engineers convert this climate IDF information into water flow and flood risk information for design, regulation, etc.
What can we do with an IDF curve?

IDF curves are most often used for design...
Governments and other approval agencies typically set out standards for design of infrastructure that include acceptable minimum extreme rainfall amounts that “drainage systems” must be able to carry.

What is Acceptable to communities?
• In reality, it is too expensive to design systems to carry the worst ever storm and also too expensive in terms of disasters to under-design a system.
• So… we design for some level of risk that is a balance between a severe, rare storm and an affordable structure.
What is an acceptable extreme rainfall capacity?

In Canada, stormwater sewers are typically designed to carry, as a minimum, the rainwater from a 5-10 year storm. This means that all of the rainwater runoff from a 5-year rainstorm from the area upstream of the sewer system must fit into the storm sewer without overflowing (onto the road).

Other structures that consider extreme storm rainfall & IDF's:
- Dams and bridges (design and risk assessment)
- Road culverts, ditches and other drainage
- Stormwater management ponds
- Flood plain management
- Soil conservation studies
- Building roof drainage
Why do we care about different durations of rainfall?

Sometimes, 5 or 15 minute heavy rainfalls are of interest. Other times, for other infrastructure and locations, 24 hour intense rain storm amounts may be greatest interest.

Why?

• The greatest rainfall, volume of flow and time of interest depends on the land area and surface.
• A forested area will be less sensitive to short heavy rainfalls than a paved built-up area (city). Flat farmland can respond differently from steep mountain valleys (sensitive to flash flooding).
• Landcover is important in selecting the duration of storm rainfall, designing storm water management facilities and estimating flood levels.
Sensitivity to intense rainstorms: Examples

An urban centre could experience flooding from heavy rains falling over a **SHORT** period of time, such as **A 5 TO 30 MINUTE PERIOD**.

- A rural highway with deep ditches on its shoulders would not likely be impacted by an intense rainfall lasting only 5 to 15 minutes, although the paved road itself would see ponding of water.
- A heavy rainfall event lasting 1 to 6 hours might be more significant for filling the ditches and overflowing the roadway.

A forested or wetland landcover can greatly reduce the risk of flood impacts from intense rainfalls (especially for shorter durations).
Weather Processes that cause Extreme Rainfall Events…

- **Severe thunderstorms** – short duration event, often lasting *minutes to hours*
- **Low pressure systems and fronts** – called weather system or synoptic, often lasting many hours to a day *(12-24 hours)*
- **Mixed** – thunderstorms embedded in a low pressure or frontal system, from an hour to a day *(3-24 hours)*
- **Tropical storms, hurricanes, typhoons** – *hours to days*, often enhanced by thunderstorm or convective rainfall
- **Upslope or orographic** – usually enhances synoptic rainfall events, or can enhance formation and intensity of thunderstorms
So, What Difference Does the Weather Process Make?

- Has an impact on the density of stations and length of records needed for good IDF estimates
- Impacts the quality of the IDF value estimates
- Minnesota study concluded that IDF values from a sparse data network likely underestimate true heavy rainfall
- If fine scale processes dominate extremes (e.g. convection), need a denser network of stations to capture heavy rainfall
- When shortage of historical stations, blend in other datasets
- PEI Government added other agricultural rainfall datasets – takes expertise to quality control the data but worthwhile
- Patterns from radar datasets also helpful
- Need to understanding the causes of historical extreme rainfall to understand future trends and projections
Heavy Rainfall from Organized Weather Systems (Synoptic)
Heavy CONVECTIVE Rainfall

Figure 2.2
Convective lifting processes that can produce heavy rainfall from isolated thunderstorm cells (left) or organized thunderstorm cells (right)
Heavy Rainfall from Tropical Systems

Figure 2.3
Cloud lifting and rain patterns in a hurricane or tropical storm
Heavy Rainfall Enhanced by Topographic/Orographic Processes
Name the Rain Event... Synoptic, Convective, Tropical Storm, Orographic?

Synoptic

Tropical storm, Hurricane Andrew

Orographic + convective
Heavy Rainfall in Atlantic Canada: Processes

- 12 & 24 hours extremes – synoptic systems + tropical systems
- Often combination heavy rainfall, high winds and coastal storm surges that result in flooding situations and damages
- PEI historically:
- NB historically: 43% from weather; 14% ice jams and snowmelt; 8% storm surges; 35% combined causes
- NS historically: 26% convective; 22% synoptic and tropical; 10% storm surges and tidal; 42% combined causes
- PEI historically?? Anyone done the analyses??
Sensitivity to accumulated rain: Examples

When the ground becomes saturated, smaller rainfall events can lead to more severe impacts. (e.g. a one-in-20 year rainfall event can give equivalent impacts to a one-in-5-year event without saturation).

We call this the impact of accumulated or antecedent rainfall. Areas become more susceptible to flooding since there is nowhere for the water to go (i.e. nil infiltration).

Under climate change, some regions are expected to “rain more often”. What might be the impact?
Flood frequencies after the Mountain Pine Beetle Infestation

Post-infestation: 13-year rain event gives similar discharge to an earlier 50-year rainfall event

From Presentation to Thompson Okanagan Interface Committee, April 2007
Flood frequencies near creeks increase after forest fires

Impacts includes water quality impacts, damage to fish habitat, infrastructure, safety, costs to reinforce existing infrastructure…
Trends in Number of Days With Rainfall (1950-2007)

- **Statistically Significant Increase**
- **Non-significant Increase**
- **Non-significant Decrease**
- **Statistically Significant Decrease**
- **Station with > 20% missing data, no trend calculated**

Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Trends in Highest 3-day Rainfall (1950-2007)

- **Statistically Significant Increase**
- **Non-significant Increase**
- **Non-significant Decrease**
- **Statistically Significant Decrease**
- **Station with > 20% missing data, no trend calculated**

**Source:** Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
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Intensity (mm/h), Intensité (mm/h)

Duration

Frequency

Intensity (mm/h) vs. Duration (Minutes / Hours)
Additions to Prince Edward Island IDF Datasets & Calculations
Deriving IDF curves...

**Based on real historical events... not predictions**

In using IDF curves, we assume that the past rainfall extremes will represent future rainfall extremes. Problem?

- IDF curves are created by analyzing years of past rainfall records.
- The longer and more complete the record, the better the quality of the statistical analysis.
- Long records of rainfall data are less likely to represent a short-term rainfall anomaly, for example, a decade of high precipitation that is not representative of the long-term rainfall pattern of the region.
Measuring Rainfall: Daily and Rate of Fall

Data often measured using automated Tipping Bucket rain gauge

MSC Type B Standard Gauge 1975 – manually read and recorded

MSC Tipping Bucket 1938 – recording – chart and data logger

TB-3 Tipping Bucket 2002 – recording – data logger

F&P/Belfort Weighing Gauge 1965 – recording – chart and data logger
The Derivation of IDF curves

Can use all rainfall events over a threshold (Peak Over Thresholds) or the maximum rainfall event each year for the period of record. Calculate for all durations of interest.

1. Quality control the data to detect bad-erroneous data,
2. Fit a probability distribution to the set of extremes,
3. Use these statistical distributions to make statements about the expected frequency of an event (e.g. expected on average once every 10 years, or once every 100 years)...
Lines on the IDF Curve graph represent probability or return period (level) extreme rainfall amounts.

e.g. The 50-year line represents rainfall events that historically had a probability of occurring once every 50 years… or…
The probability of a 50-year magnitude storm rainfall occurring or being exceeded in any given year is 1/50 or 2% per year
Likewise, the probability of a 10-year storm occurring, on average, is 1/10 or 10% per year
What is a 50 year return period rainstorm amount?

Does a 50 year extreme storm occur every 50 years?

No, but over enough time, it could be expected on average to be reached or exceeded once every 50 years

Like playing a lottery... and randomly expecting a large gift of money

Sometimes 50-year events happen multiple times in 50 years. Sometimes no equal events happen for over 150 years

Each section represents 50 years and the dots show years in which the 50-year return period event is equalled or exceeded

Figure 5.10 Idealized sample of occurrences of a 50-year return period event over 5000 years
Probability of a T-year return period event occurring in a period of N years - not guaranteed

<table>
<thead>
<tr>
<th>T = Return Period</th>
<th>N = Number of years</th>
<th>(* denotes &gt; 0.9995)</th>
<th>Period of Time (N years)</th>
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</thead>
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<tr>
<td>2</td>
<td>2</td>
<td>0.750 0.969 0.999</td>
<td>0.969 0.999*</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.360 0.672 0.893 0.965 0.988 0.996 0.999*</td>
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<tr>
<td></td>
<td>10</td>
<td>0.190 0.410 0.651 0.794 0.878 0.928 0.958 0.995</td>
<td>0.969 0.999*</td>
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<td>15</td>
<td>0.129 0.292 0.498 0.645 0.748 0.822 0.874 0.968</td>
<td>0.999*</td>
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<td>20</td>
<td>0.098 0.226 0.401 0.537 0.642 0.723 0.785 0.923</td>
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<tr>
<td></td>
<td>25</td>
<td>0.078 0.185 0.335 0.458 0.558 0.640 0.706 0.870 0.953 0.983 0.998*</td>
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<td></td>
<td>30</td>
<td>0.066 0.156 0.288 0.399 0.492 0.572 0.638 0.816 0.921 0.966 0.994 0.999*</td>
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<tr>
<td></td>
<td>50</td>
<td>0.040 0.096 0.183 0.261 0.332 0.397 0.455 0.636 0.780 0.867 0.952 0.982 0.998*</td>
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<tr>
<td></td>
<td>75</td>
<td>0.026 0.065 0.126 0.182 0.235 0.285 0.331 0.489 0.635 0.739 0.866 0.932 0.982 0.995 0.999</td>
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<tr>
<td></td>
<td>100</td>
<td>0.020 0.049 0.096 0.140 0.182 0.222 0.260 0.395 0.529 0.634 0.779 0.866 0.951 0.982 0.993</td>
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</tr>
<tr>
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<td>150</td>
<td>0.013 0.033 0.065 0.095 0.125 0.154 0.182 0.284 0.394 0.488 0.633 0.738 0.866 0.931 0.965</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>0.010 0.025 0.049 0.072 0.095 0.118 0.140 0.222 0.313 0.394 0.529 0.633 0.778 0.865 0.918</td>
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<tr>
<td></td>
<td>300</td>
<td>0.007 0.017 0.033 0.049 0.065 0.080 0.095 0.154 0.222 0.284 0.394 0.487 0.633 0.737 0.812</td>
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<tr>
<td></td>
<td>400</td>
<td>0.005 0.012 0.025 0.037 0.049 0.061 0.072 0.118 0.171 0.221 0.313 0.394 0.528 0.633 0.714</td>
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<td></td>
<td>500</td>
<td>0.004 0.010 0.020 0.030 0.039 0.049 0.058 0.095 0.139 0.181 0.259 0.330 0.452 0.551 0.632</td>
<td></td>
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</tbody>
</table>

50-year event has:
~64% chance occurring in 50 years, ~40% chance in 25 years, ~87% chance in 100 years.
Environment Canada IDF Station Locator / Localisateur de station IDF d'Environnement Canada

To locate IDF stations zoom map or search on location of interest. / Pour trouver les stations IDF, aggrandissez la carte ou faites une recherche par endroit d'intérêt.
For general station information click on the station icon. / Pour obtenir des données générales sur les stations, cliquez sur l'icône des stations.


Climate.weatheroffice.gc.ca
Harrington CDA

6 hour duration extreme rainfall
50 year return level (period) ~78mm

~22 mm/hr

~13mm/hr rate or 13X6=~78mm

One hour duration extreme rainfall
5 year return period rainfall ~22 mm/hr
Table 2a : Return Period Rainfall Amounts (mm)

<table>
<thead>
<tr>
<th>Duration/Durée</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>#Years</th>
</tr>
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<tbody>
<tr>
<td>yr/ans</td>
<td>yr/ans</td>
<td>yr/ans</td>
<td>yr/ans</td>
<td>yr/ans</td>
<td>yr/ans</td>
<td>yr/ans</td>
<td>Années</td>
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<tr>
<td>5 min</td>
<td>5.0</td>
<td>6.8</td>
<td>7.9</td>
<td>9.4</td>
<td>10.4</td>
<td>11.5</td>
<td>10</td>
</tr>
<tr>
<td>10 min</td>
<td>7.9</td>
<td>10.1</td>
<td>11.5</td>
<td>13.3</td>
<td>14.7</td>
<td>16.1</td>
<td>10</td>
</tr>
<tr>
<td>15 min</td>
<td>10.0</td>
<td>13.0</td>
<td>14.9</td>
<td>17.4</td>
<td>19.2</td>
<td>21.1</td>
<td>10</td>
</tr>
<tr>
<td>30 min</td>
<td>15.0</td>
<td>18.9</td>
<td>21.5</td>
<td>24.7</td>
<td>27.1</td>
<td>29.5</td>
<td>10</td>
</tr>
<tr>
<td>1 h</td>
<td>18.1</td>
<td>21.8</td>
<td>24.2</td>
<td>27.3</td>
<td>29.6</td>
<td>31.8</td>
<td>10</td>
</tr>
<tr>
<td>2 h</td>
<td>24.7</td>
<td>30.5</td>
<td>34.3</td>
<td>39.1</td>
<td>42.7</td>
<td>46.3</td>
<td>10</td>
</tr>
<tr>
<td>6 h</td>
<td>38.6</td>
<td>51.2</td>
<td>59.5</td>
<td>70.0</td>
<td>77.8</td>
<td>85.5</td>
<td>10</td>
</tr>
<tr>
<td>12 h</td>
<td>51.5</td>
<td>67.9</td>
<td>78.8</td>
<td>92.5</td>
<td>102.7</td>
<td>112.8</td>
<td>10</td>
</tr>
<tr>
<td>24 h</td>
<td>58.5</td>
<td>75.3</td>
<td>86.5</td>
<td>100.6</td>
<td>111.1</td>
<td>121.5</td>
<td>10</td>
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</tbody>
</table>

NOTE: Short period of record. Caution required.
Using IDF tables for Harrington… Caution on interpretation

Two tables: (1) total rainfall for minutes or hours (duration) and (2) rates of rainfall in mm/hr

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

<table>
<thead>
<tr>
<th>Duration/Durée</th>
<th>2 yr/ans</th>
<th>5 yr/ans</th>
<th>10 yr/ans</th>
<th>25 yr/ans</th>
<th>50 yr/ans</th>
<th>100 yr/ans</th>
<th>#Years Années</th>
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<tr>
<td>5 min</td>
<td>60.5</td>
<td>81.2</td>
<td>95.0</td>
<td>112.4</td>
<td>125.3</td>
<td>138.1</td>
<td>10</td>
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<tr>
<td></td>
<td>+/- 13.4</td>
<td>+/- 22.5</td>
<td>+/- 30.4</td>
<td>+/- 41.0</td>
<td>+/- 49.1</td>
<td>+/- 57.2</td>
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<tr>
<td>10 min</td>
<td>47.2</td>
<td>60.4</td>
<td>69.1</td>
<td>80.1</td>
<td>88.2</td>
<td>96.3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>+/- 8.5</td>
<td>+/- 14.2</td>
<td>+/- 19.2</td>
<td>+/- 25.9</td>
<td>+/- 31.1</td>
<td>+/- 36.2</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>40.1</td>
<td>51.9</td>
<td>59.8</td>
<td>69.6</td>
<td>77.0</td>
<td>84.2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>+/- 7.6</td>
<td>+/- 12.8</td>
<td>+/- 17.3</td>
<td>+/- 23.3</td>
<td>+/- 27.9</td>
<td>+/- 32.5</td>
<td></td>
</tr>
<tr>
<td>30 min</td>
<td>30.0</td>
<td>37.8</td>
<td>42.9</td>
<td>49.4</td>
<td>54.3</td>
<td>59.1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>+/- 5.0</td>
<td>+/- 8.4</td>
<td>+/- 11.4</td>
<td>+/- 15.4</td>
<td>+/- 18.4</td>
<td>+/- 21.4</td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td>18.1</td>
<td>21.8</td>
<td>24.2</td>
<td>27.3</td>
<td>29.6</td>
<td>31.8</td>
<td>10</td>
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<tr>
<td></td>
<td>+/- 2.4</td>
<td>+/- 4.0</td>
<td>+/- 5.4</td>
<td>+/- 7.3</td>
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<td>2 h</td>
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<td>15.2</td>
<td>17.1</td>
<td>19.6</td>
<td>21.4</td>
<td>23.1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>+/- 1.9</td>
<td>+/- 3.1</td>
<td>+/- 4.2</td>
<td>+/- 5.7</td>
<td>+/- 6.8</td>
<td>+/- 8.0</td>
<td></td>
</tr>
</tbody>
</table>
How well did the new dataset fit the Extreme Value Distribution?
Harrington CDA
Charlottetown A
1967-2008

One hour duration extreme rainfall
5 year return period rainfall ~24 mm/hr

IDF values higher than for Harrington CDA
The current approach to developing a suite of IDF Curves includes:

- A statistical TBRG station specific analysis based upon all available historical data
  - The concept is that the climate is **stationary**; therefore characteristics of the historical precipitation data will continue to be similar in future.

- The premise that precipitation patterns and the atmospheric processes driving them will remain unchanged

- Traditional use of the point rainfall data has assumed that the single precipitation site will be representative for a surrounding region
Changes in IDF Return Period Rainfalls
From 1990 to 2007 IDF Update: Ontario

- Return Period Rainfalls **DECREASE** in many cases

- High profile extreme rainfall events in recent years lead to expectations that return period rainfalls will all show **INCREASES**
Downward Trends in Short Duration Rainfall Amounts
And the Message Is?

- Majority of trends not significant
- Variable in magnitude, direction between stations, durations, including DECREASES
- Climate change projections imply more active hydrological cycle. Suggests that IDF values NOT be decreased without strong evidence (e.g. earlier short datasets).
Why does a 50-year return period rainstorm happen every year in my area? Because...

IDF values provide single point estimates of extremes

• A rainstorm with a 100 year return period is a rare event for a single location, but a few of these 100 year events can occur in a large region each year.

• IDF curves are less likely to capture the short duration extreme rainfall risks at a point unless it has a rainfall monitoring station with a LONG period of record.

• It may take a long period of record to show consistent increases.
Trends in Highest 10-day Rainfall (1950-2007)

- Statistically Significant Increase
- Non-significant Increase
- Non-significant Decrease
- Statistically Significant Decrease
- Station with > 20% missing data, no trend calculated

Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Trends in Highest 1-day Rainfall (1950-2007)

Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Existing and Future Data Challenges for Traditional Point Based Rainfall IDF Approaches

- Loss of stations
- Limited long-term stations
- Station network density insufficient to capture all fine scale events
- Missing data? Station automation?
- Some issues with single station IDF approach?

[Map showing Environment Canada IDF Station Locations with red dots for open stations as of 2003 and black dots for closed stations prior to 2003. The map also highlights declining Archived TBRG Stations.]
Large Spatial Variability in Station IDF Values – especially for short data records

NOTE: Toronto North York only had 9 years of data

50-yr values of 60-minute or 1-hour rain (mm)
New IDF Calculation Methodologies are being developed around the world – regional approaches

Can use other rainfall information (other agency data, radar, etc) to improve estimates of probabilities

Define similar climatological regions for extreme rainfall

10 RFA Defined Homogeneous regions in warm season for 24-hour extreme rainfall, based on daily & TBRG data

• Supplemented with radar

Source: Paixao et al. 2011
Common Pitfalls in using IDF Values

- IDF values often used for return periods MUCH LONGER than data record – not more than twice record length
- Poor spatial network of rainfall stations … creates additional uncertainties. IDF curves are site specific and not directly transferrable to other sites (sometimes correction factors are used)
- Regional IDF values can adjust for some of problems above
- Confidence intervals or uncertainty rarely considered in applying IDF values – watch the shorter datasets and long return periods!
- El Nino and other decadal oscillations in atmospheric circulation can mess with calculations (e.g. tropical rainfalls)!
- Winter rainfalls and shoulder season rainfall extremes often missed – sometimes biggest events – look at daily rainfall values
- Not all flooding events result from 15 min to 24 hour rainfalls – watch for accumulated rainfalls and other causes
Climate Change Adjusted IDF Curves??

- No accepted methodologies for “climate change” IDF’s;
- Climate change models underestimate extreme events;
- Some extreme precipitation events are very small scale and are not seen well by the climate models;
- ENSO (e.g. El Nino) events, Decadal Oscillations, etc are important – but, most models do NOT handle these well;
- Weather map type methodologies have promise in projecting future extreme rainfall;
- All “climate change adjusted IDF curves” try to relate short duration rainfall to annual or daily rainfall extremes. Is this reasonable?
- Differences likely in heavy rainfall processes…
Projected changes in extreme 24-hour precipitation amounts and return periods for mid to late 21st century compared to 1990 values (SRES A2)

(From Karin et al (2007))
20-year Return Period (Level) Extreme Precipitation Projections from an Ensemble of Climate Change Models

**Preliminary results**: Projected changes in 20-year return values of annual maximum 24-hour precipitation rates (%) by 14 GCMs under three different SRES emission scenarios B1 (blue), A1B (green) and A2 (red).
Changes in atmospheric processes driving extreme rainfall (15 min, 1 hour, days) are not likely to uniformly change in future.

How to go forward? GCM and RCM results?

Can consider different trends in atmospheric processes… requires expertise

IPCC SREX claimed four sources of climate change projection information:

- GCMs;
- downscaling of GCM simulations;
- physical understanding of the processes governing regional climate responses;
- recent historical climate change
Projected Percentage Changes in Future Rainfall in southern Ontario (3 river basins – urban, rural & mixed)

Warm Season: April-November

- 3-GCM ensemble
- Increase in seasonal total (20-35%)
- Increase in # of days with rainfall, regardless of daily rainfall amount
- 45-120% increase in LOW flow

BUT
- Greatest increases (30-50%) in the heavier rainfall days (>=25 mm)
% Change in Total annual Precipitation: Charlottetown grid
5 Day Maximum Precipitation – change (mm): Charlottetown grid
% change in heavy precipitation years: Fraction of time when annual precipitation is very high or > 95 percentile: Charlottetown grid
How do we mainstream/bridge climate change information into infrastructure and community decisions?

• Moving beyond NATO (“No Action Talk Only”)
• Meaningful climate change information
• “Due diligence” – best practices, not perfect
• Multi-disciplinary considerations
• Support from regulations, codes, standards, legal community…
**Climate Model-led Approach**

**Models-Scenarios-Impacts**

Climate science/models are the essential system knowledge without which adaptation and mitigation strategies cannot readily be built.

*Implications:* Large investments in climate model capacity and improved predictions are needed if society is to adapt.

*Strength:* Identifies impacts; quantitative

*Climate Data:* multiple models; downscaling needed

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**Vulnerability-Thresholds**

**Stakeholder-led Approach**

Significant benefits may accrue by allowing adaptation options appraisal to take centre stage, rather than climate change scenarios.

*Implications:* Uncertainty is unavoidable, yet society can move forward with actions that are robust to the range of plausible futures.

*Strength:* Stakeholder & adaptation focus

*Climate Data:* can work with less detailed modelling
# Climate Change Adaptation Approaches

## "CC models-impacts first"

### What if climate extremes change according to scenarios x, y, z?

#### Climate Pressures and Changes?
- e.g. sea level rise, precipitation

#### Sensitivities to Climate?
- e.g. water quantity, heat waves

#### Adaptation needed for impacts?
- Safety, failure, durability
  - yes
  - no

### Response:
- No new measures.

## "Vulnerability-thresholds first"

### What can national systems cope with? “Thresholds”, priorities for action?

#### Climate sensitivities?
- e.g. wind loads, sea level rise

#### Vulnerabilities, failure thresholds?
- e.g. tolerance, critical storm surge

#### Resilience of current adaptation?
- Will it fail under scenarios (a, b, c)?
  - Response: New adaptation measures needed from roughly 20xx.

### Engineers Canada approach
Adapted from Byers et al., 2011
TECHNICAL GUIDE
Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners

- First official version
- Guidance for water practitioners
- Shop.csa.ca
CSA Rainfall IDF Guideline

Introduction to the issue
CHAPTER 1

Background
Drivers of extreme rainfall events

CHAPTER 2: Meteorological processes and analysis
CHAPTER 5: Climate change

GUIDANCE/STATE OF PLAY

CHAPTER 3: Rainfall observations and networks
CHAPTER 4: Derivation and dissemination of IDF values
CHAPTER 6: Applying IDF information
CHAPTER 7: Adapting to climate change
CHAPTER 8: Forward direction

Needs and opportunities

Figure 1.2
Structure and content of the Guideline
Sample Best Practices for Future Climate

- Use local knowledge, local climate understanding – how did the system respond in the past?
- Consider the planned service life of infrastructure
- Consider the sensitivity of new infrastructure to range of climate tolerances. Might not be very sensitive.
- Consider design increment or safety factors when designing long-lived infrastructure
- Phased adaptation – work with future upgrades where possible (e.g. detention pond might need to be expanded in future – acquire lands now)
- Arrange for future expansion of a major flow path
- Green infrastructure and low impact development
- Maintenance (e.g. culverts)
Managing Uncertainty and Surprises

Under “deep uncertainties”, high sensitivities, robust adaptation options will reduce risks of mal-adaptation i.e. options that work under all climate scenarios and reduce vulnerability to the current climate.

Increased safety factors/margins, phased or sequenced adaptation, flexible design, climate change model ensembles all deal with uncertainties.

**Flexibility:** building flood wall with larger foundations so that it can be heightened if needed, rather than replaced

**No regrets:** Good integrated water management, good design, conservation, preserving ecosystems, best practice

**Sequencing strategies:** “no-regrets” options are taken earlier, and more inflexible measures delayed in anticipation of better climate change information, regular monitoring and review
Climate Change Adaptation Options: Hard and Soft Engineering Options (Wetland Ecosystem Services)

Damage and Adaptation Costs (Millions of 2000$)

Boston (US) sub-area with and without wetlands preservation

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<th>Year</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
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Rainfall Records in Canada

Note: Rainfall amount in millimetres.
According to this report, climate change may cause serious flooding! Well, we'll cross that bridge when we come to it.

Why Wait?
Thank You!

Contact:

Heather Auld
Principal Climate Scientist
Risk Sciences International
hauld@risksciencessint.com

Tel: 613-260-1424 X214; Cell: 647-225-6026
Fax: 613-260-1443
www.RiskSciencesInt.com