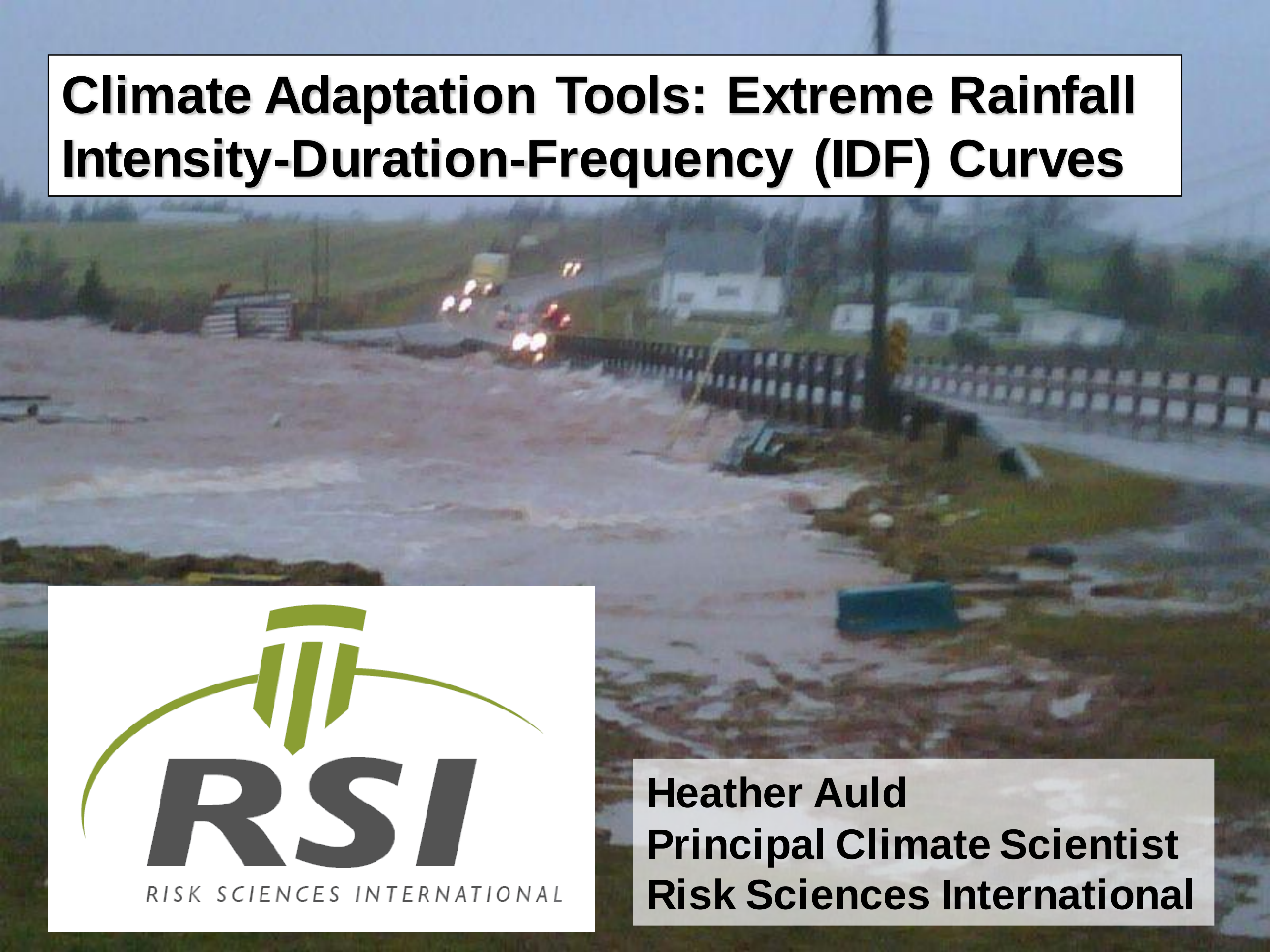
Climate Adaptation Tools: Extreme Rainfall Intensity-Duration-Frequency (IDF) Curves



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Risk Sciences International

OBJECTIVES

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.

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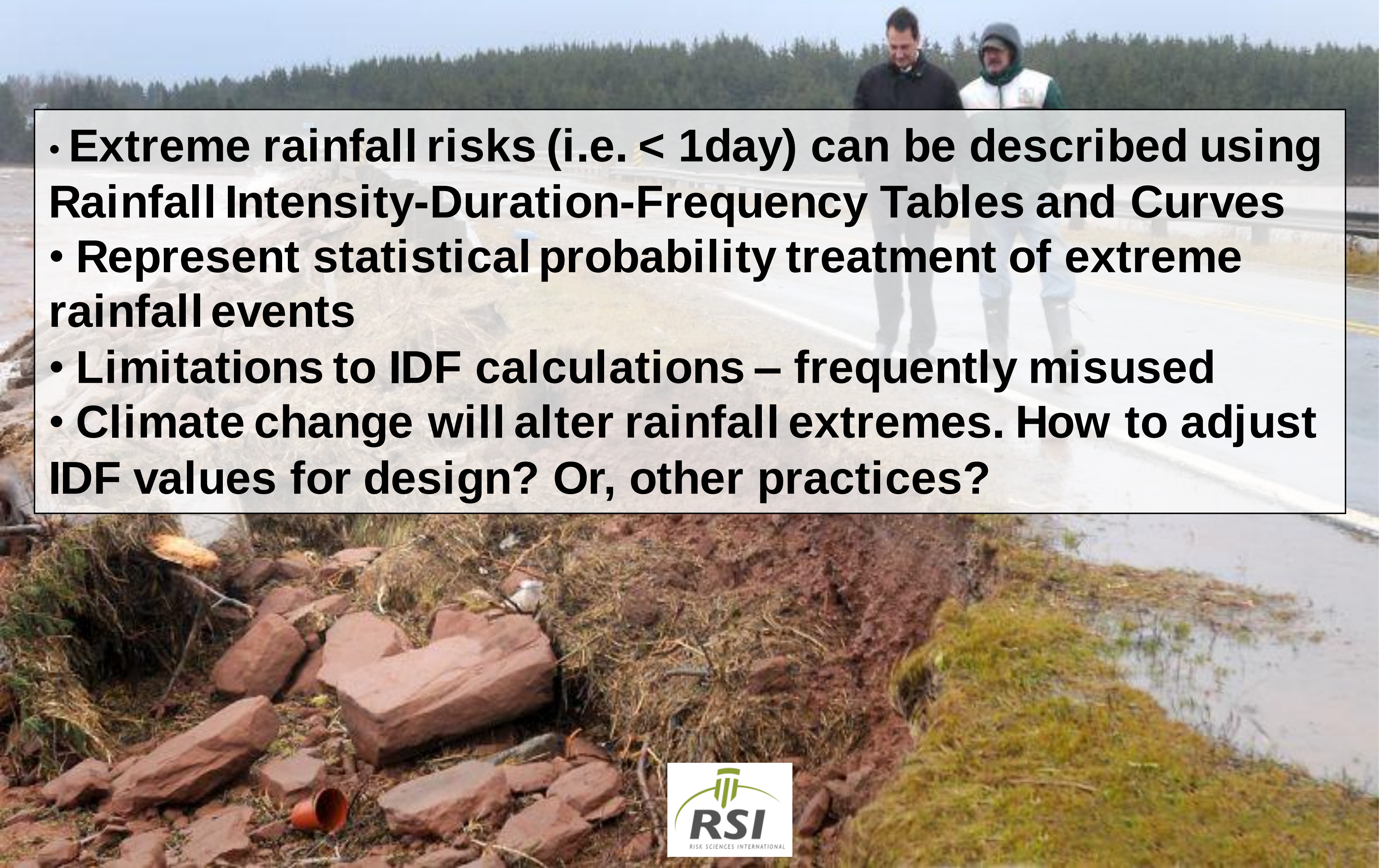
Figure 1.1
Locations of Environment Canada intensity-duration-frequency (IDF) stations

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?

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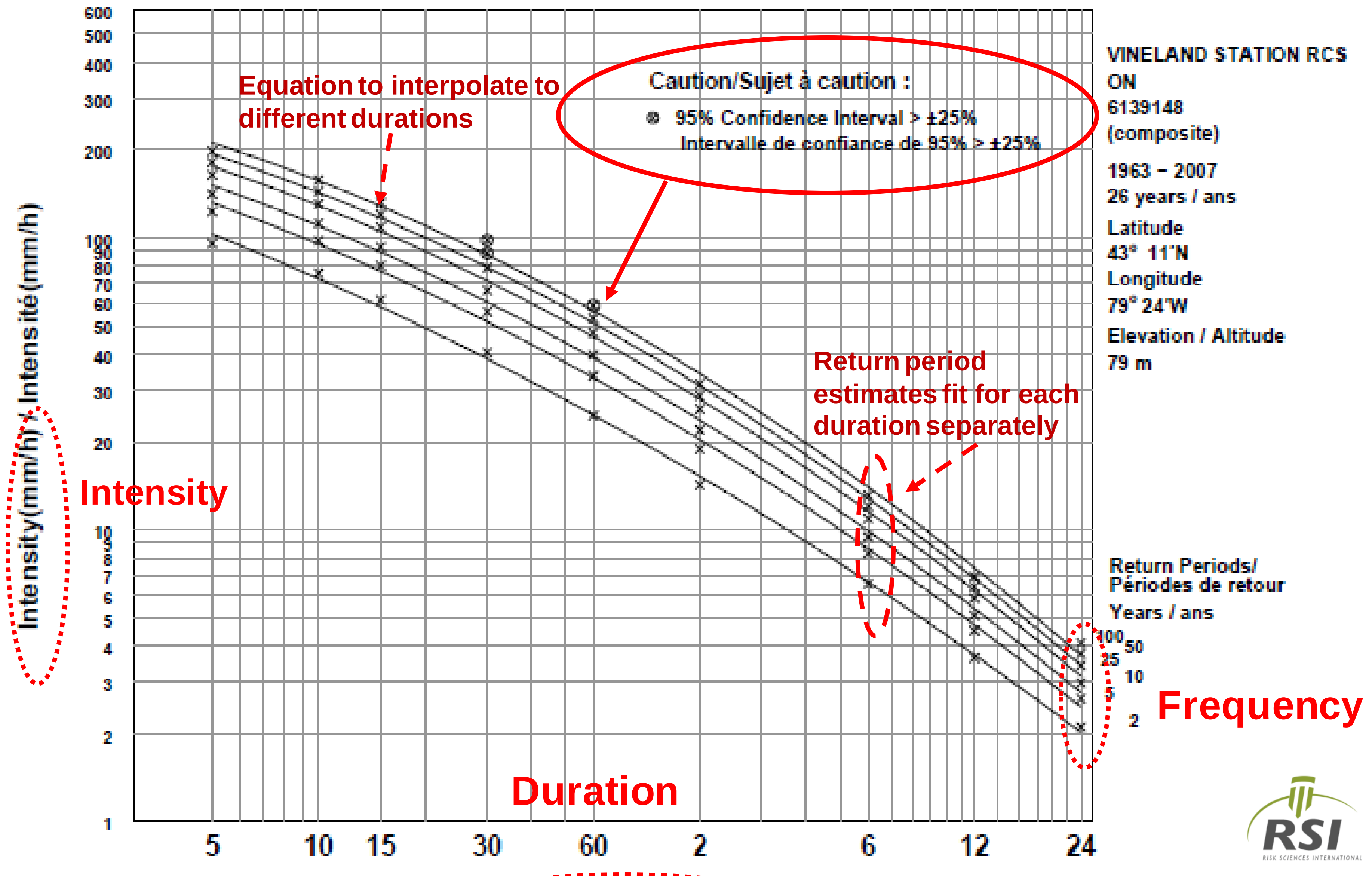
Introducing an Extreme Rainfall Intensity-Duration-Frequency (IDF) Curve



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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?

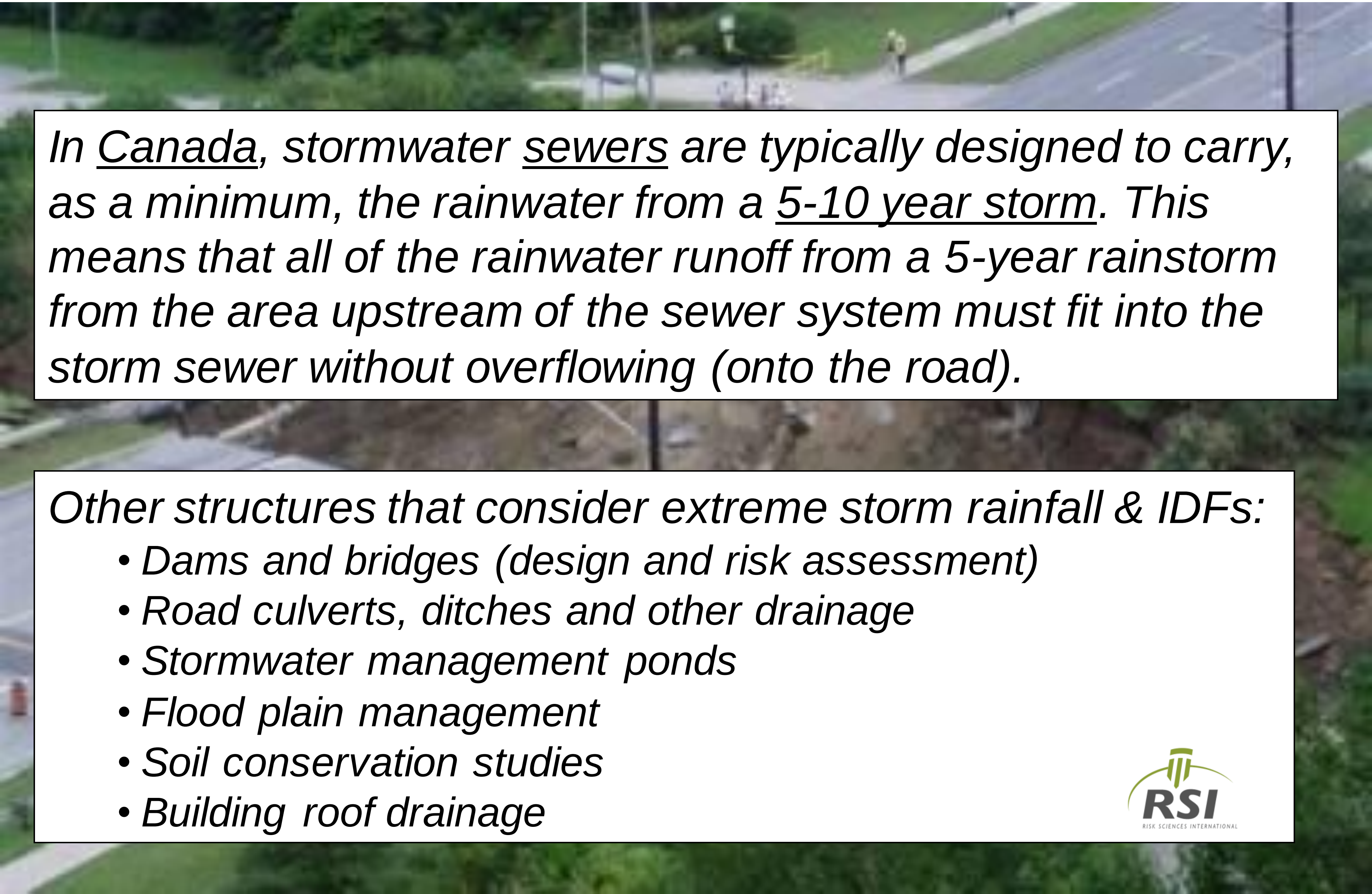
IDF curves are most often used for design…

*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?

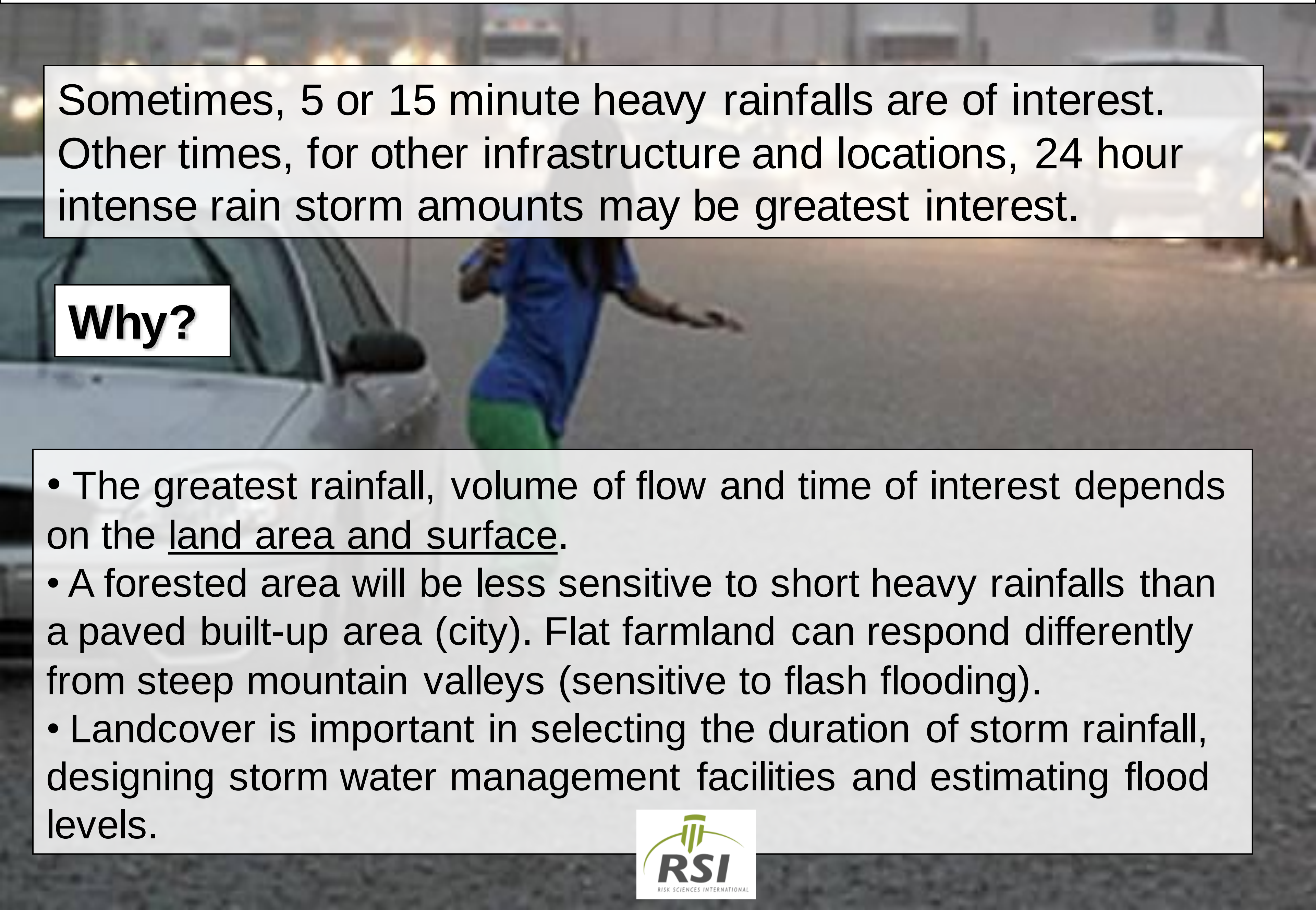


In Canada, stormwater sewers are typically designed to carry, as a minimum, the rainwater from a 5-10 year storm. This means that all of the rainwater runoff from a 5-year rainstorm from the area upstream of the sewer system must fit into the storm sewer without overflowing (onto the road).

Other structures that consider extreme storm rainfall & IDFs:

- *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.

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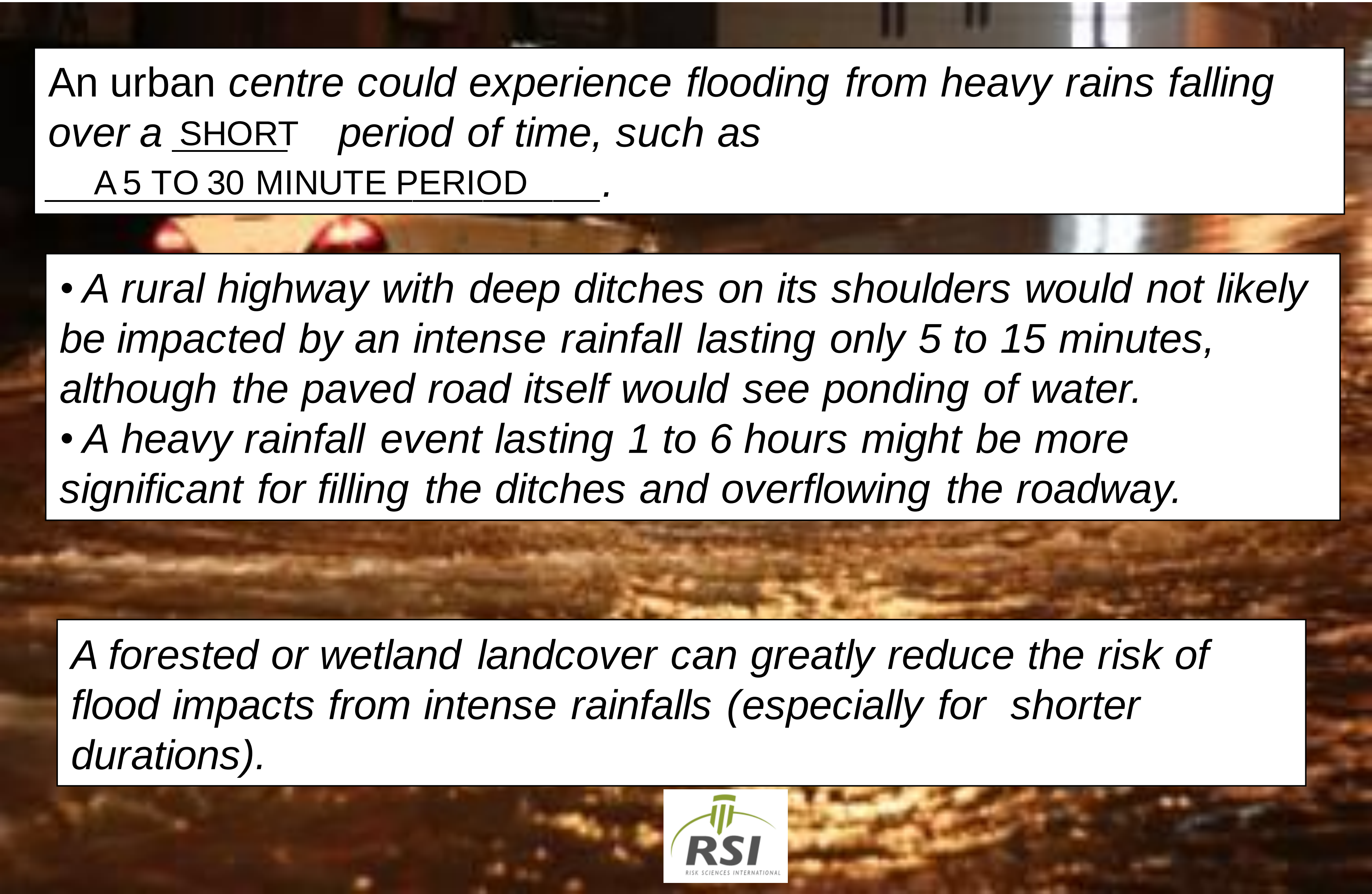
Sensitivity to intense rainstorms: Examples



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).

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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

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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**

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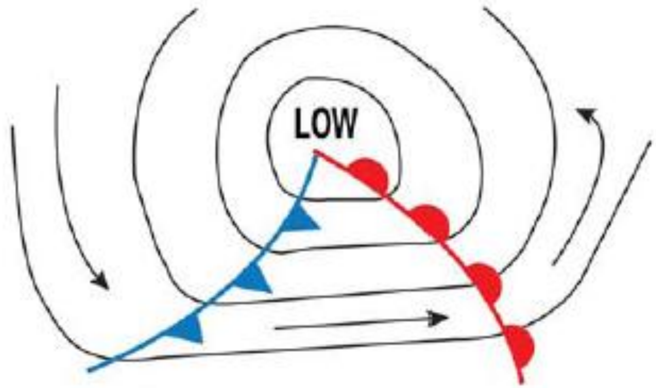
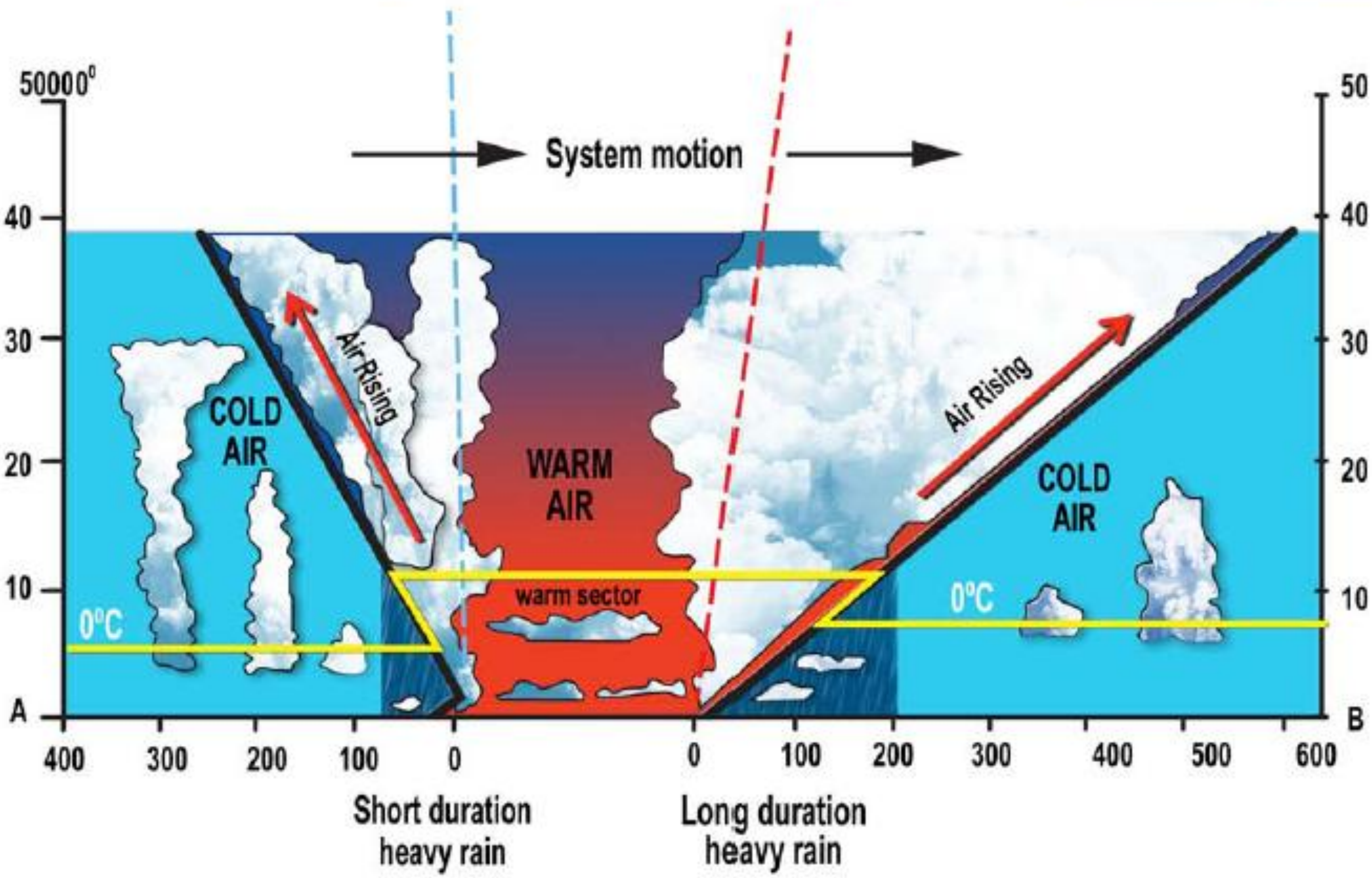
Heavy Rainfall from Organized Weather Systems (Synoptic)





Heavy CONVECTIVE Rainfall

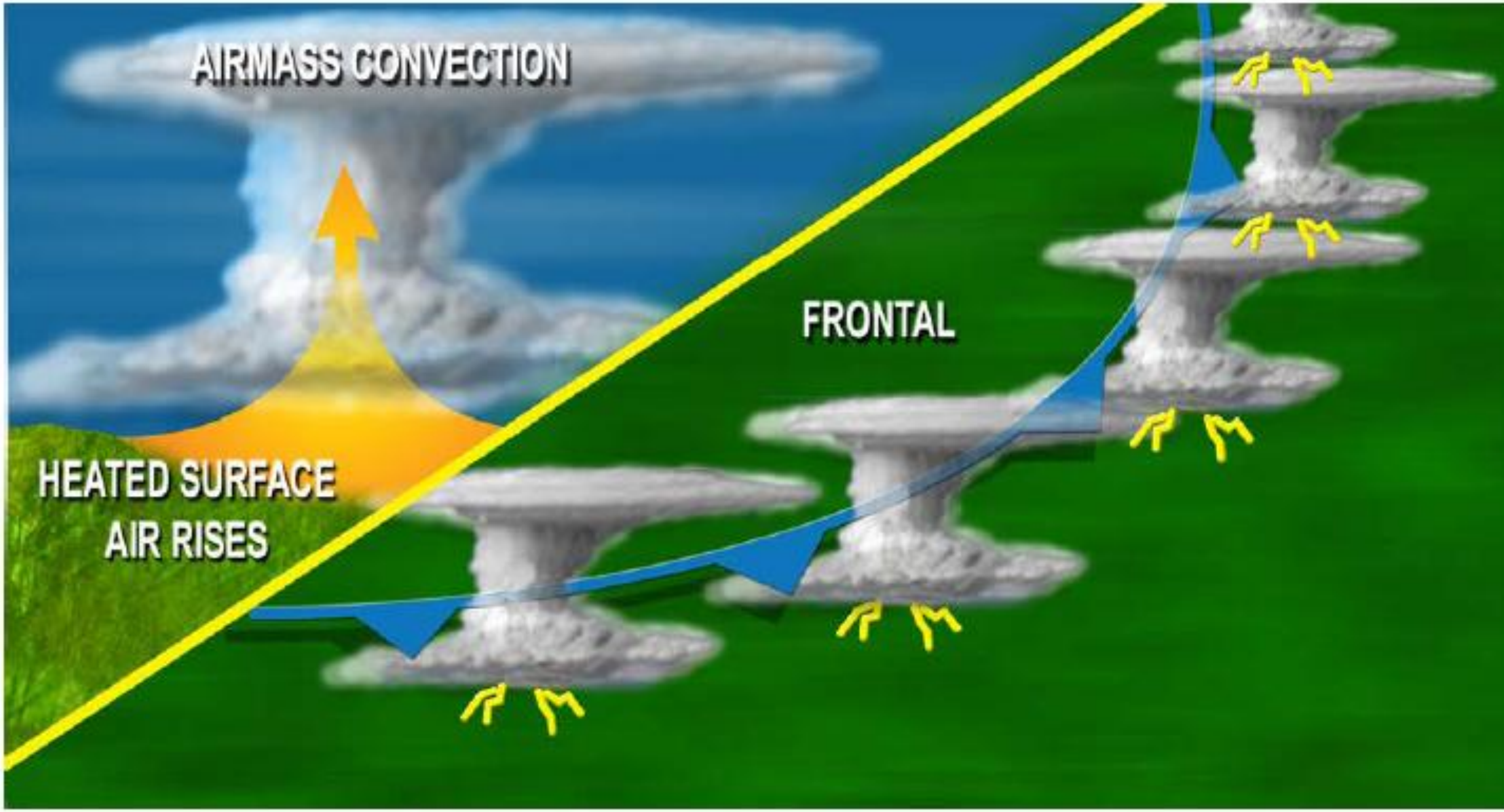


Figure 2.2
Convective lifting processes that can produce heavy rainfall from isolated thunderstorm cells (left) or organized thunderstorm cells (right)

Heavy Rainfall from Tropical Systems

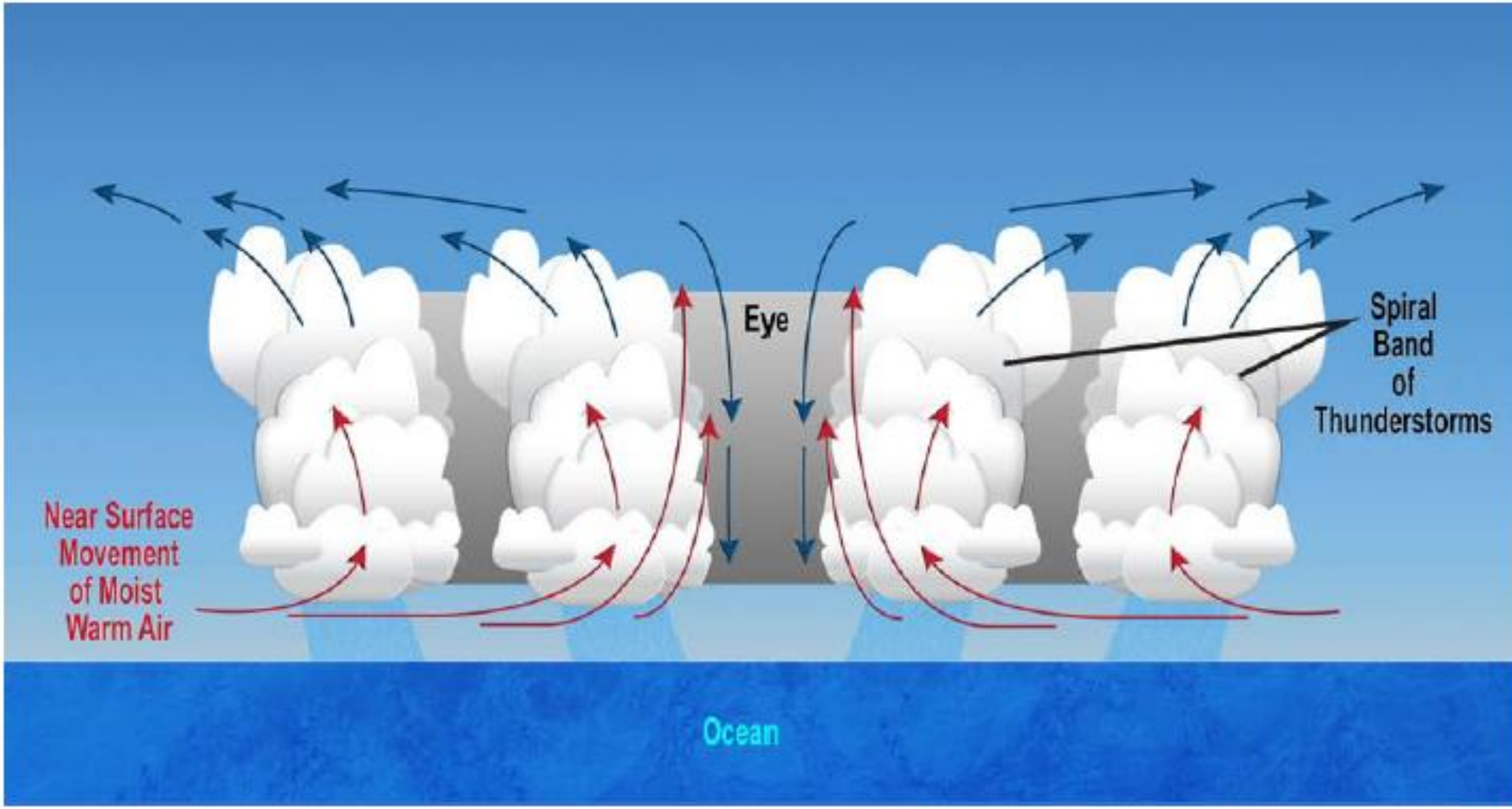


Figure 2.3
Cloud lifting and rain patterns in a hurricane or tropical storm

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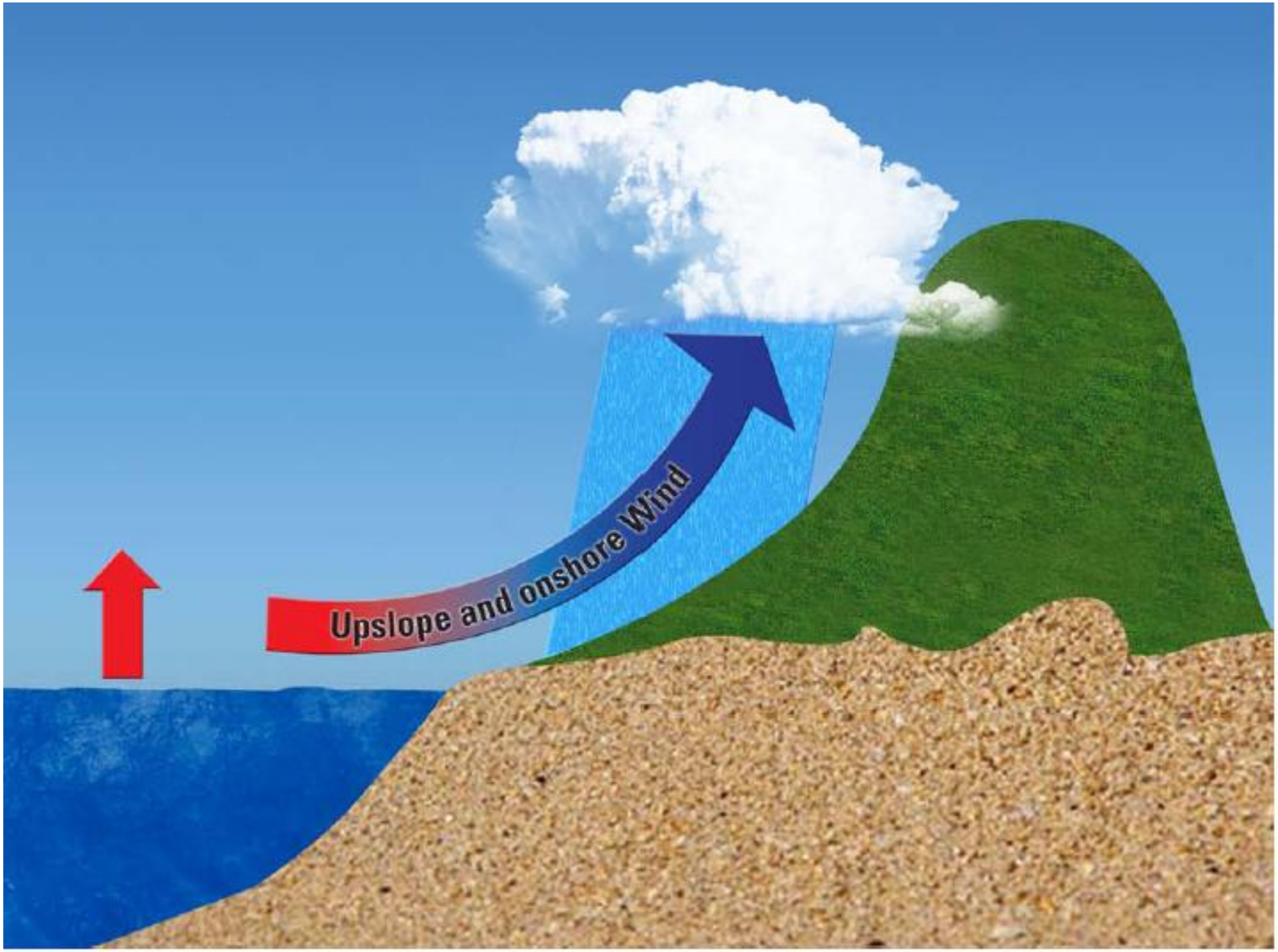
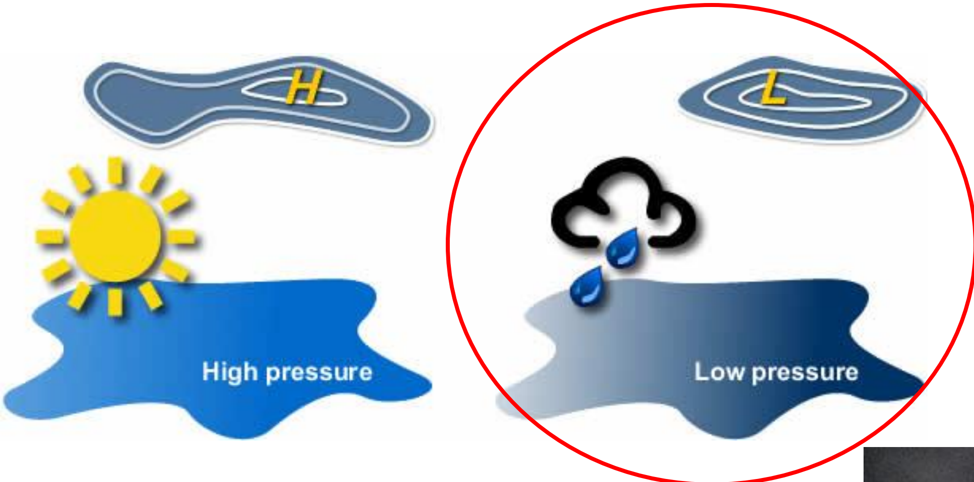
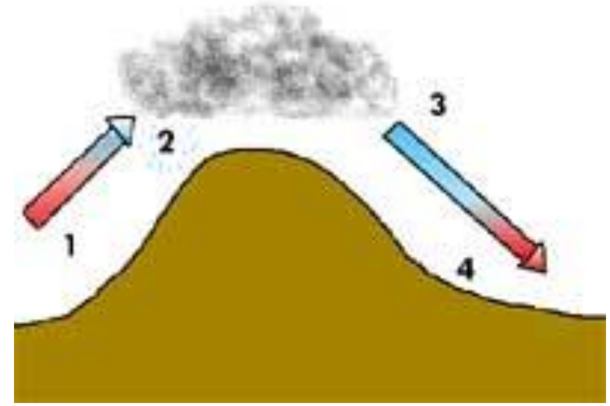
Heavy Rainfall Enhanced by Topographic/Orographic Processes



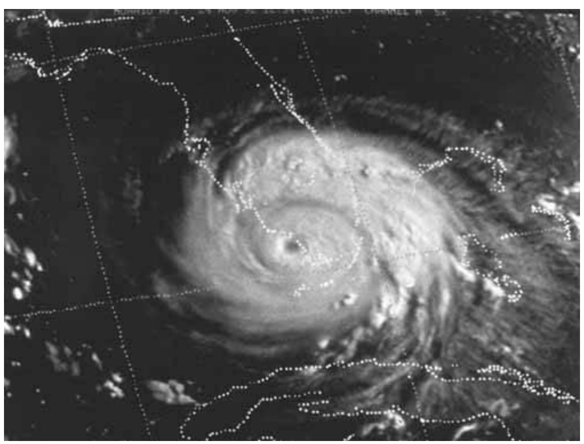
Name the Rain Event… Synoptic, Convective, Tropical Storm, Orographic?



Synoptic



orographic



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??

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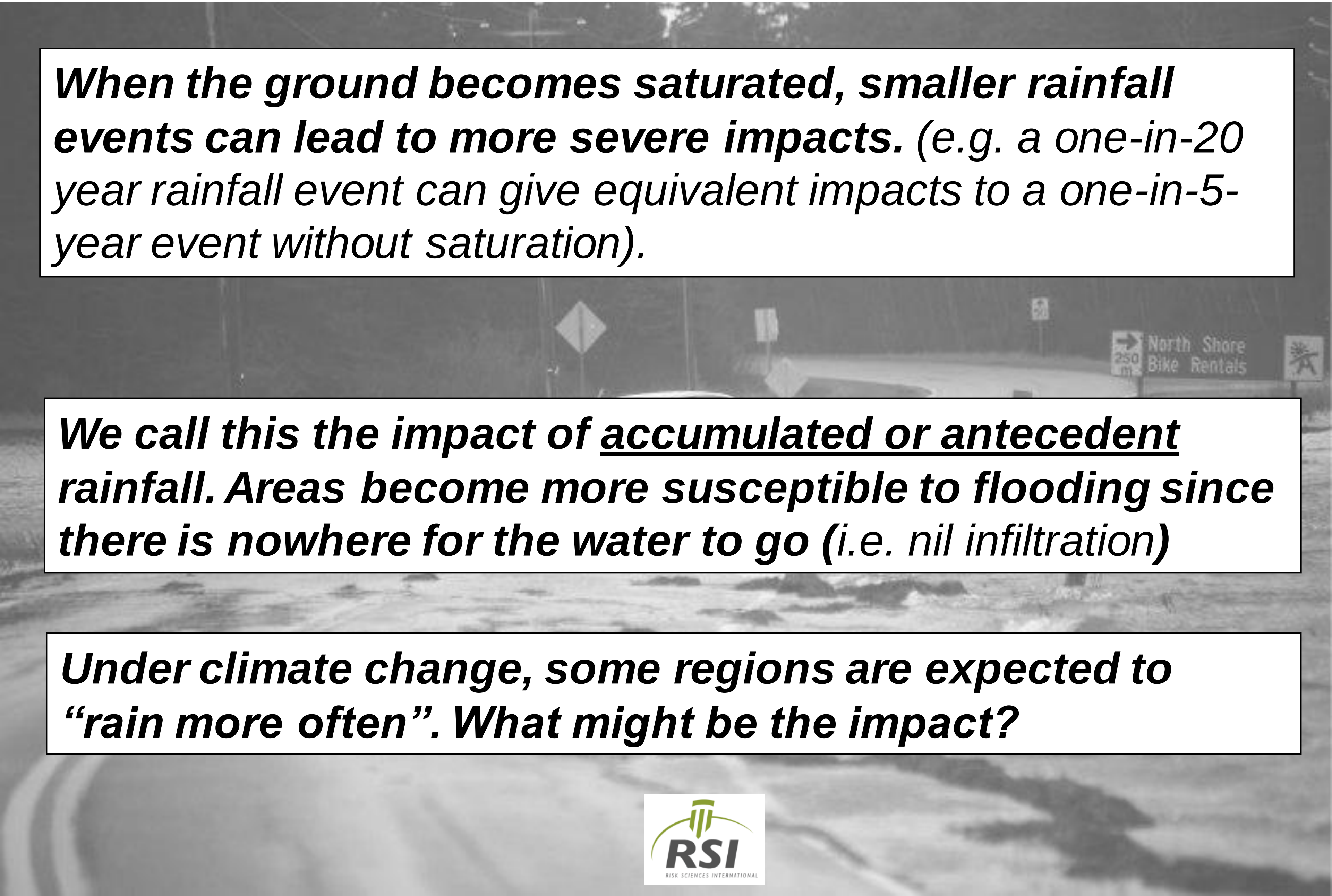
Sensitivity to accumulated rain: Examples

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 <u>accumulated or antecedent</u> 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?



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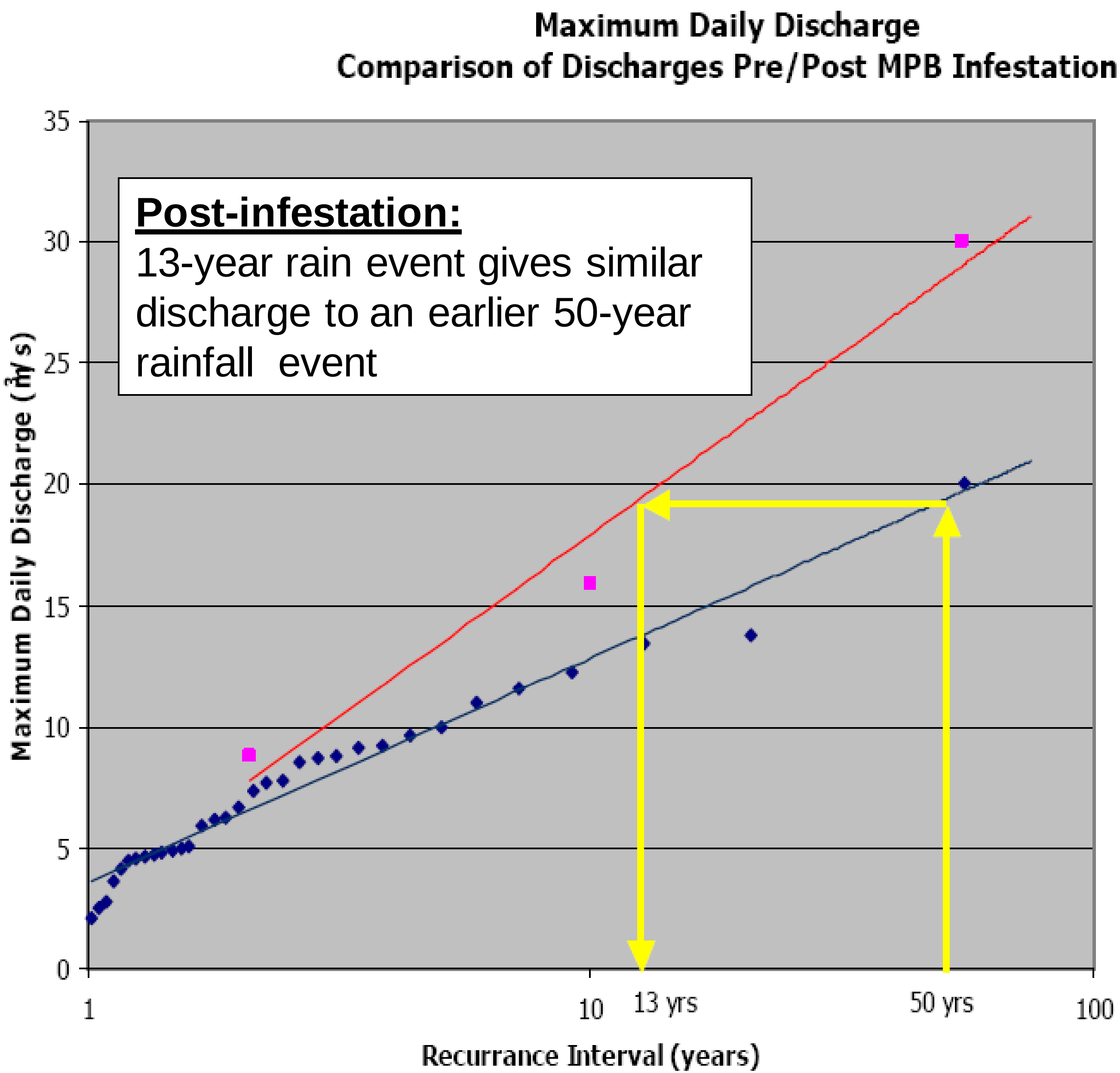
Flood frequencies after the Mountain Pine Beetle Infestation



From Presentation to Thompson Okanagan Interface Committee, April 2007

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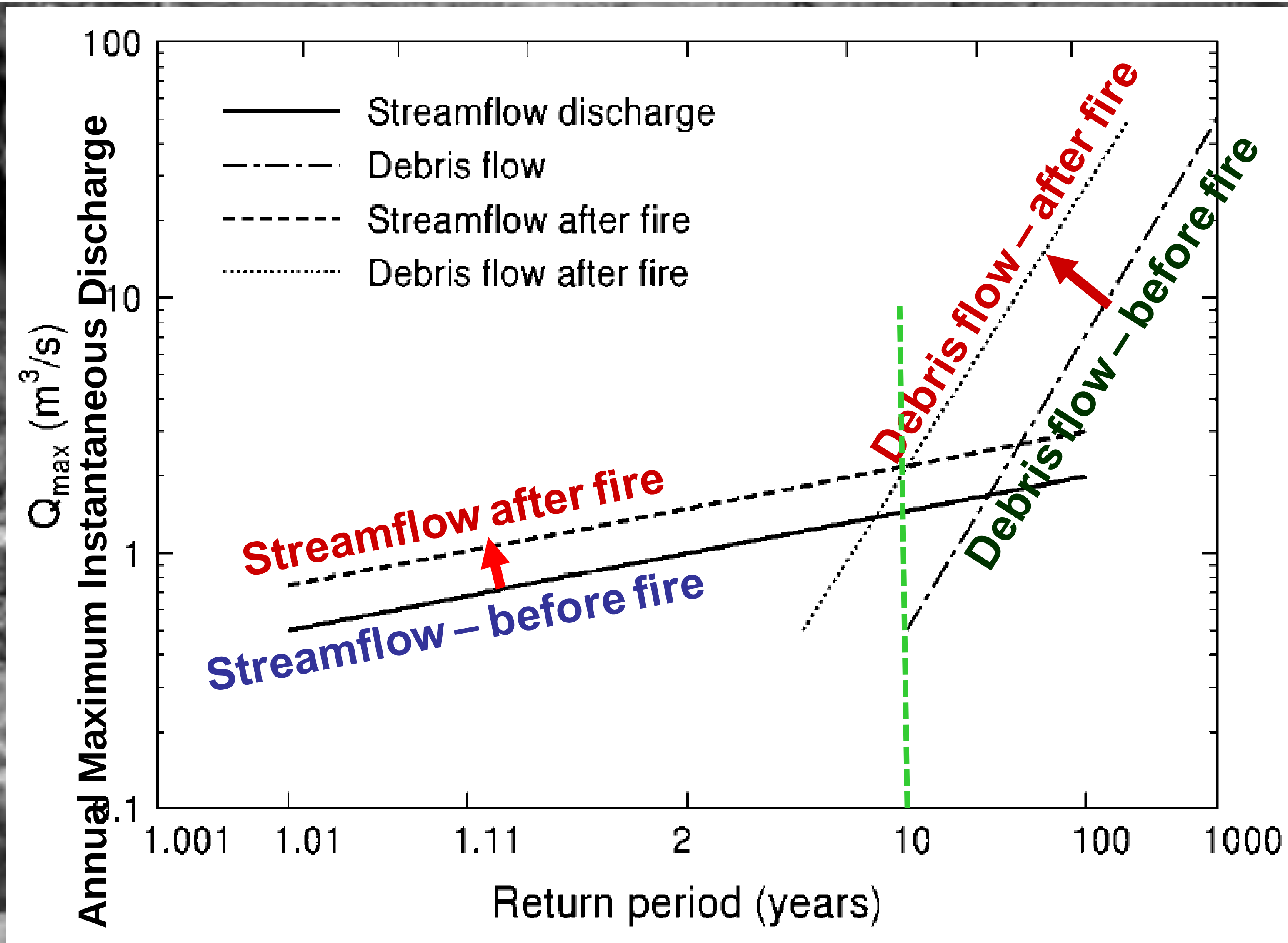
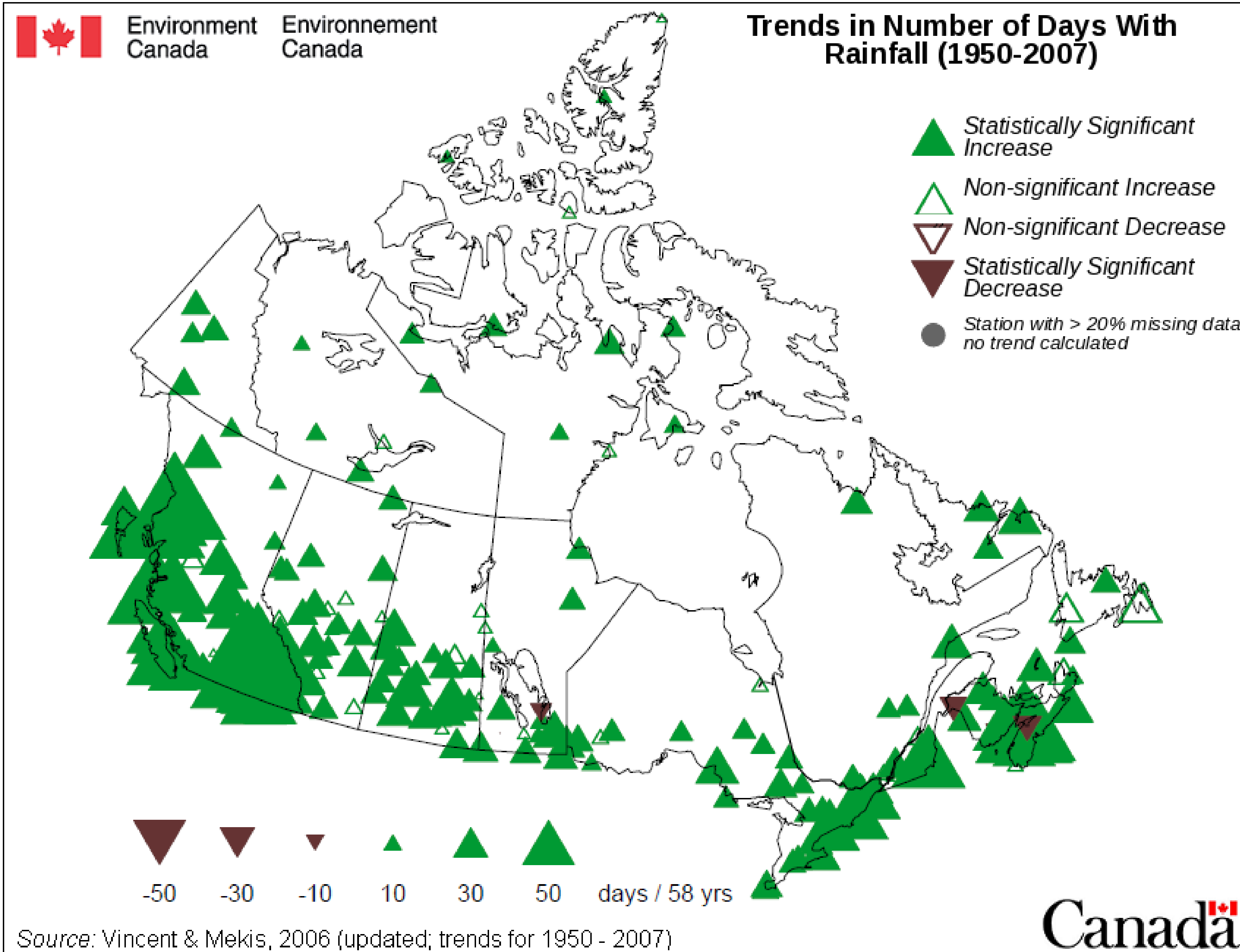
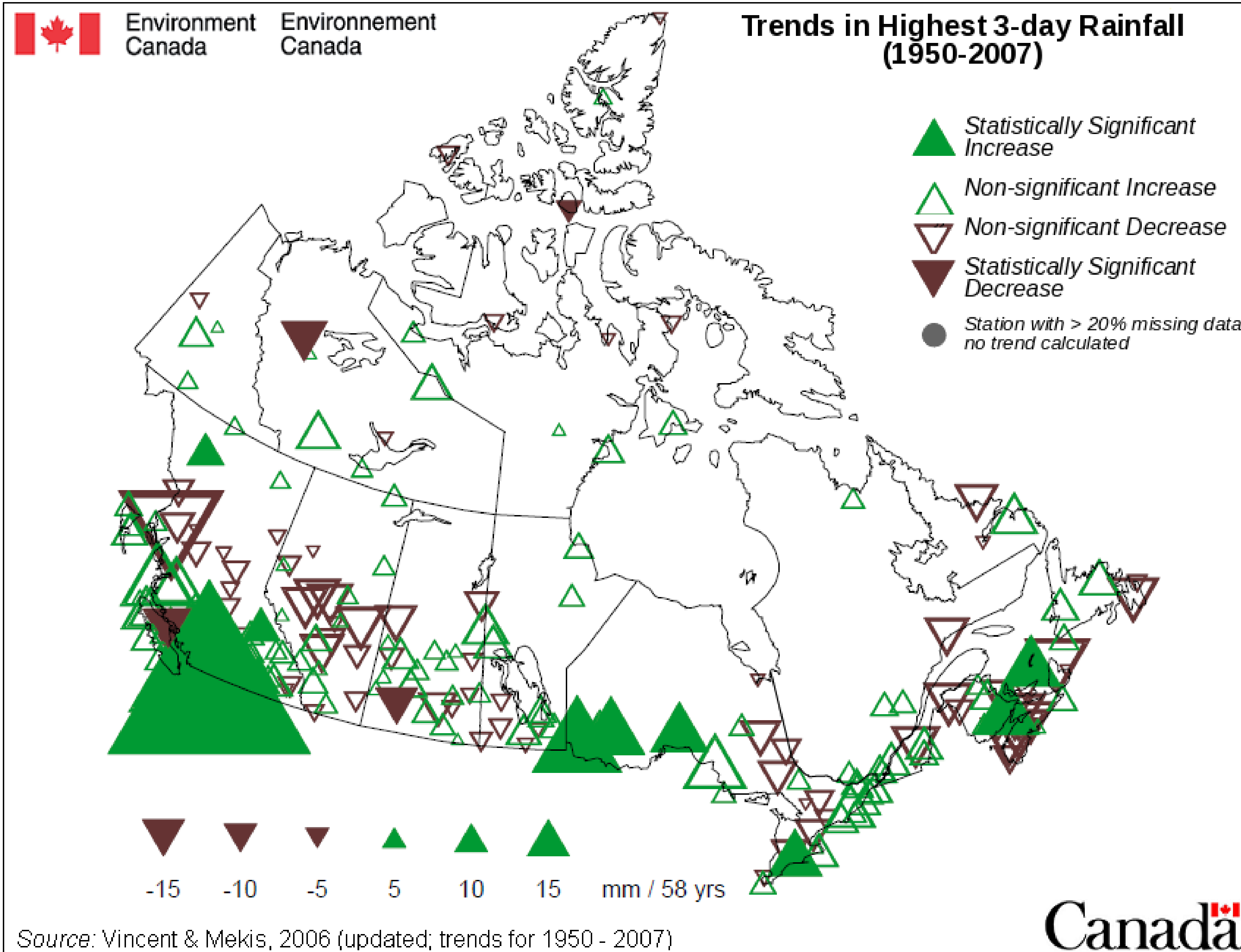
Flood frequencies near creeks increase after forest fires

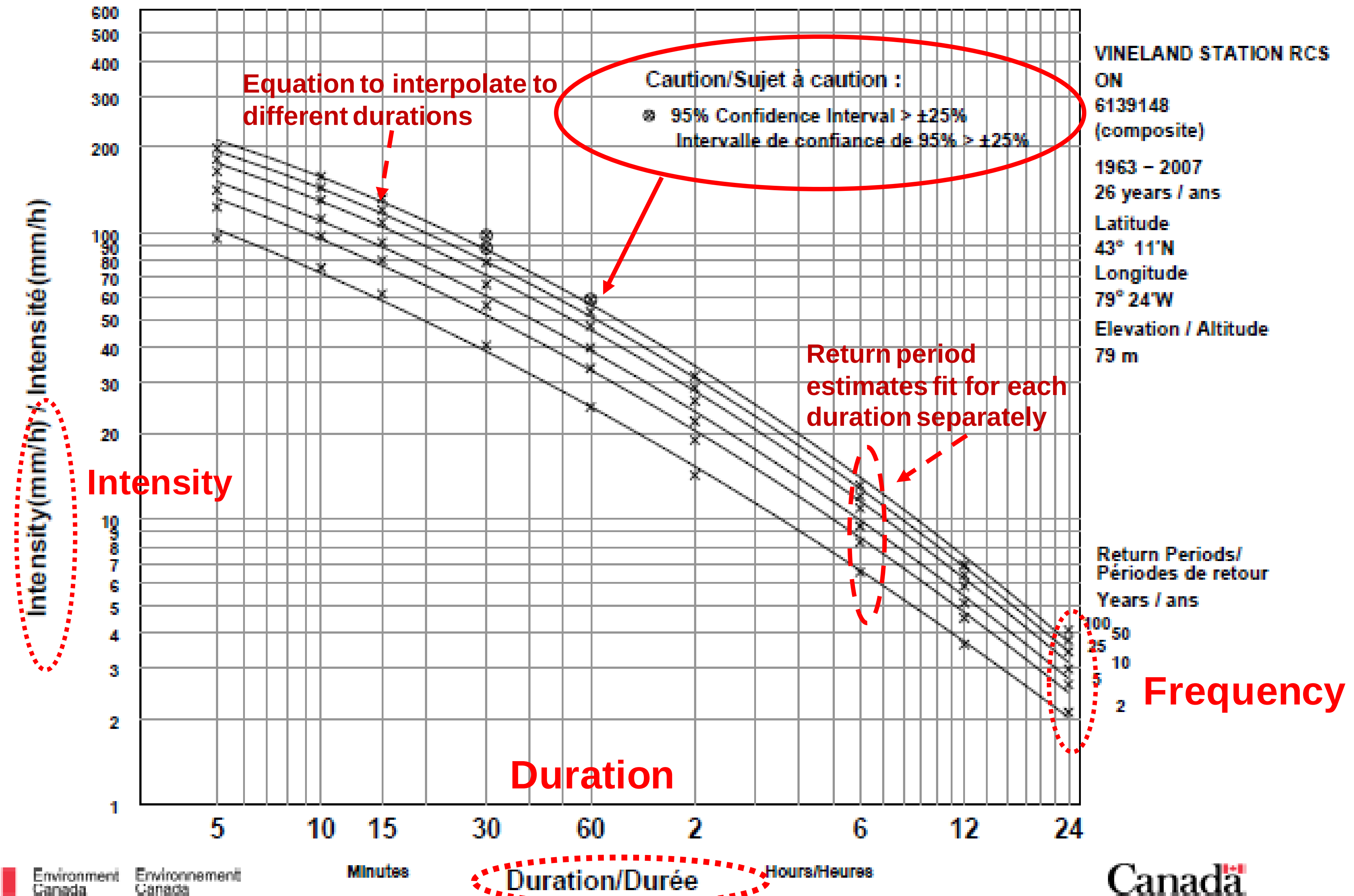
Impacts includes water quality impacts, damage to fish habitat, infrastructure, safety, costs to reinforce existing infrastructure…




Environment Canada
Environnement Canada
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
-50
-30
-10
10
30
50
days / 58 yrs
Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Canada


Environment Canada
Environnement Canada
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
-15
-10
-5
5
10
15
mm / 58 yrs
Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Canada

Introducing an Extreme Rainfall Intensity-Duration-Frequency (IDF) Curve



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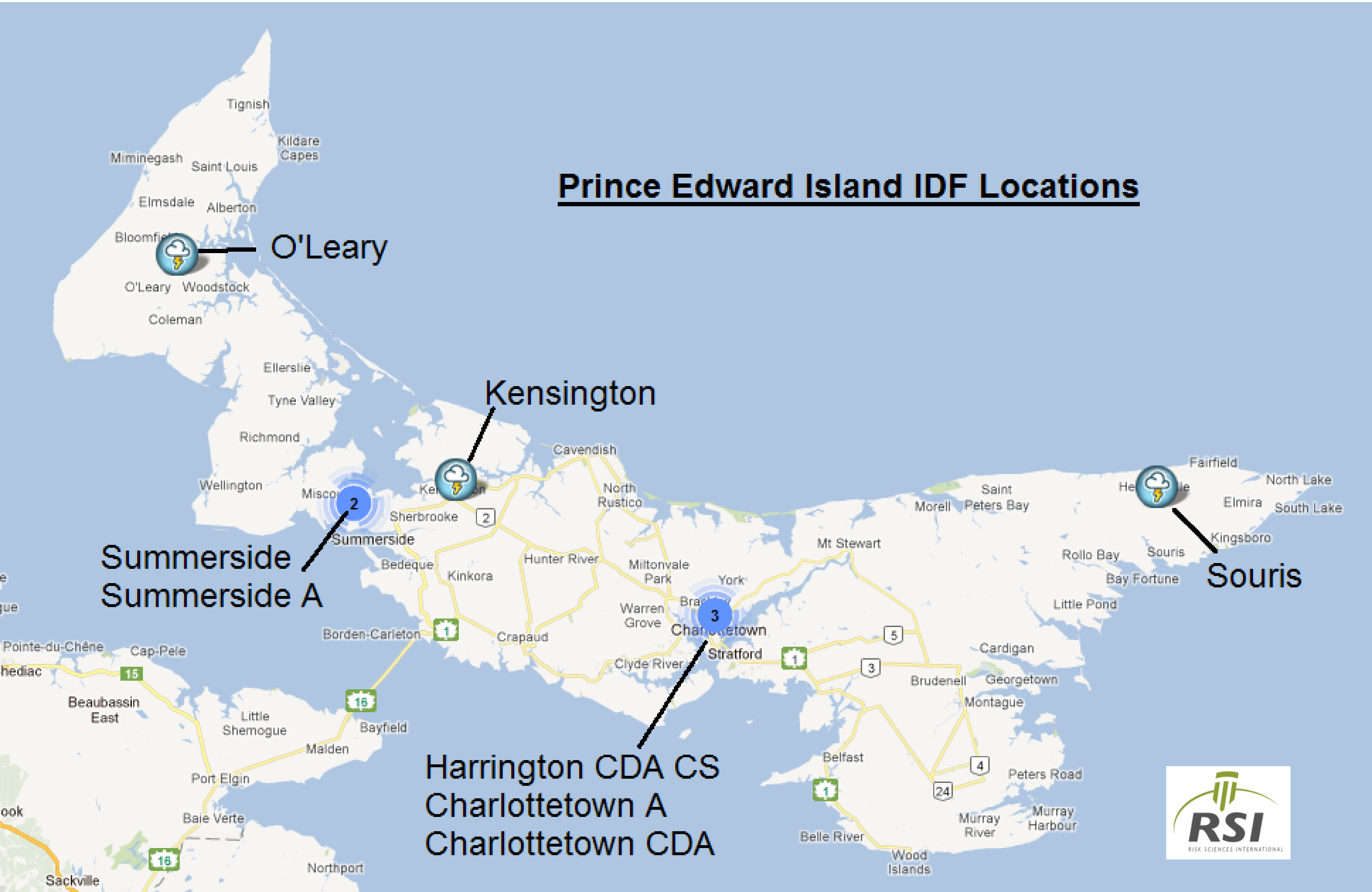
Additions to Prince Edward Island IDF Datasets & Calculations



Deriving IDF curves…

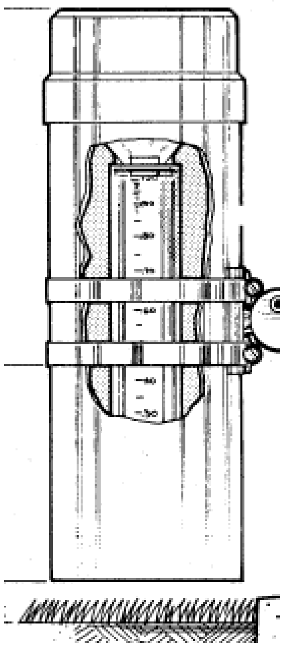
Based on real historical events… not predictions

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

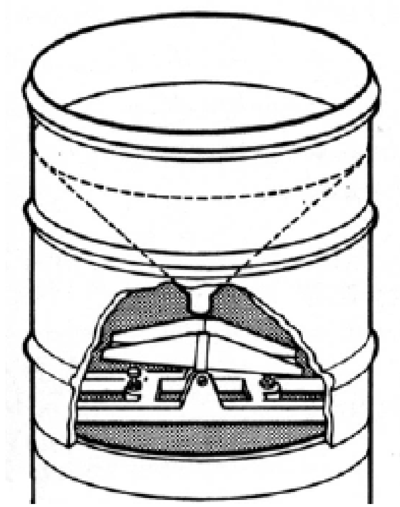
- IDF curves are created by analyzing years of past rainfall records.
- The longer and more complete the record, the better the quality of the statistical analysis.
- Long records of rainfall data are less likely to represent a short-term rainfall anomaly, for example, a decade of high precipitation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

Measuring Rainfall: Daily and Rate of Fall

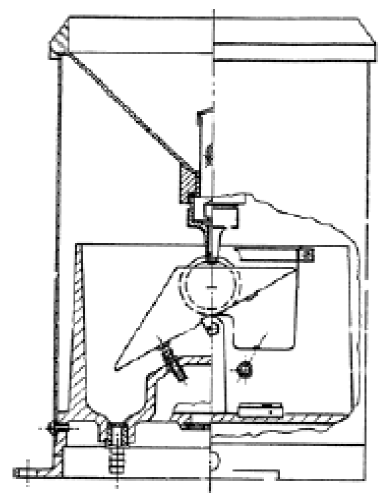
Data often measured using automated Tipping Bucket rain gauge



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)...*

Probability of WHAT?

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

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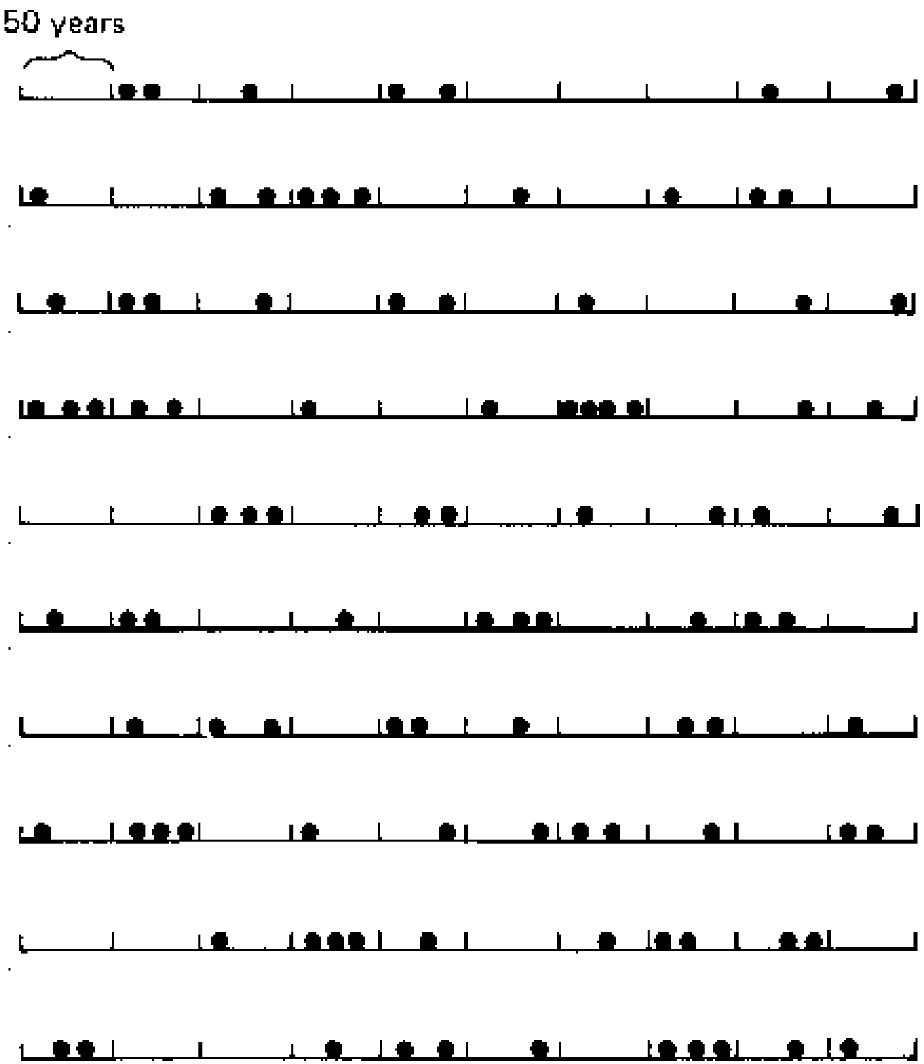
What is a 50 year return period rainstorm amount?



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

Figure 6.10 Idealized sample of occurrences of a 50-year return period event over 5000 years

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

Probability of a T-year return period event occurring in a period of N years - not guaranteed

T = Return Period	N = Number of years			(* denotes > 0.9995)					Period of Time (N years)						
	2	5	10	15	20	25	30	50	75	100	150	200	300	400	500
2	0.750	0.969	0.999	*	*	*	*	*							
5	0.360	0.672	0.893	0.965	0.988	0.996	0.999	*							
10	0.190	0.410	0.651	0.794	0.878	0.928	0.958	0.995							
15	0.129	0.292	0.498	0.645	0.748	0.822	0.874	0.968							
20	0.098	0.226	0.401	0.537	0.642	0.723	0.785	0.923							
25	0.078	0.185	0.335	0.458	0.558	0.640	0.706	0.870	0.953	0.983	0.998	*	*	*	*
30	0.066	0.156	0.288	0.399	0.492	0.572	0.638	0.816	0.921	0.966	0.994	0.999	*	*	*
50	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	*	*
75	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
100	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
150	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
200	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
300	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
400	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
500	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

50-year event has: ~64% chance occurring in 50 years, ~40% chance in 25 years, ~87% chance in 100 years.

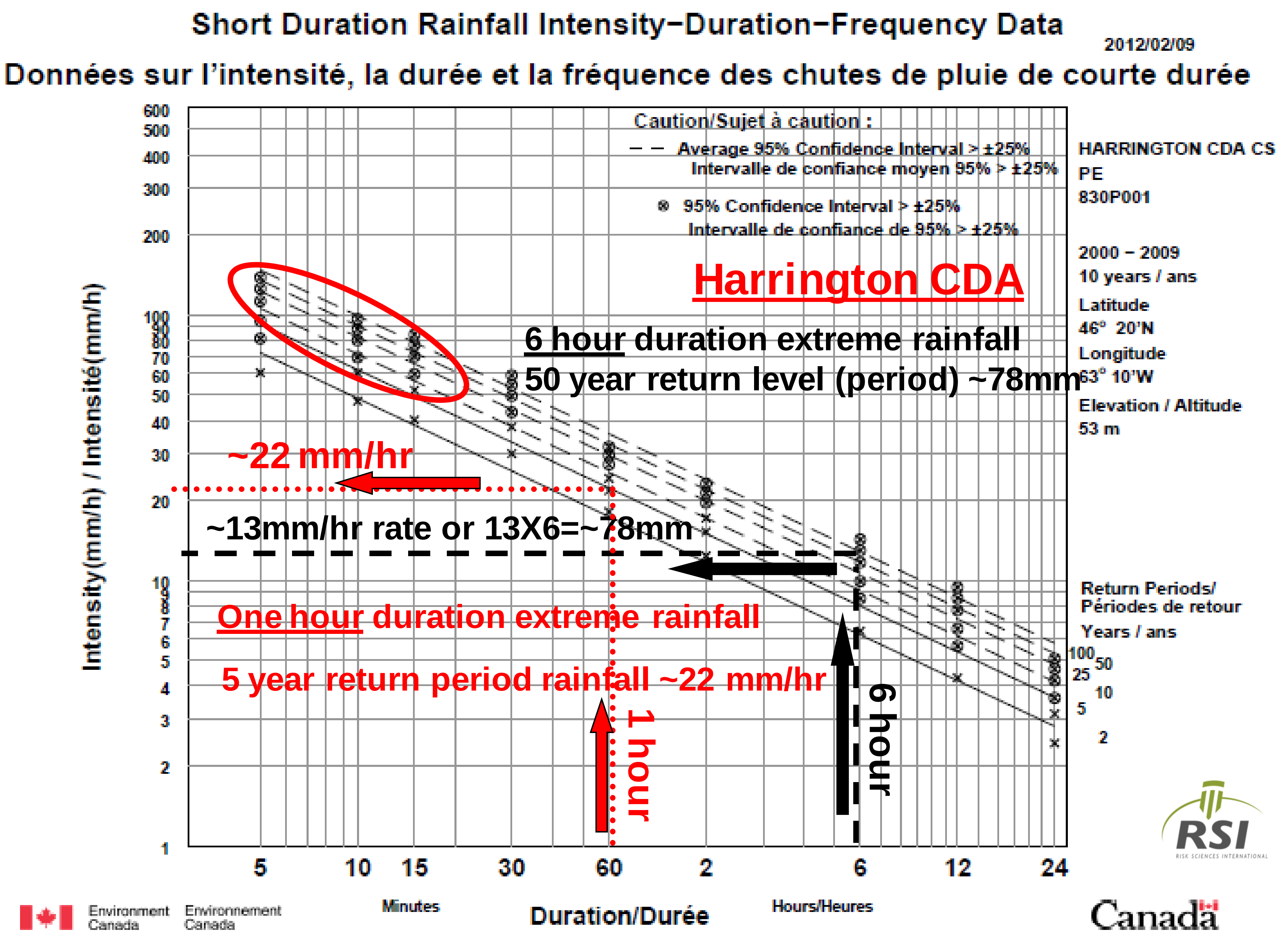
Environment Canada IDF Station Locator / Localisateur de station IDF d'Environnement Canada

To locate IDF stations zoom map or search on location of interest. / Pour trouver les stations IDF, agrandissez 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.

Print Map / Imprimer la carte

Climate.weatheroffice.gc.ca

Location / Localisation: Search / Recherche



Short Duration Rainfall Intensity−Duration−Frequency Data
2012/02/09
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée
Caution/Sujet à caution :
Average 95% Confidence Interval > ±25%
Intervalle de confiance moyen 95% > ±25%
95% Confidence Interval > ±25%
Intervalle de confiance de 95% > ±25%
HARRINGTON CDA CS
PE
830P001
2000 − 2009
10 years / ans
Latitude
46° 20'N
Longitude
63° 10'W
Elevation / Altitude
53 m
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
1 hour
6 hour
Return Periods/
Périodes de retour
Years / ans
100
50
25
10
5
2
Intensity(mm/h) / Intensité(mm/h)
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
5
10
15
30
60
2
6
12
24
Minutes
Duration/Durée
Hours/Heures
Environment Canada
Environnement Canada
Canada

Harrington CDA: 2000-2009

NOTE: Short period of record. Caution required.

****

Table 2a : Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années	
5 min	5.0	6.8	7.9	9.4	10.4	11.5	10	
10 min	7.9	10.1	11.5	13.3	14.7	16.1	10	
15 min	10.0	13.0	14.9	17.4	19.2	21.1	10	
30 min	15.0	18.9	21.5	24.7	27.1	29.5	10	
1 h	18.1	**21.8**	24.2	27.3	29.6	31.8	10	**22**
2 h	24.7	30.5	34.3	39.1	42.7	46.3	10	
6 h	38.6	51.2	59.5	70.0	**77.8**	85.5	10	**78**
12 h	51.5	67.9	78.8	92.5	102.7	112.8	10	
24 h	58.5	75.3	86.5	100.6	111.1	121.5	10	

****

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%
****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	60.5	81.2	95.0	112.4	125.3	138.1	10
	+/- 13.4	+/- 22.5	+/- 30.4	+/- 41.0	+/- 49.1	+/- 57.2	10
10 min	47.2	60.4	69.1	80.1	88.2	96.3	10
	+/- 8.5	+/- 14.2	+/- 19.2	+/- 25.9	+/- 31.1	+/- 36.2	10
15 min	40.1	51.9	59.8	69.6	77.0	84.2	10
	+/- 7.6	+/- 12.8	+/- 17.3	+/- 23.3	+/- 27.9	+/- 32.5	10
30 min	30.0	37.8	42.9	49.4	54.3	59.1	10
	+/- 5.0	+/- 8.4	+/- 11.4	+/- 15.4	+/- 18.4	+/- 21.4	10
1 h	18.1	21.8	24.2	27.3	29.6	31.8	10
	+/- 2.4	+/- 4.0	+/- 5.4	+/- 7.3	+/- 8.7	+/- 10.1	10
2 h	12.3	15.2	17.1	19.6	21.4	23.1	10
	+/- 1.9	+/- 3.1	+/- 4.2	+/- 5.7	+/- 6.8	+/- 8.0	10

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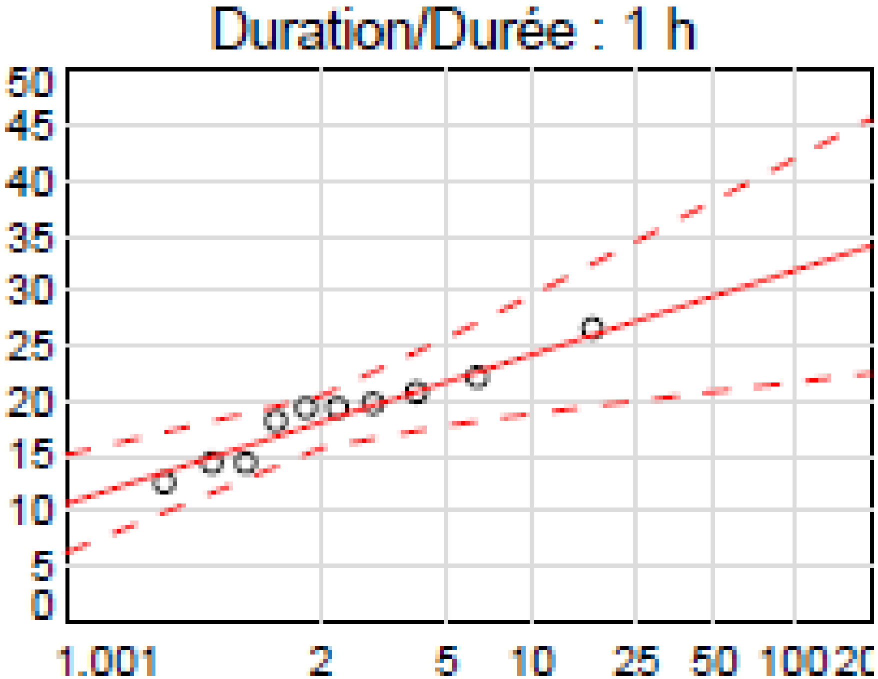
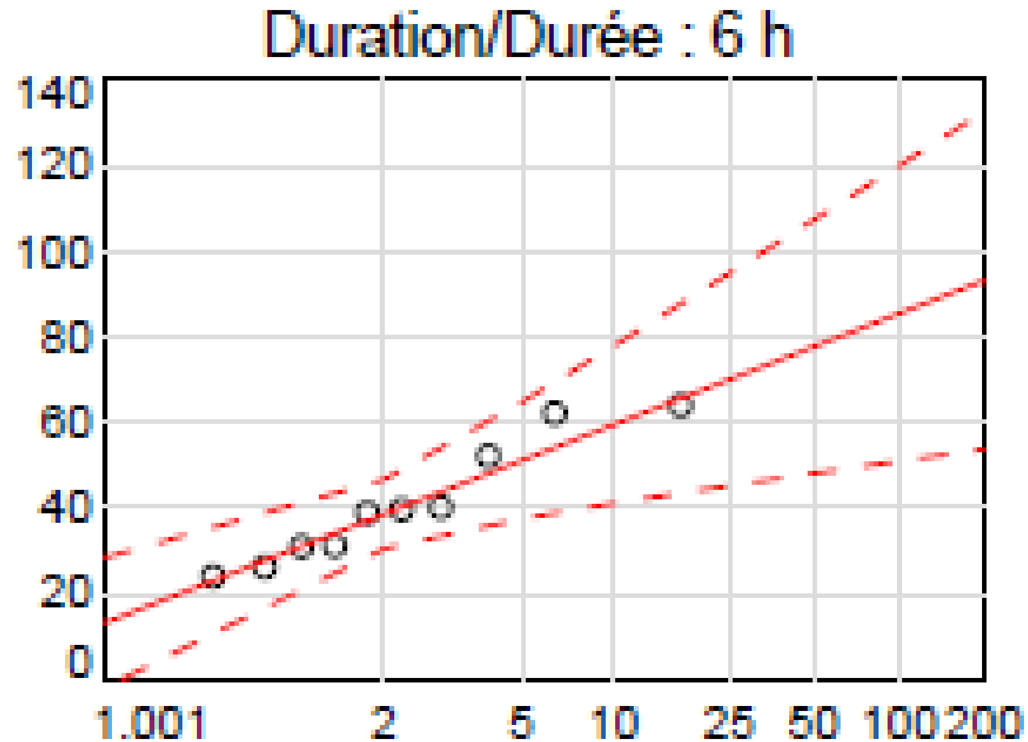
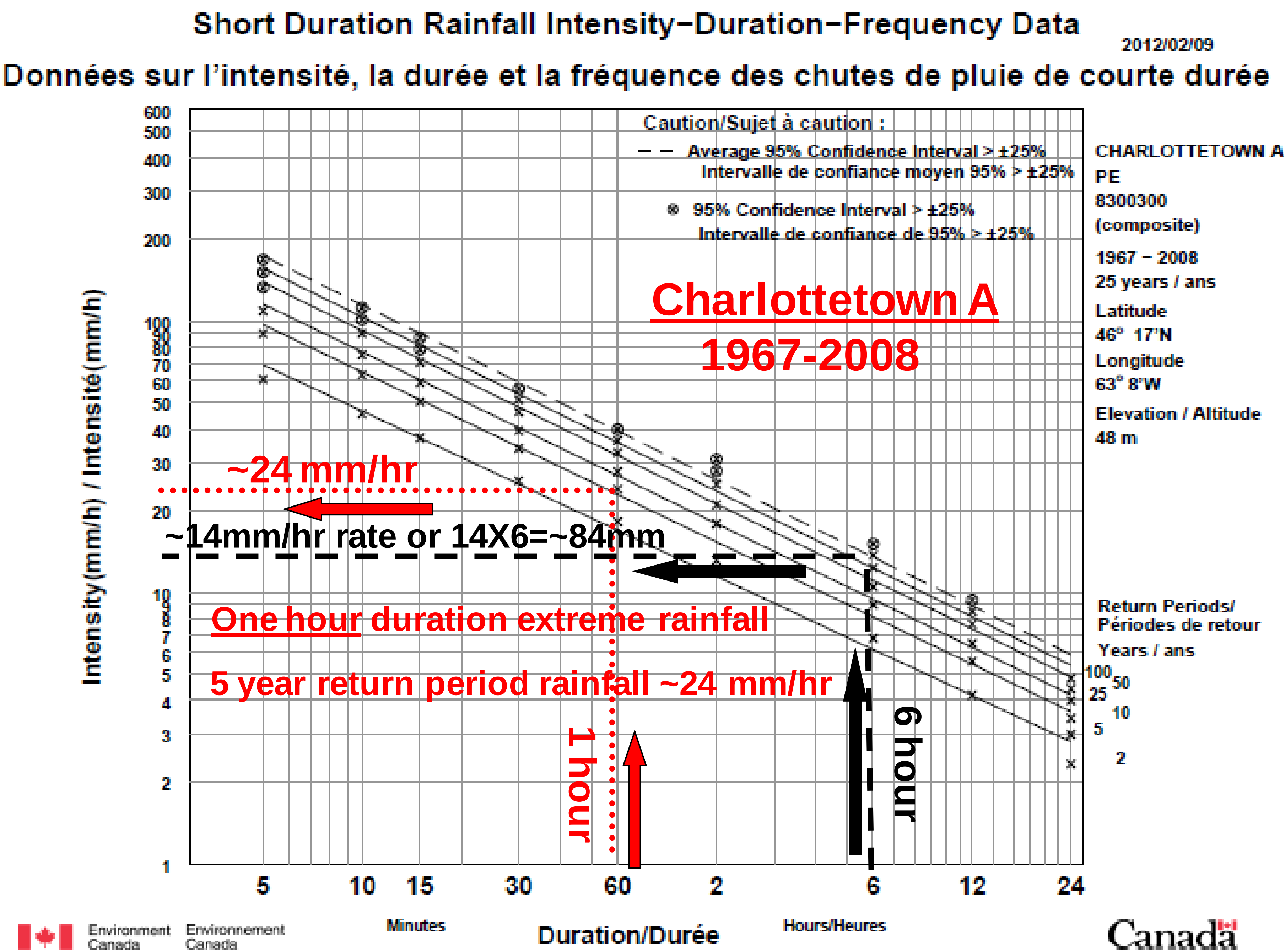
How well did the new dataset fit the Extreme Value Distribution?

Harrington CDA







IDF values higher than for Harrington CDA

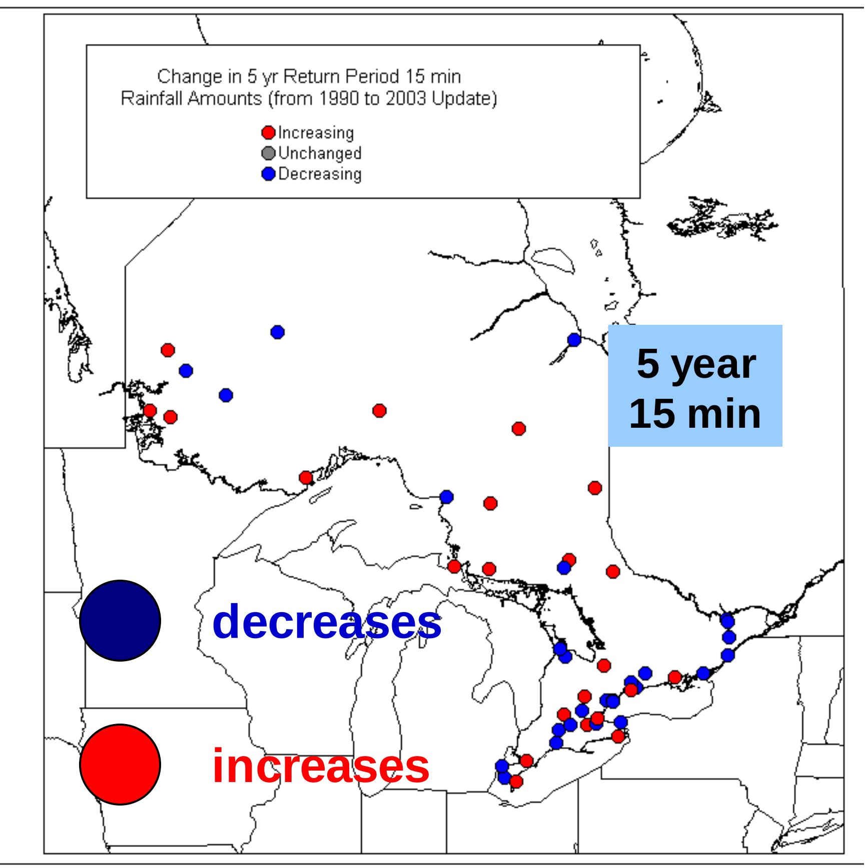
Point IDF Calculations: Limits

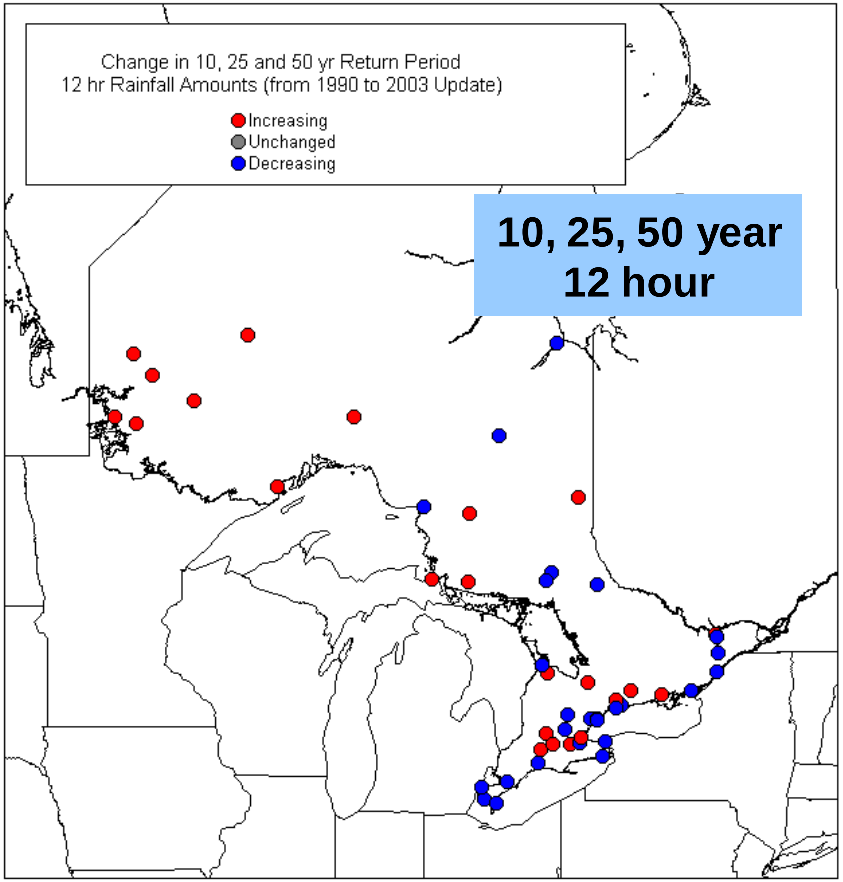
The current approach to developing a suite of IDF Curves includes:

- 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

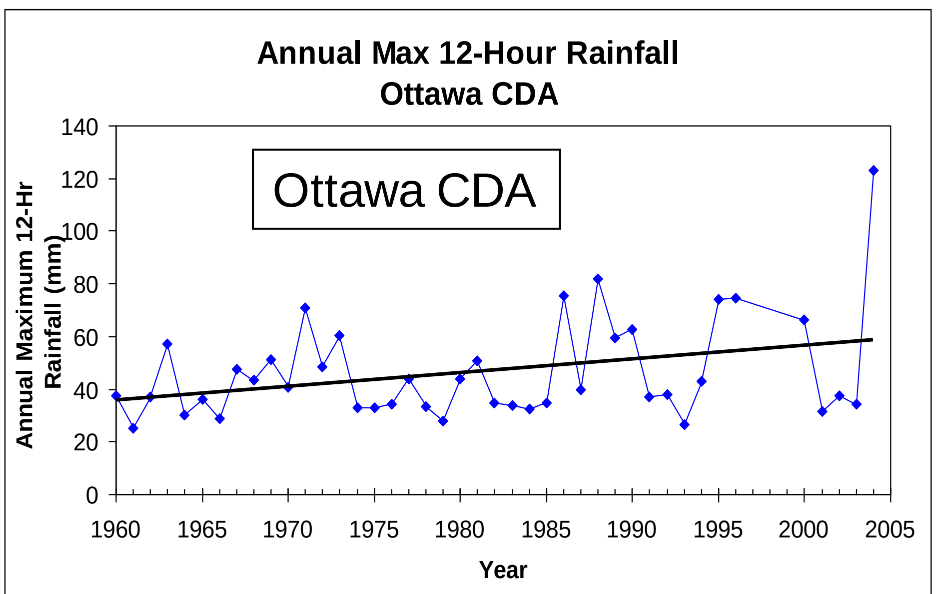
- **Return Period Rainfalls DECREASE in many cases**
- **High profile extreme rainfall events in recent years lead to expectations that return period rainfalls will all show INCREASES**

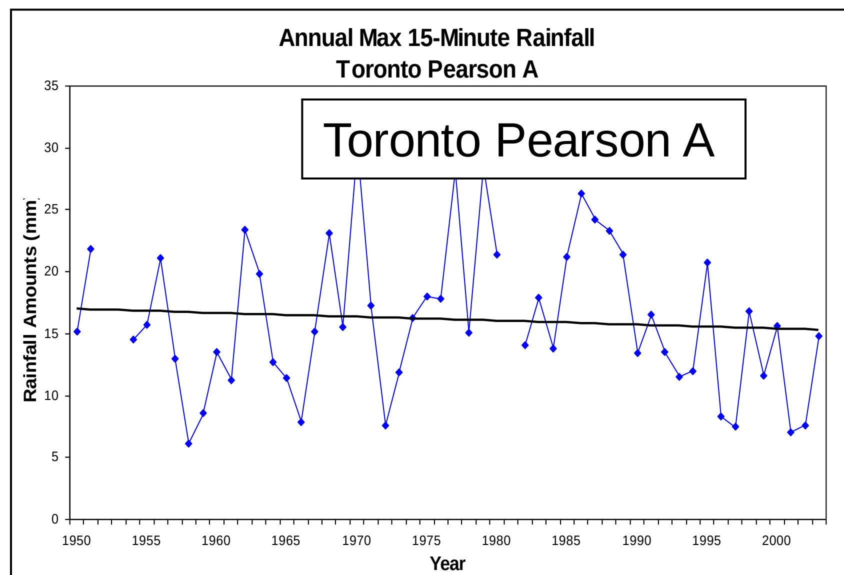




Downward Trends in Short Duration Rainfall Amounts
And the Message Is?

- **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).**

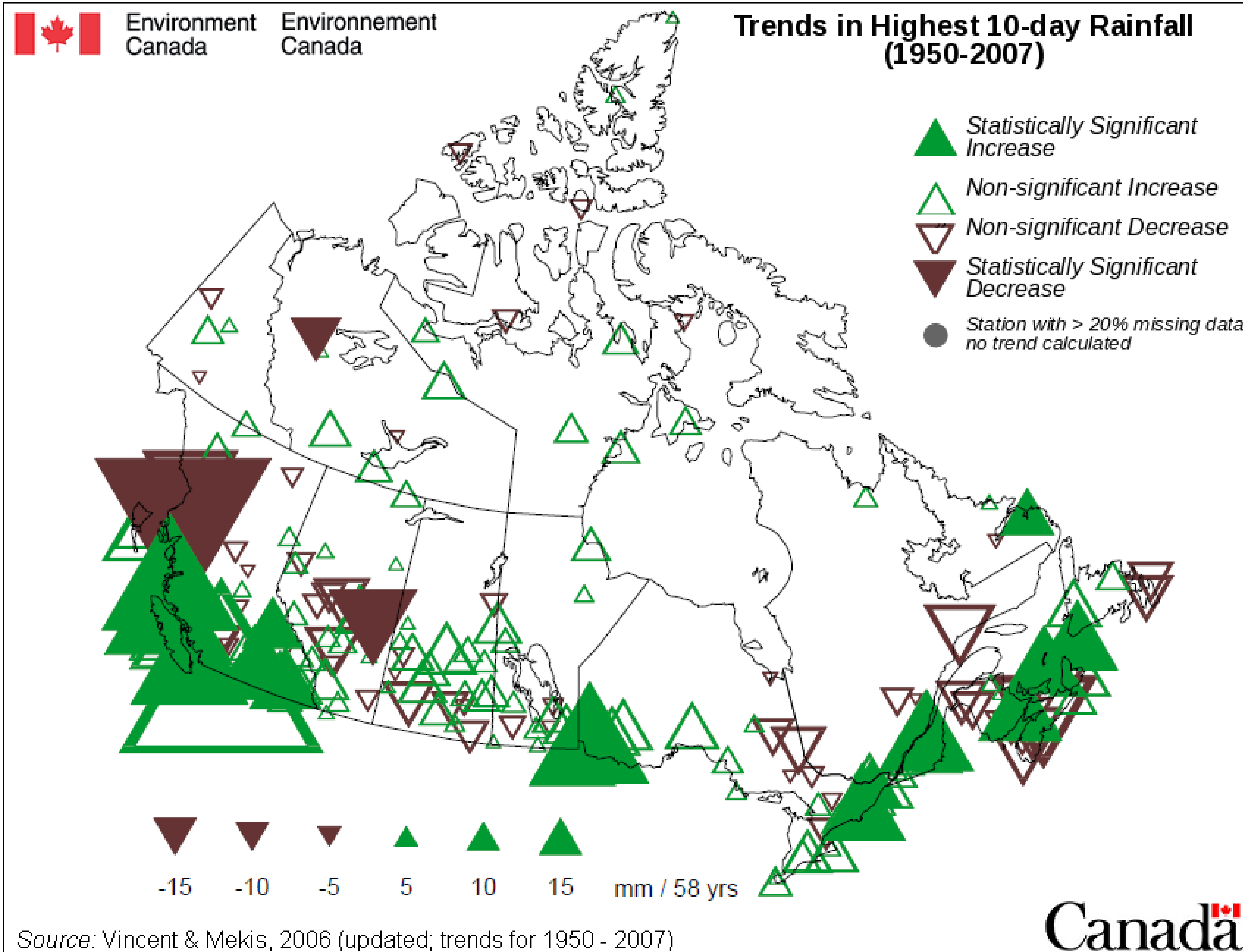


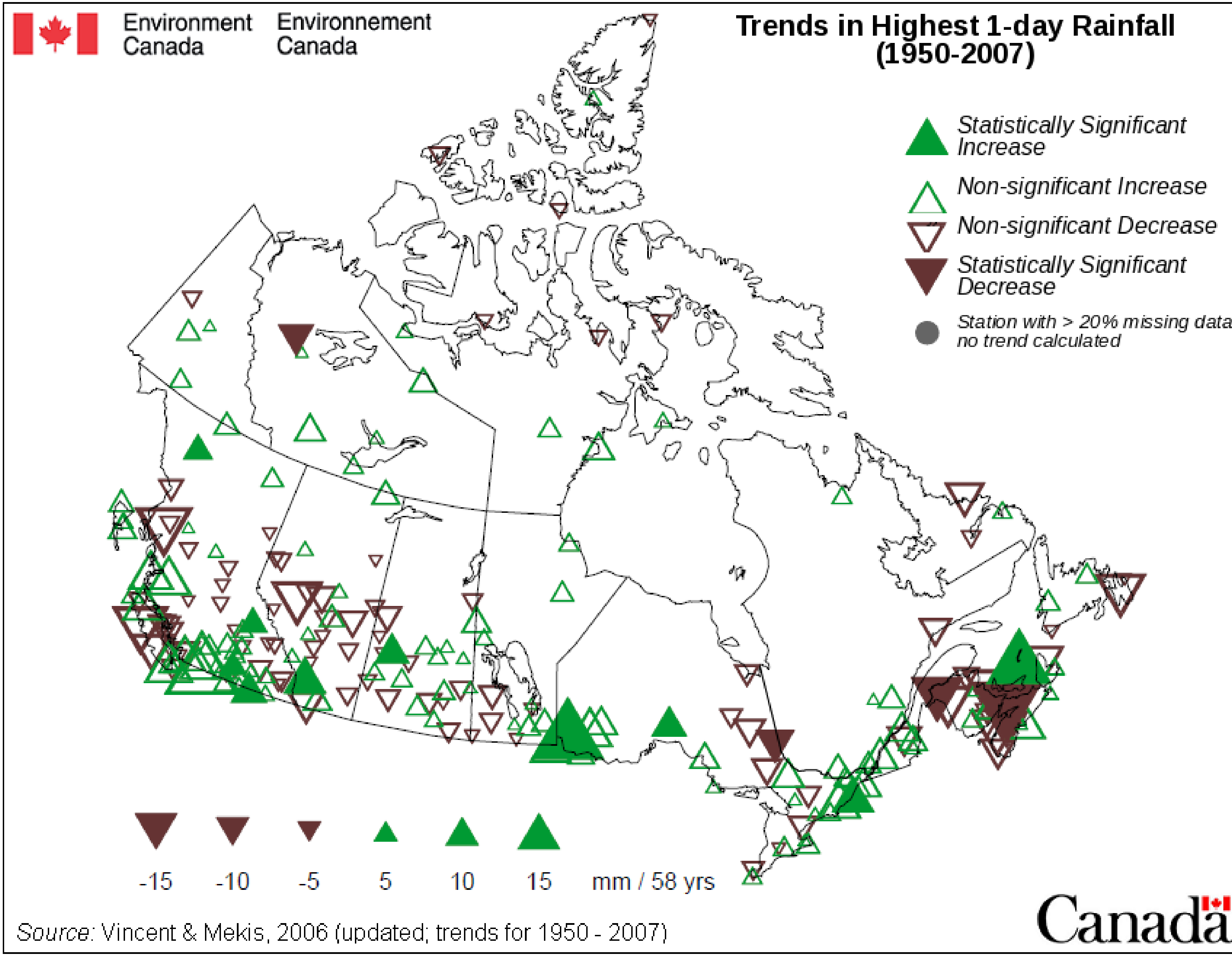


Why does a 50-year return period rainstorm happen every year in my area? Because…

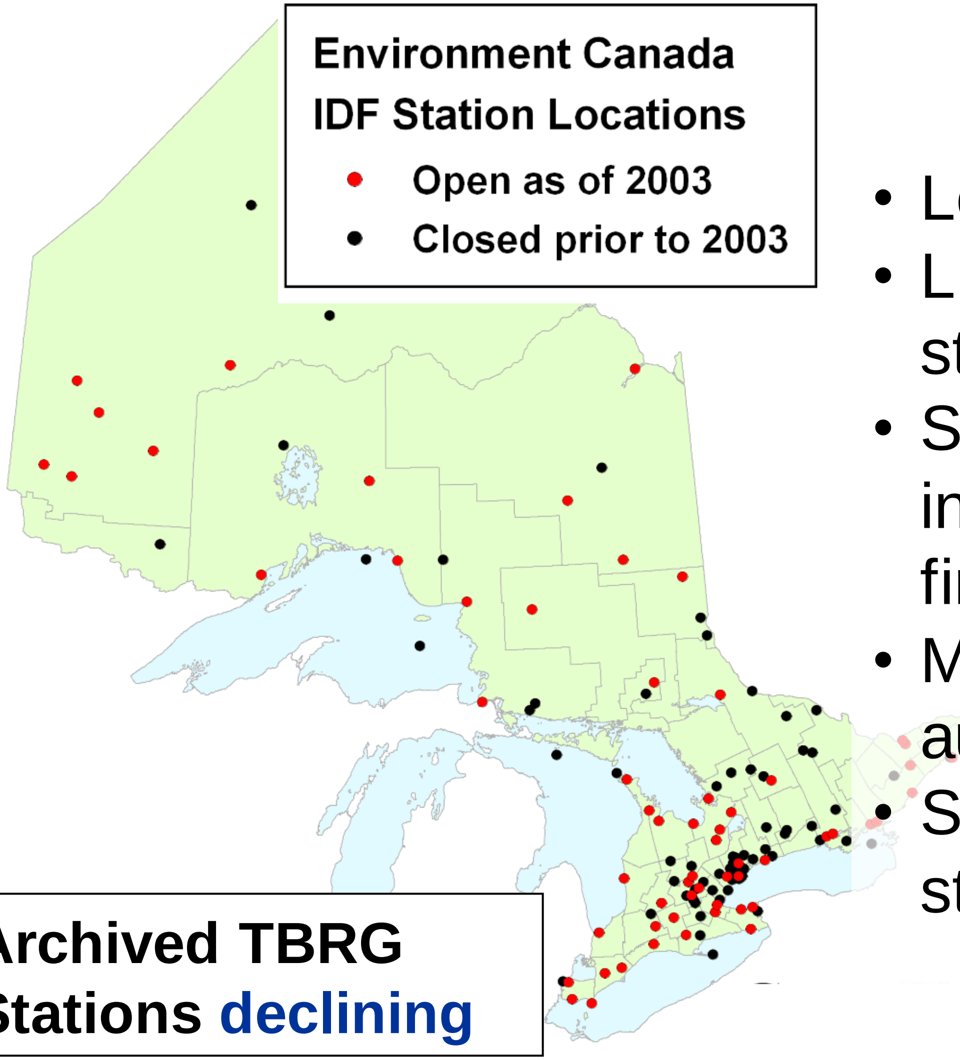
IDF values provide single point estimates of extremes

- 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 <u>region</u> 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.


Environment Canada
Environnement Canada
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
-15
-10
-5
5
10
15
mm / 58 yrs
Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Canada


Environment Canada
Environnement Canada
Trends in Highest 1-day Rainfall (1950-2007)
Statistically Significant Increase
Non-significant Increase
Non-significant Decrease
Statistically Significant Decrease
Station with > 20% missing data, no trend calculated
-15
-10
-5
5
10
15
mm / 58 yrs
Source: Vincent & Mekis, 2006 (updated; trends for 1950 - 2007)
Canada

Existing and Future Data Challenges for Traditional Point Based Rainfall IDF Approaches



Archived TBRG Stations declining

- 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?

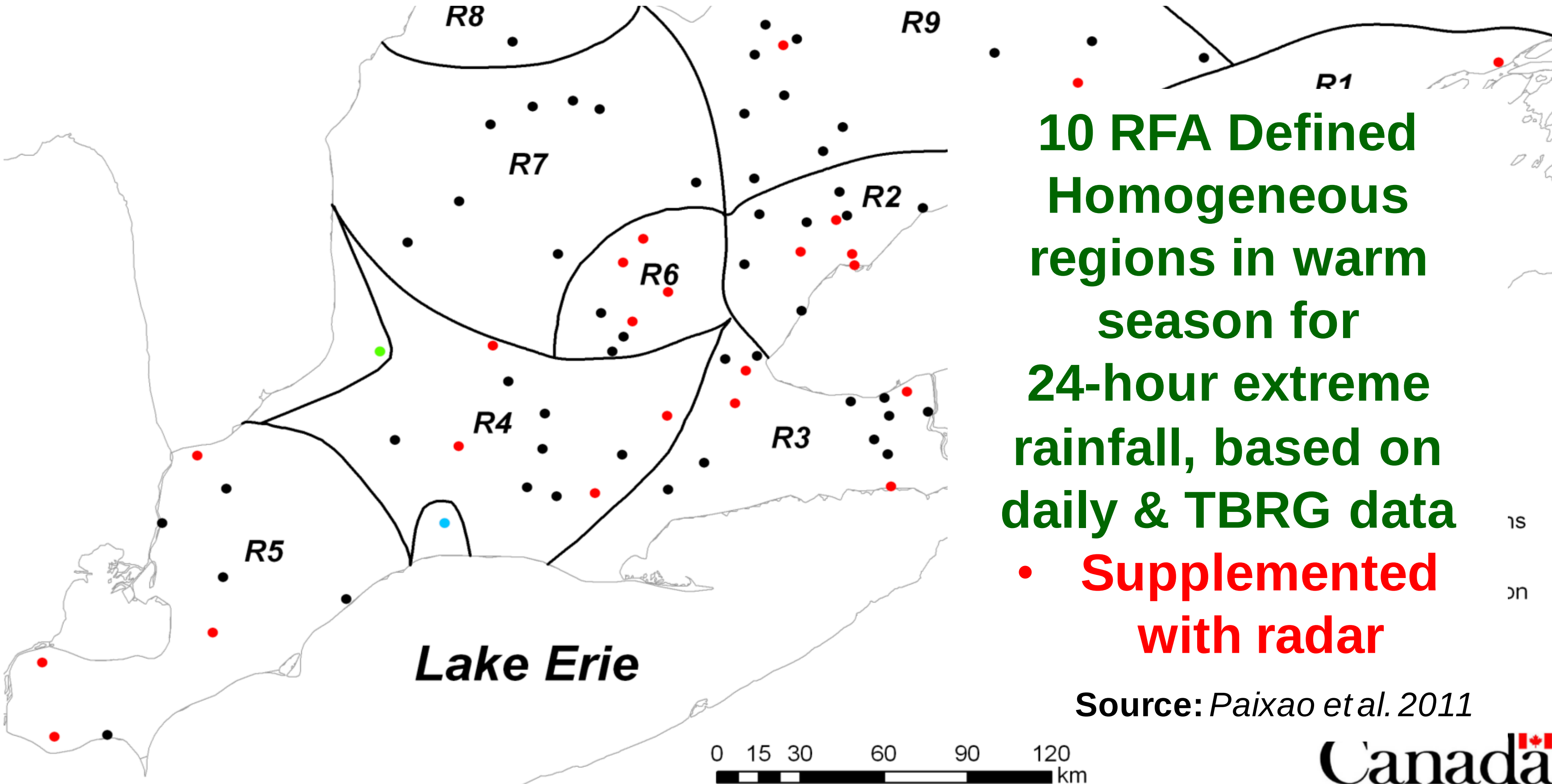
Large Spatial Variability in Station IDF Values – especially for short data records

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*

Canada

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 IDFs – 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

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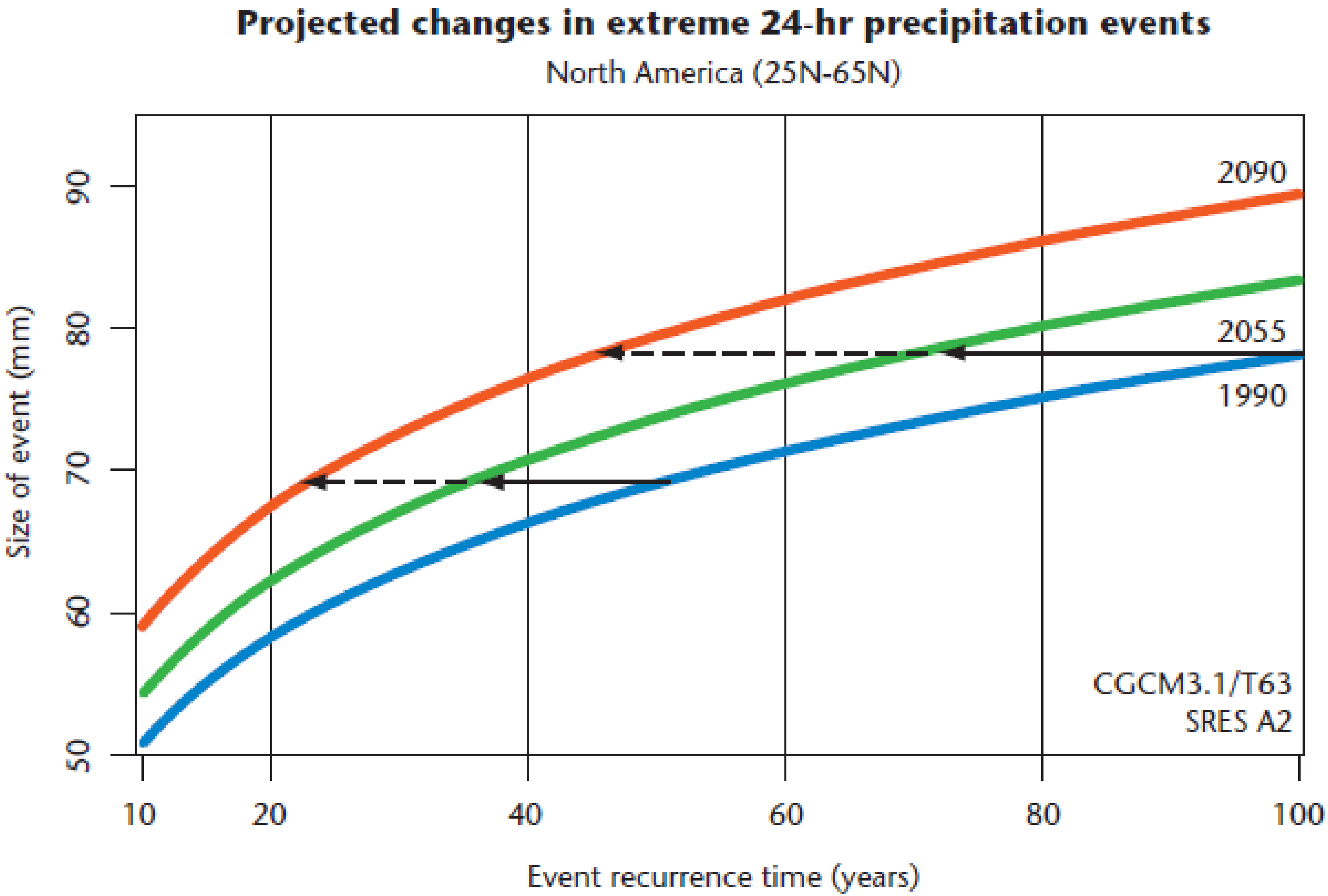
Climate Change Adjusted IDF Curves??

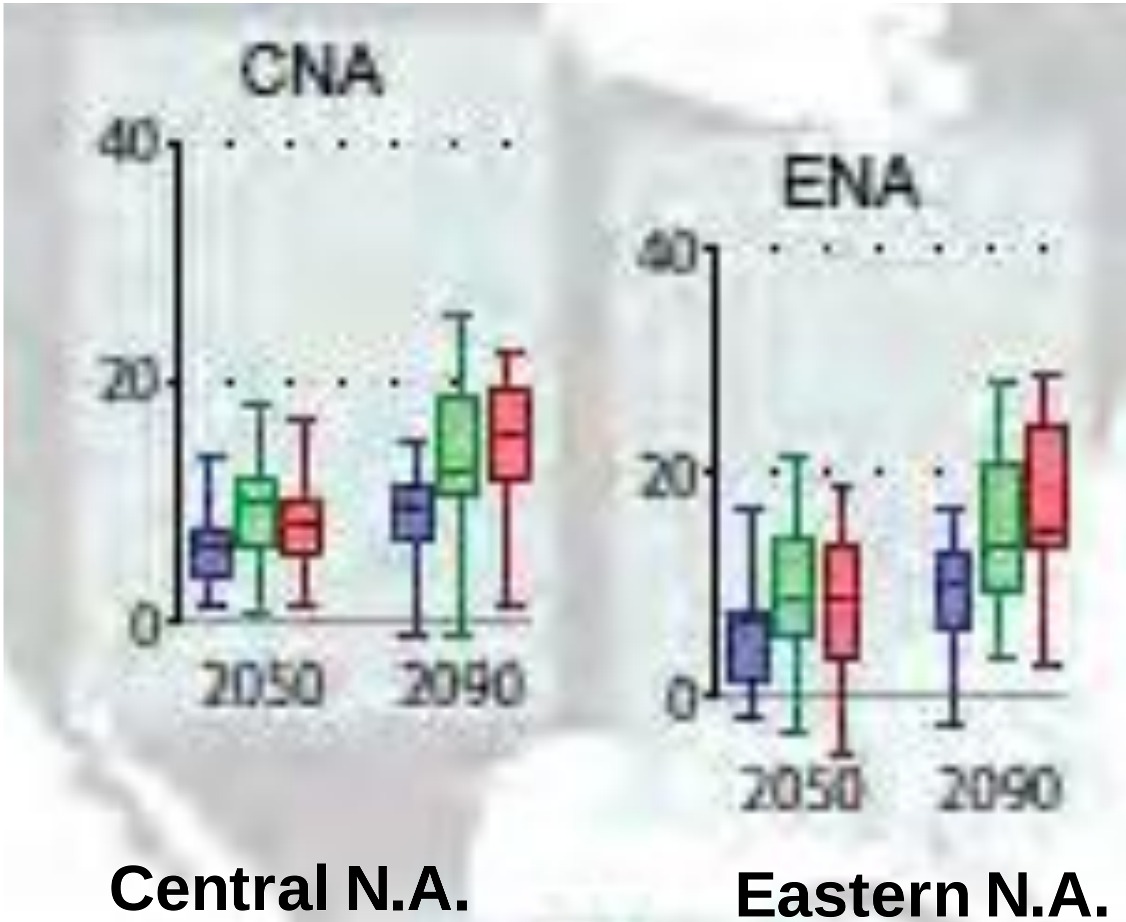
- No accepted methodologies for "climate change" IDFs;
- Climate change models underestimate extreme events;
- Some extreme precipitation events are very small scale and are not seen well by the climate models;
- ENSO (e.g. El Nino) events, Decadal Oscillations, etc are important – but, most models do 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…



(From Karin et al (2007)

Projected changes in extreme 24-hour precipitation amounts and return periods for mid to late 21st century compared to 1990 values (SRES A2)

20-year Return Period (Level) Extreme Precipitation Projections from an Ensemble of Climate Change Models



<u>Preliminary results</u>: 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**).

Extreme Rainfalls and IDF Values for the Future Climate??

- 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

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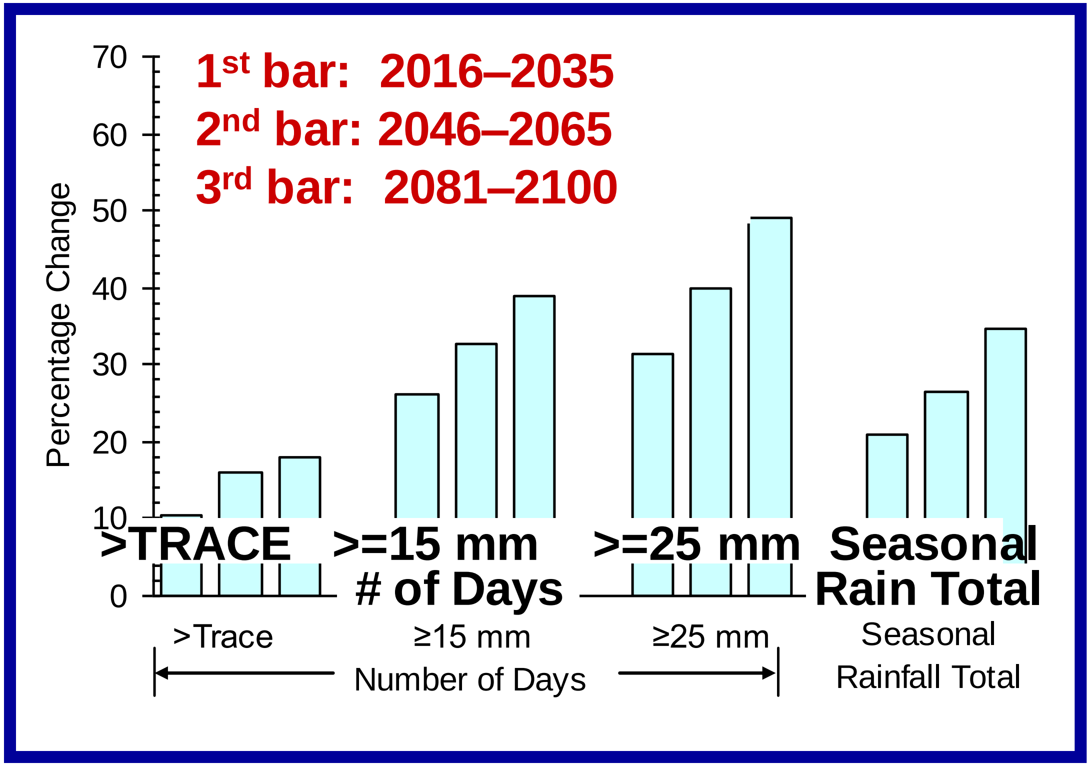
Projected Percentage Changes in Future Rainfall in southern Ontario (3 river basins – urban, rural & mixed)

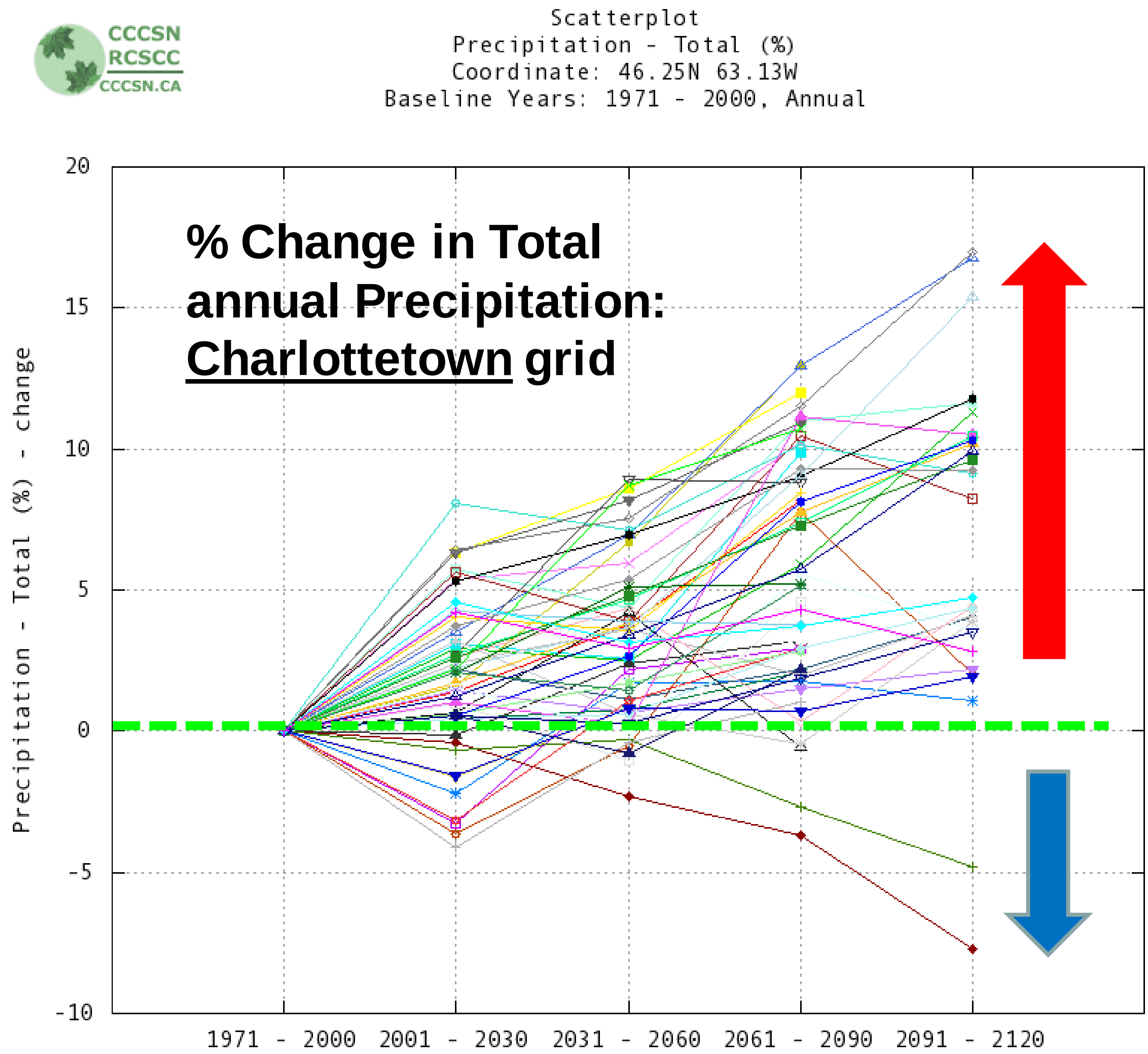
Warm Season: April-November

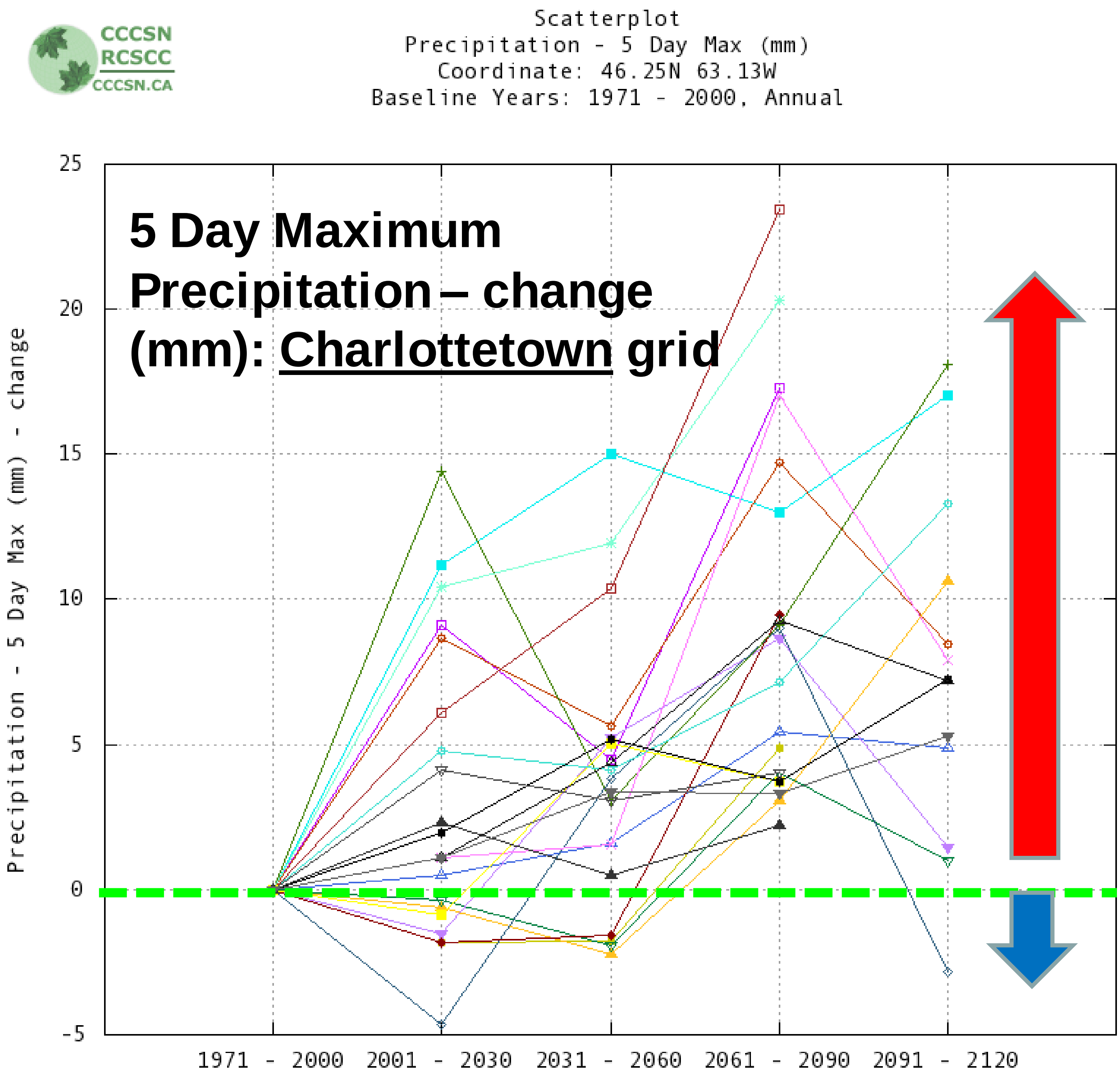


- 3-GCM ensemble
- Increase in seasonal total (20-35%)
- Increase in # of days with rainfall, regardless of daily rainfall amount
- 45-120% increase in LOW flow

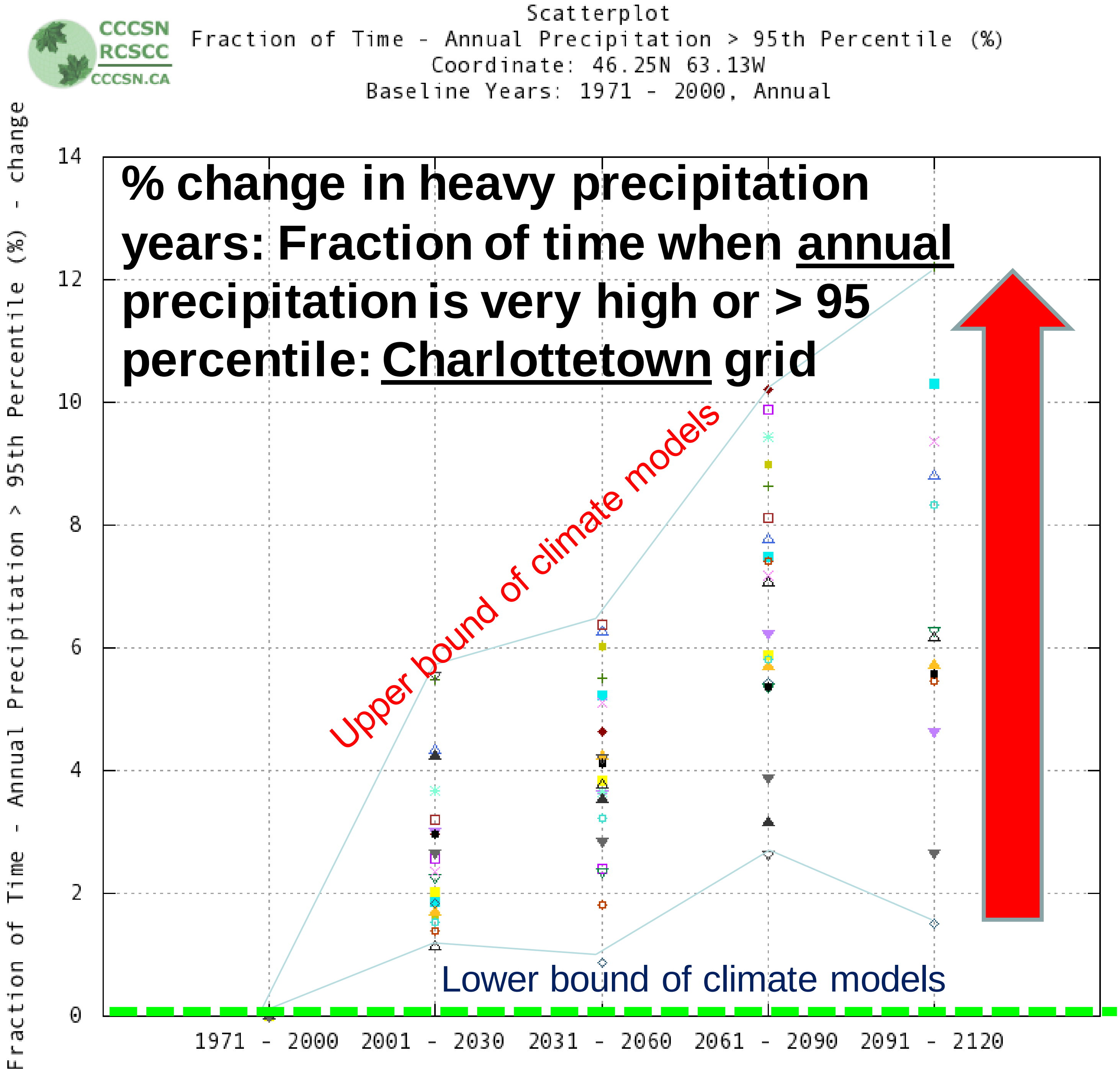
BUT

- **Greatest increases (30-50%) in the heavier rainfall days (>=25 mm)**


CCCSN
RCSCC
CCCSN.CA
Scatterplot
Precipitation - Total (%)
Coordinate: 46.25N 63.13W
Baseline Years: 1971 - 2000, Annual
% Change in Total annual Precipitation: Charlottetown grid
Precipitation - Total (%) - change
20
15
10
5
0
-5
-10
1971 - 2000
2001 - 2030
2031 - 2060
2061 - 2090
2091 - 2120



Scatterplot
Precipitation - 5 Day Max (mm)
Coordinate: 46.25N 63.13W
Baseline Years: 1971 - 2000, Annual
5 Day Maximum Precipitation – change (mm): Charlottetown grid
Precipitation - 5 Day Max (mm) - change
25
20
15
10
5
0
-5
1971 - 2000
2001 - 2030
2031 - 2060
2061 - 2090
2091 - 2120


CCCSN
RCSCC
CCCSN.CA
Scatterplot
Fraction of Time - Annual Precipitation > 95th Percentile (%)
Coordinate: 46.25N 63.13W
Baseline Years: 1971 - 2000, Annual
% change in heavy precipitation years: Fraction of time when annual precipitation is very high or > 95 percentile: Charlottetown grid
Upper bound of climate models
Lower bound of climate models
Fraction of Time - Annual Precipitation > 95th Percentile (%) - change
0
2
4
6
8
10
12
14
1971 - 2000
2001 - 2030
2031 - 2060
2061 - 2090
2091 - 2120

<u>How</u> 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" – <u>best practices, not perfect</u>**
- **Multi-disciplinary considerations**
- **Support from regulations, codes, standards, legal community…**

Climate Model-led Approach

Vulnerability-Thresholds

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

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

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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

Response: No new measures.

no

Response:
New measures needed.

"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.

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Engineers Canada approach

ADAPTATION OPTIONS

Resilience to the Current Climate/Weather

Preparing for the Future Climate

Mainstreaming Future Climate Change

Do nothing

Add **ecosystem services**: wetlands, forests, stream buffer zones

Financial: extra insurance, disaster reserves

Prioritize retrofits- strengthen before climate thresholds

New adaptation: water efficiency, overland flow, extra capacity

Add redundancy (e.g. water reservoirs)

Staged adaptation: able to include greater adaptation in future, as needed

Increase disaster response & planning

Rigorous maintenance - extend service life

Best management practices for current climate: no to low regrets

Know climate "breaking points" & Monitor

Replace & abandon: unsafe & cannot be retrofitted

Flexible designs & options: works under current and future climates & increasing uncertainty

Make CC-resilient: include current & future Climate

Adapted from Byers et al. 2011

CSA STANDARDS

PLUS 4013-12

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

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CSA Rainfall IDF Guideline

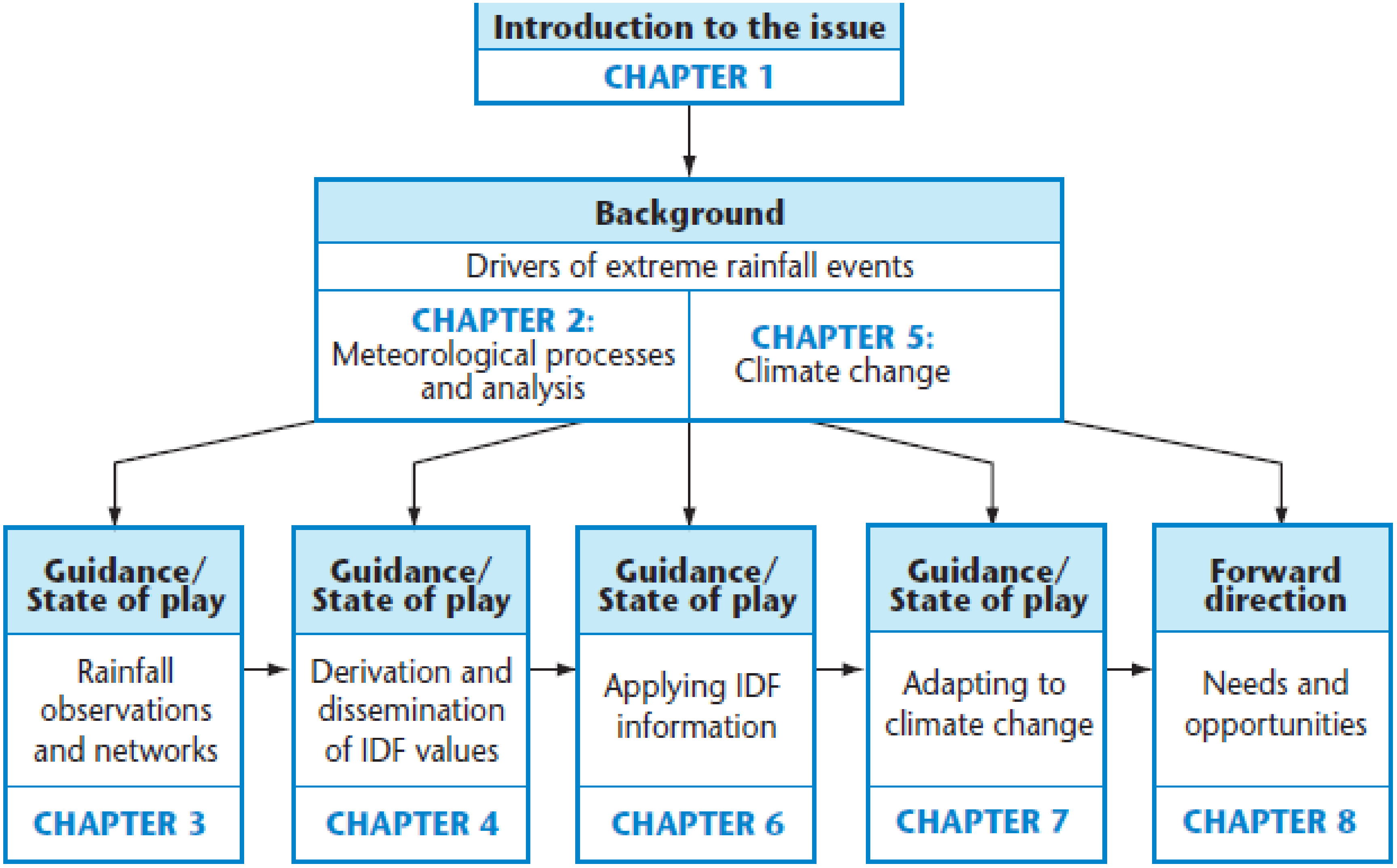

Figure 1.2
Structure and content of the Guideline

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)

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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.*

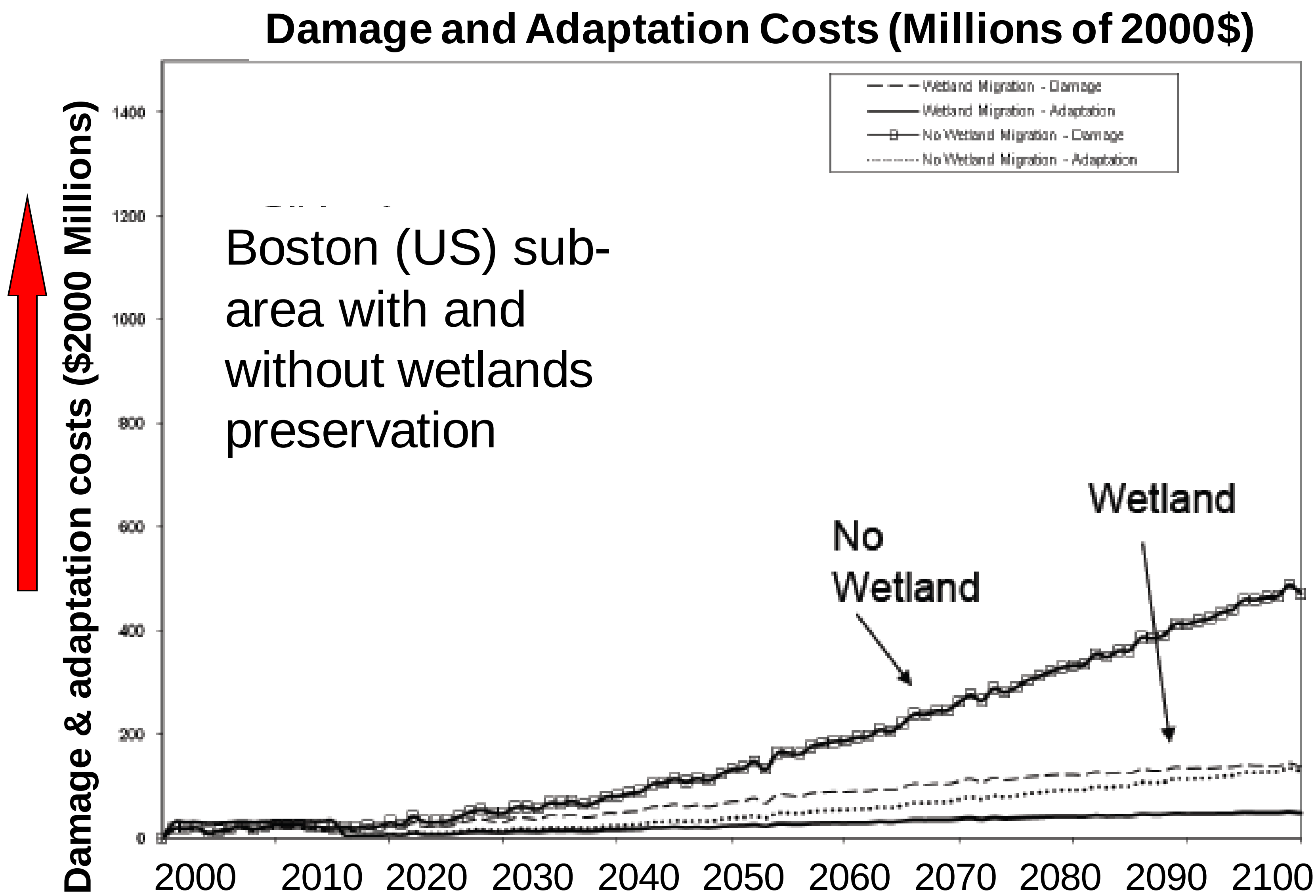
Increased safety factors/margins, phased or sequenced adaptation, flexible design, climate change model ensembles all deal with uncertainties.

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

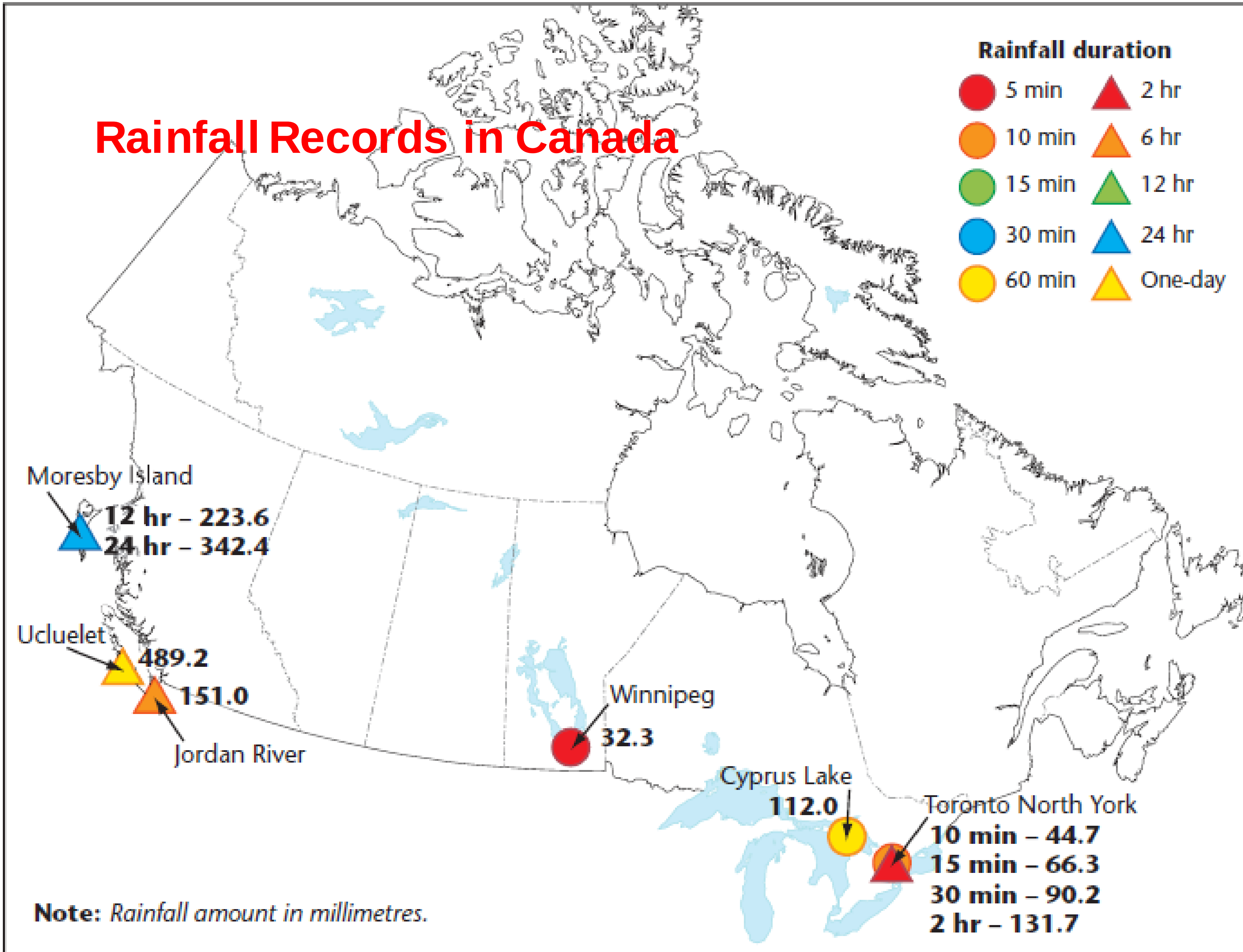
No regrets: *Good integrated water management, good design, conservation, preserving ecosystems, best practice*

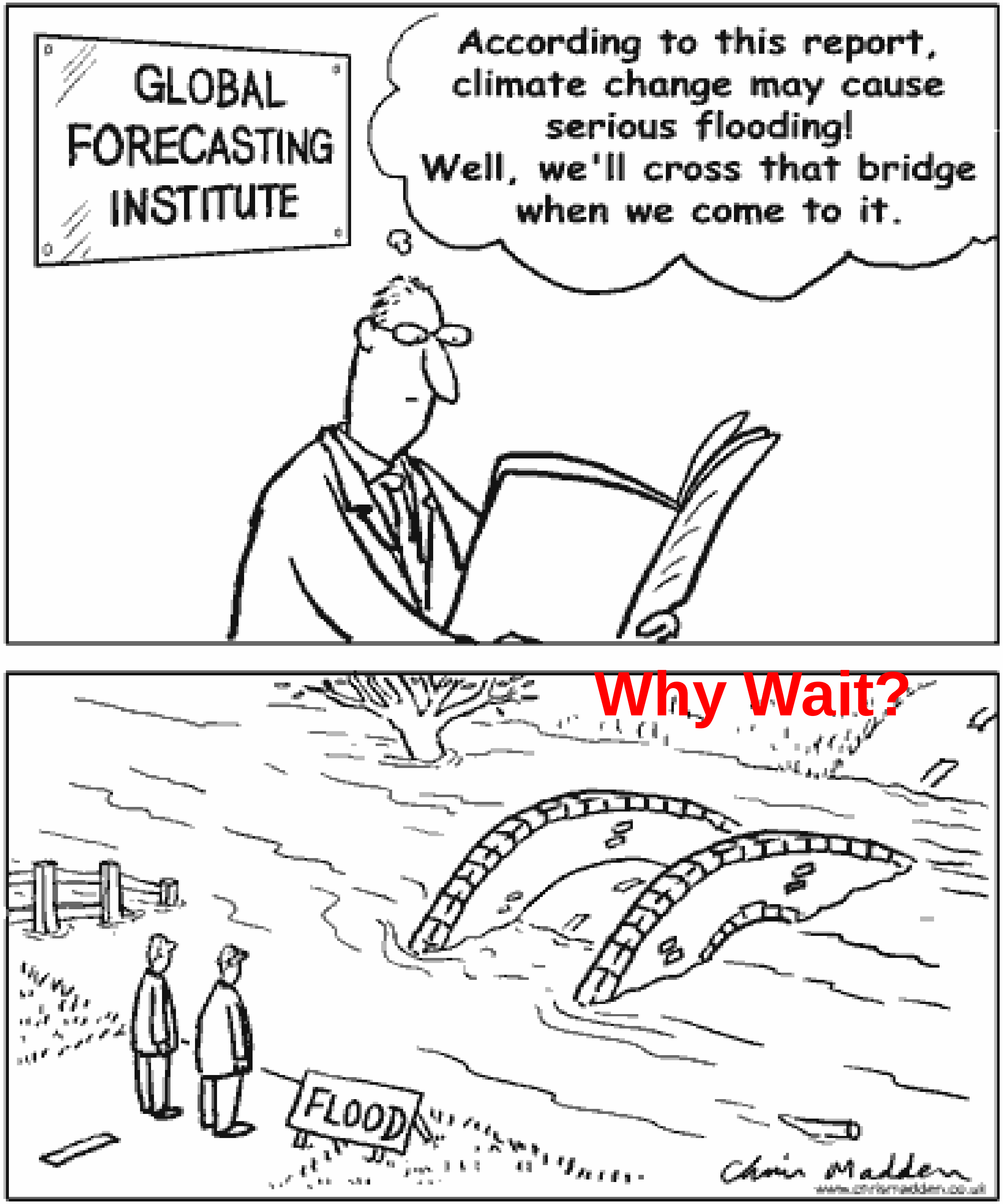
Sequencing strategies*: "no-regrets" options are taken earlier, and more inflexible measures delayed in anticipation of better climate change information, regular monitoring and review*

Climate Change Adaptation Options: Hard and Soft Engineering Options (Wetland Ecosystem Services)



Rainfall Records in Canada





Why Wait?

From: Green Boston: Urban Scale Climate Adaptation

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Thank You!

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Fax: 613-260-1443
www.RiskSciencesInt.com