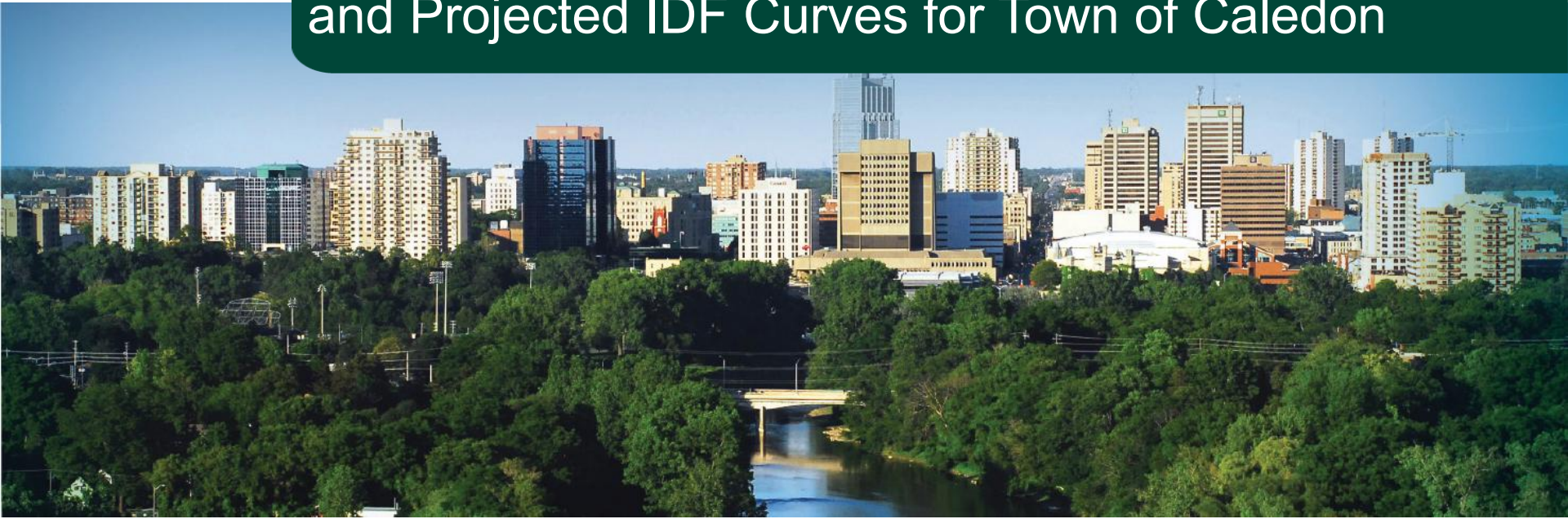
Building Climate Resilience: Updating Historical and Projected IDF Curves for Town of Caledon



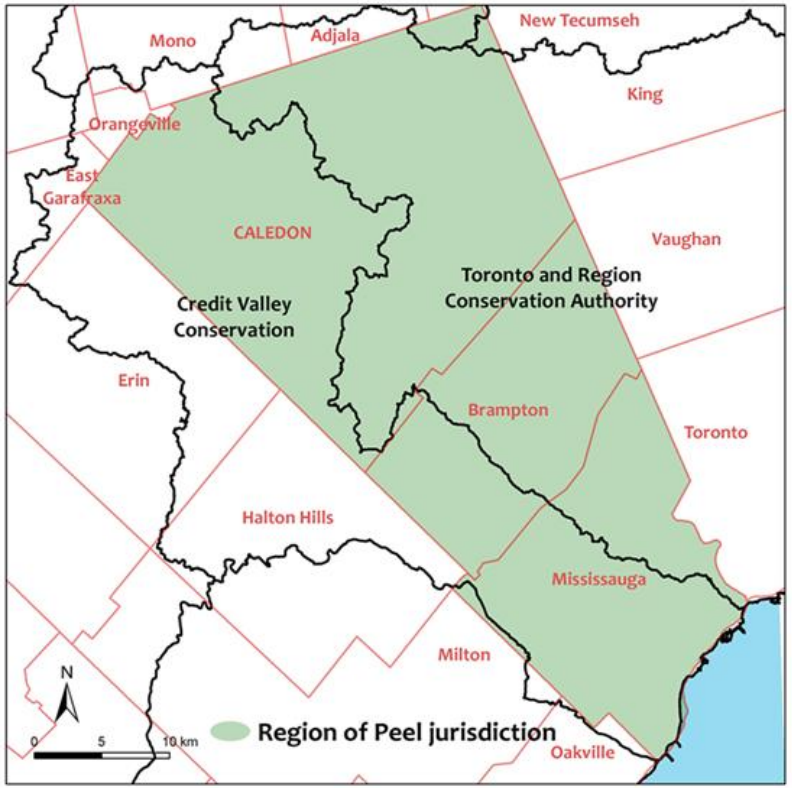
[1]Hadiseh Bolkhari, [2]Reza Najafi

[1]Town of Caledon, [2]Department of Civil and Environmental Engineering, Western University

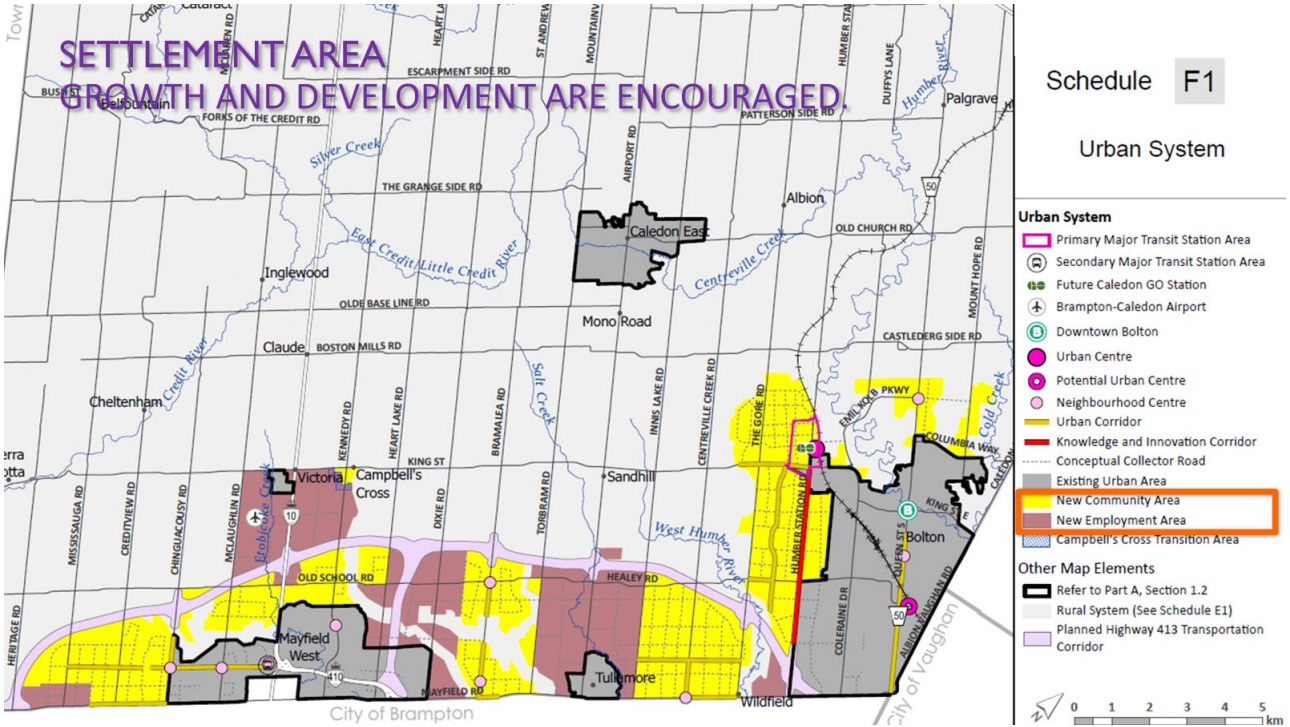
Friday November 14th

Where is Caledon?

- 55% of the total area in Peel Region
- Slightly smaller than Berlin
- 6.5 times larger than Paris

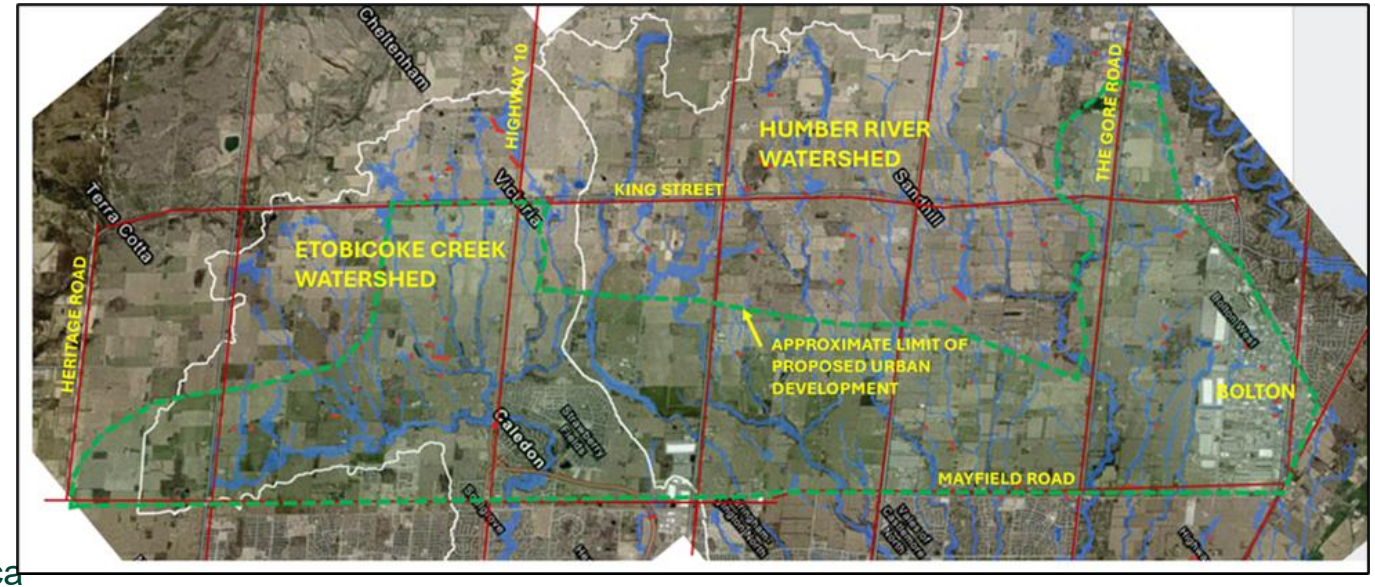


Future Caledon Official Plan

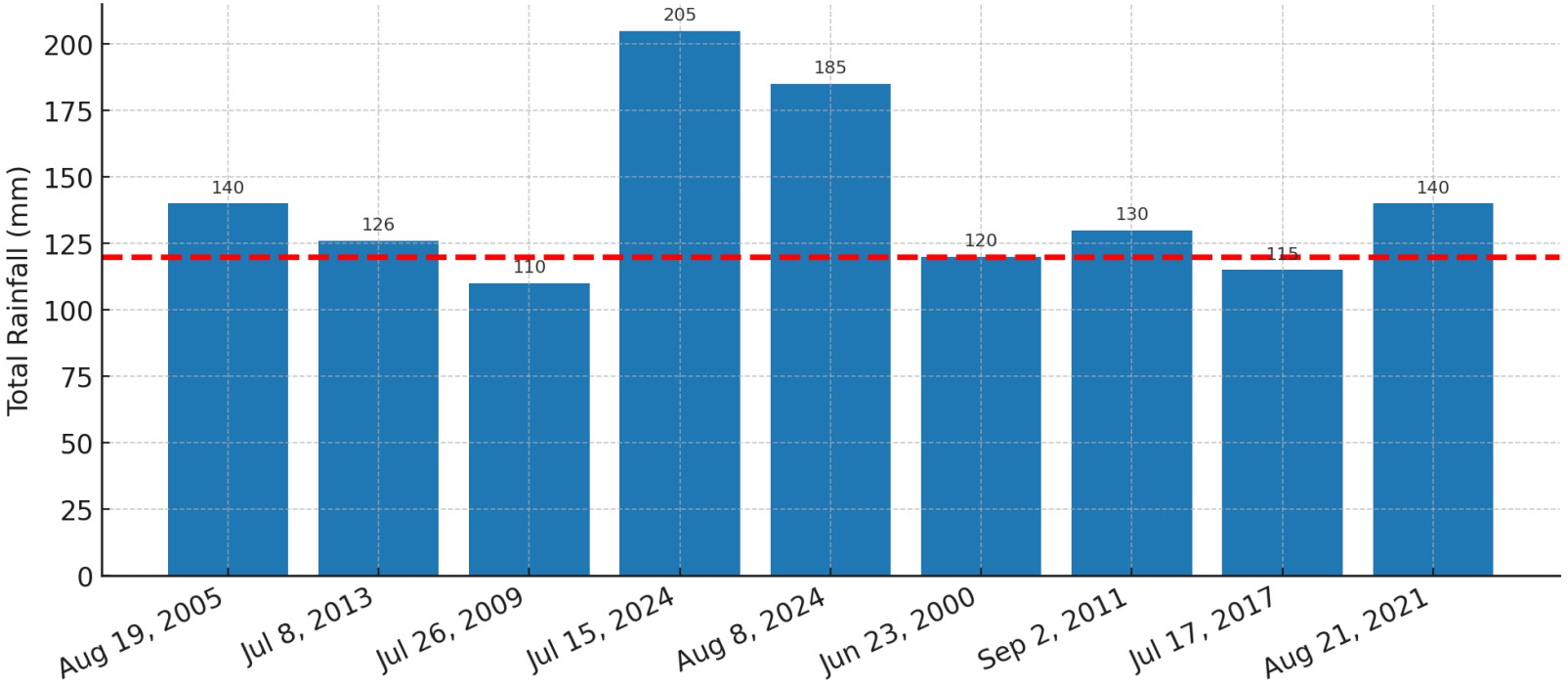


Flood Hazard Identification and Mapping Program (FHMIP)

Growth happens, Floods shouldn't



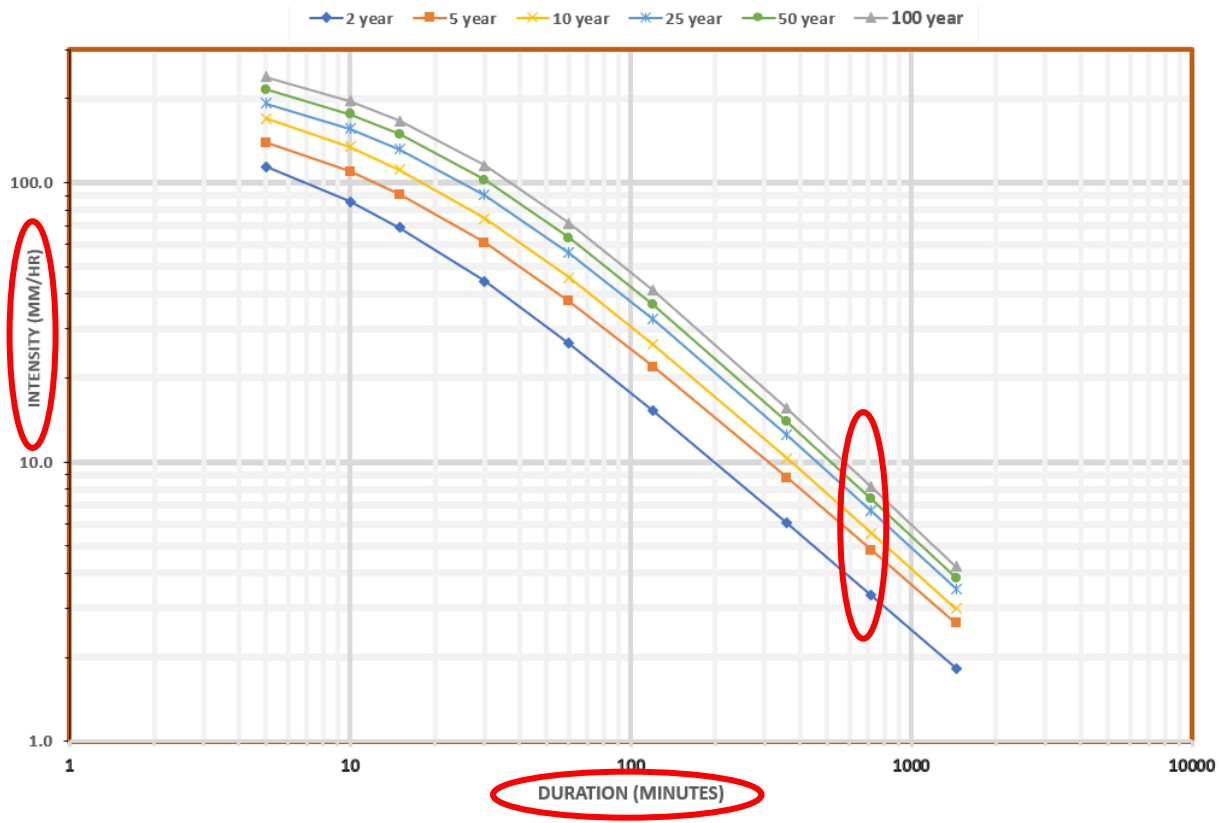
Historical Rainfall Events - GTA



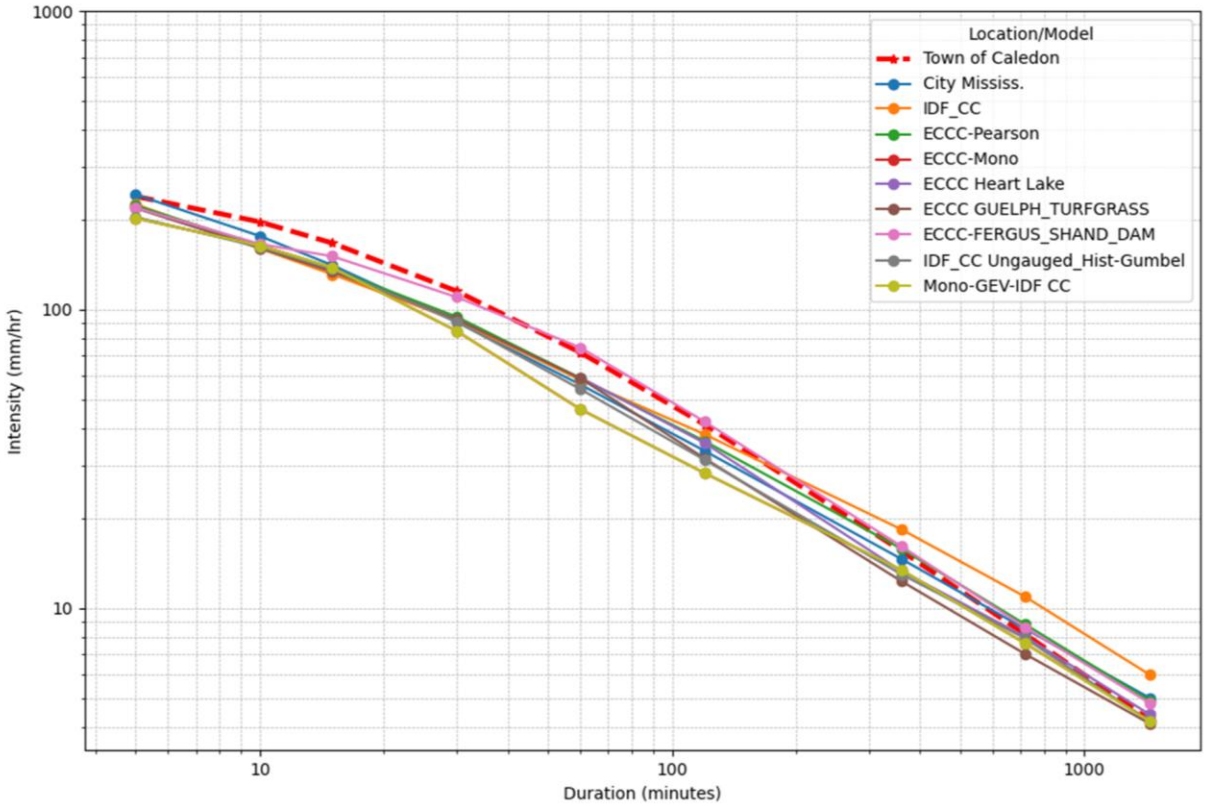
Historical **Intensity-Duration-Frequency** Caledon

Rainfall Intensity (mm/h)				
Duration	**2 year**	**10 year**	**50 year**	**100 year**
5 min	114.3	169.6	215.8	239.4
10 min	85.7	134.2	176.2	196.5
15 min	69.0	111.4	149.1	166.9
30 min	44.4	74.6	102.5	115.3
1 hr	26.6	45.7	63.6	71.7
2 hr	15.3	26.4	36.6	41.2
6 hr	6.1	10.3	13.9	15.5
12 hr	3.3	5.6	7.4	8.2
24 hr	1.8	3.0	3.9	4.2

EC data - Guelph O.A.C
1881 to 1973



100 Year IDF Comparison



Challenges in Updating IDF Curves

Historical IDF Curves

- Data gaps, short records, and gauge malfunctions
- Sparse data coverage
- Limited sub-hourly rainfall observations

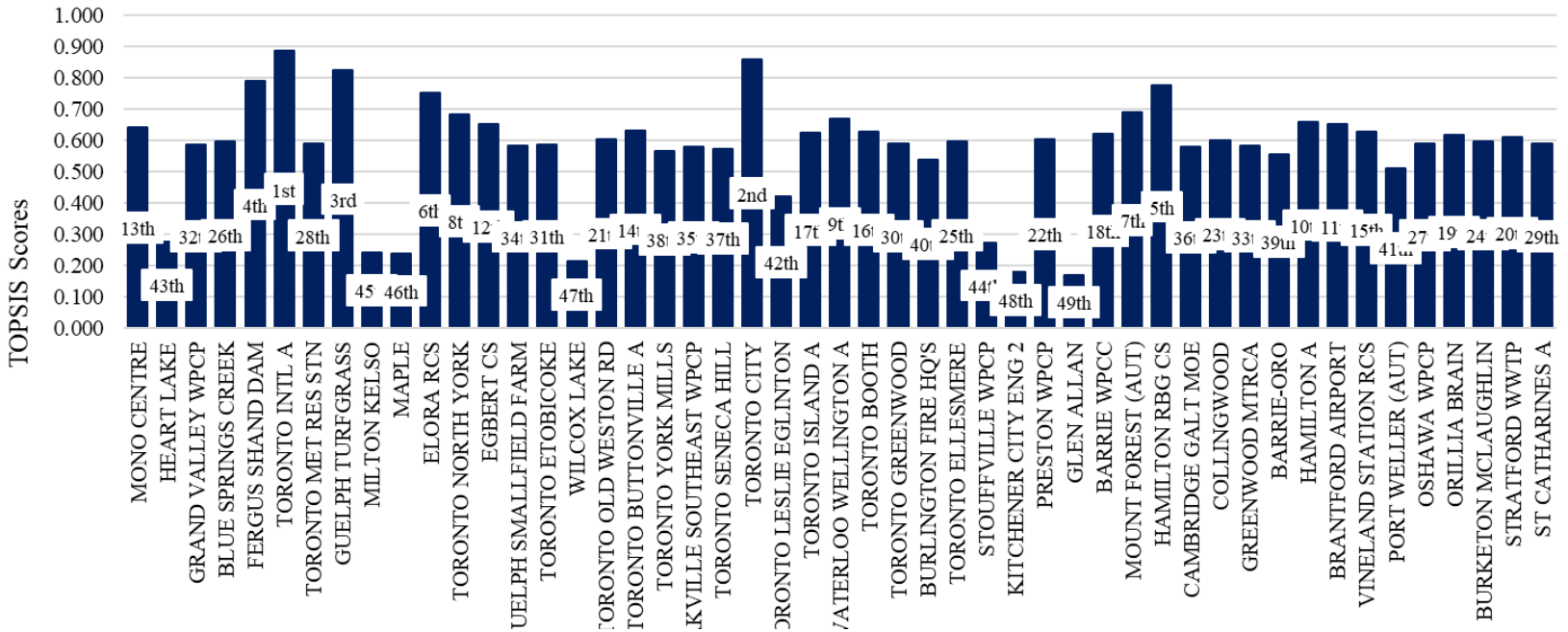
Projected IDF Curves

- Global and Regional Climate Models too coarse to capture local rainfall extremes
- Raw model outputs require adjustment due to systemic biases

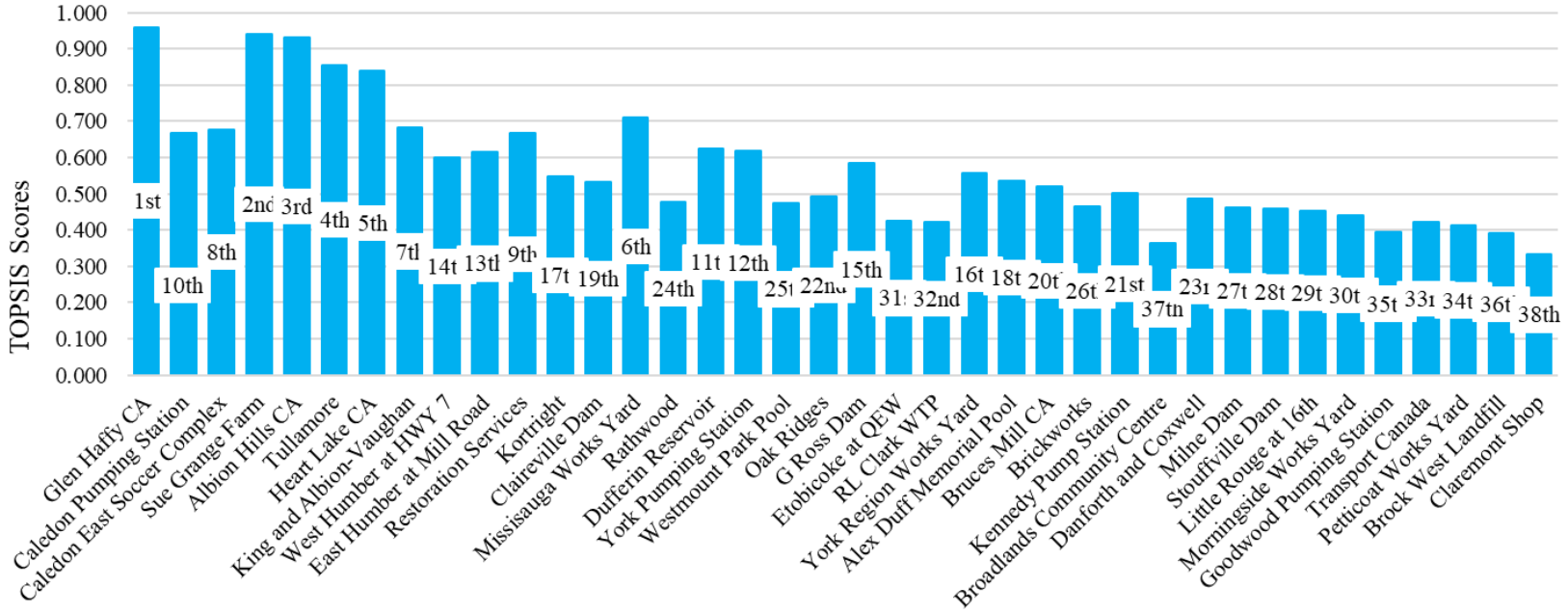
Overview of Historical Rainfall Datasets

Data Source	No. of Total Stations	Years of Data				Frequency of Data
		< 10 years	10–20 years	20-30 years	>= 30 years	
ECCC Historical Data	114	49	31	20	14	1-hr
ECCC Annual Maxima	49	-	21	10	18	5, 10, 15, 30-min 1, 2, 6, 12, 24-hr
TRCA	38	4	33	1	-	5,15, 30-min
CVC	16	2	11	1	-	5,15, 30-min

ECCC Rain Gauges Ranking

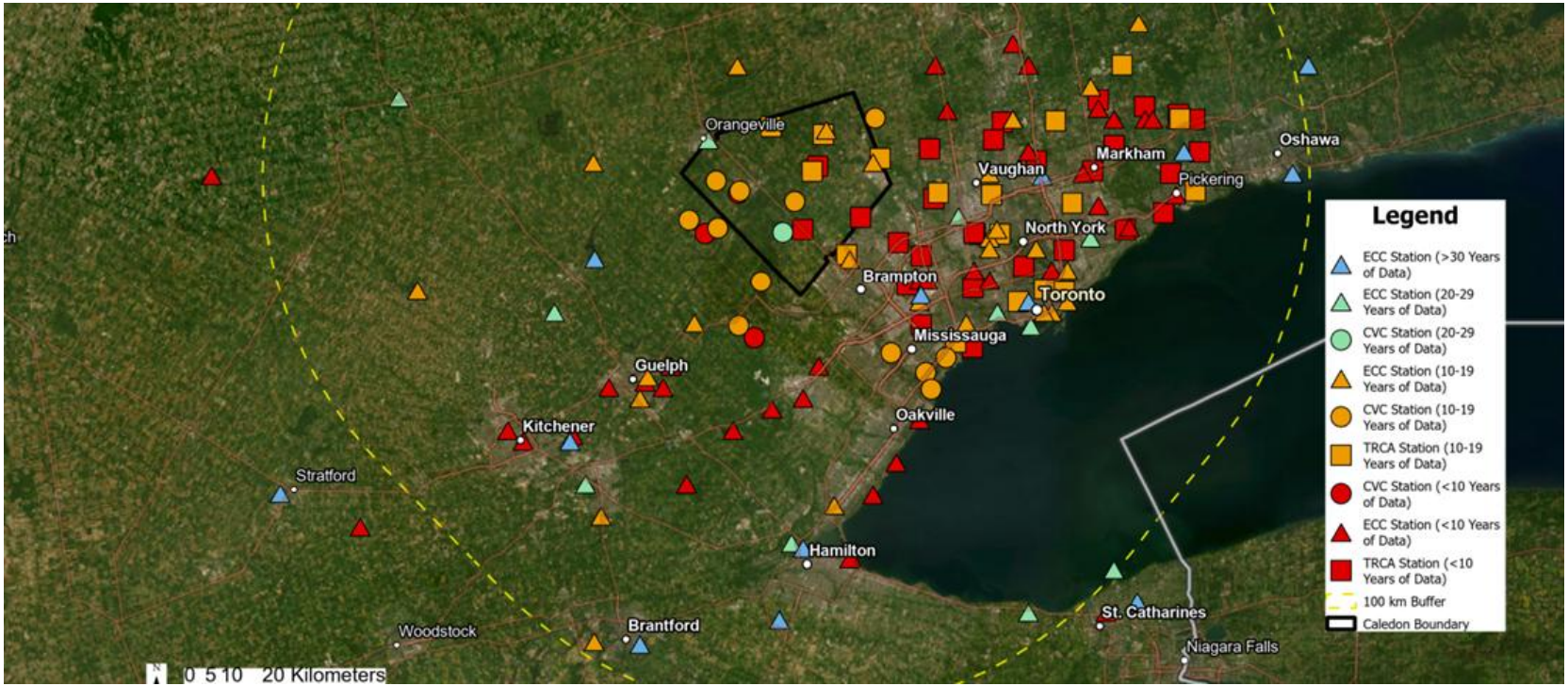


TRCA Rain Gauges Ranking



CVC Rain Gauges Ranking

Ranked Gauges within 100 km of Caledon



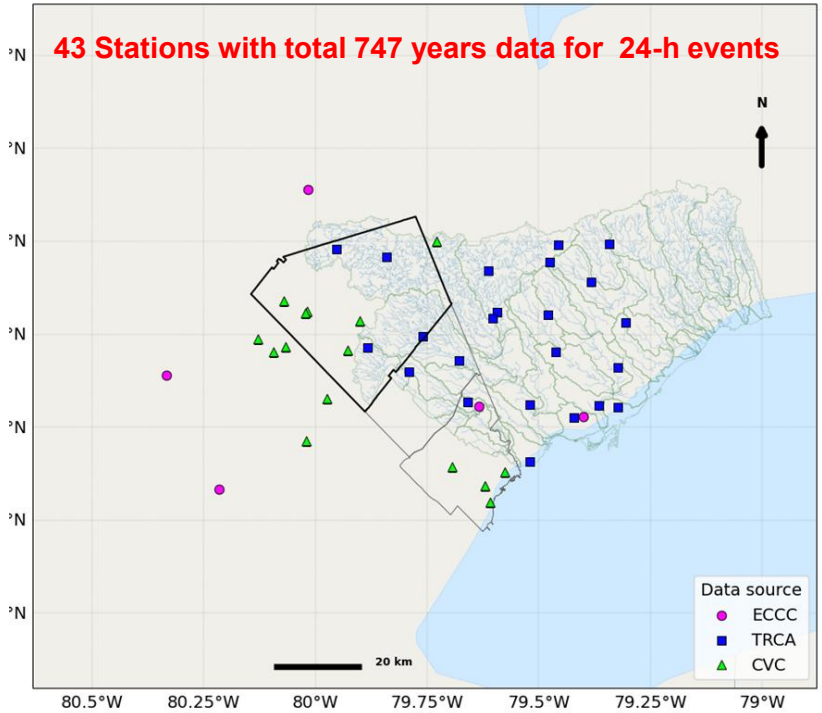
Regional Frequency Analysis (RFA)

- Estimate design storms in partially/ ungauged regions by combining storm event data from hydrologically similar gauge stations instead of relying on just one station.

- It groups stations with similar rainfall characteristics, pool their annual-maximum rainfall series, and fits one optimal regional curve.

Station Selection-Return Period Estimation

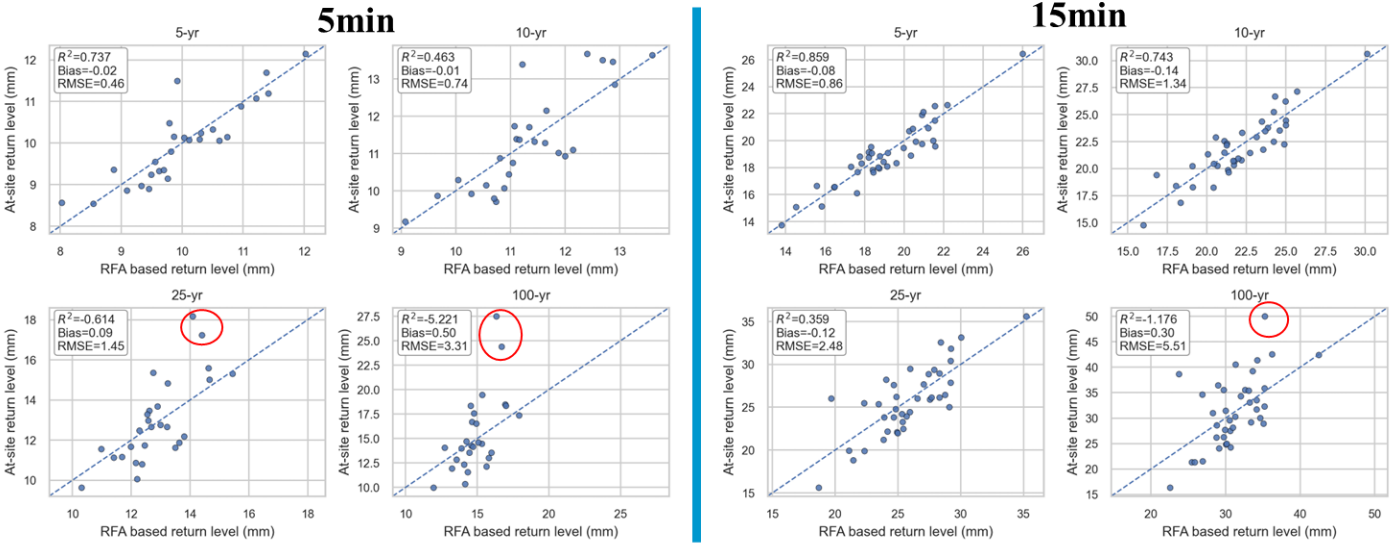
- Compare each station rainfall patterns to neighbor stations
  - Remove outlier station
- Test if stations behave similarly as one region
  - If too mixed
    - Refine the group before pooling



Regional frequency analysis Statistics Summary

	Heterogeneity Measure			Z-DIST test				Total Station No	Total Station Year
	H1	H2	H3	GLO	GEV	GNO	PE3		
5min	[illegible]	0.16	-0.61	**0.7**	-1.7	-1.6	-1.92	27	507
10min	1.93	1.06	0.7	**0.87**	-1.52	-1.58	-2.07	29	545
15min	1.23	-1.04	-0.52	2.38	**-0.15**	-0.31	-0.94	39	679
30min	1.83	-0.34	-0.44	1.26	**-0.83**	-1.27	-2.21	39	687
1h	1.29	0.53	0.84	1.54	**-0.51**	-1.08	-2.21	43	746
2h	-0.08	-0.9	-0.54	**-0.47**	-1.48	-2.81	-4.29	42	727
6h	-0.14	0.32	0.38	1.31	**-0.74**	-3.53	-4.94	42	731
12h	-0.01	0.15	0.44	**-0.22**	-1.18	-2.69	-3.72	43	744
24h	-0.85	0.14	-0.22	1.37	**-0.6**	-1.14	-2.23	43	747

RFA vs. At Site Estimates

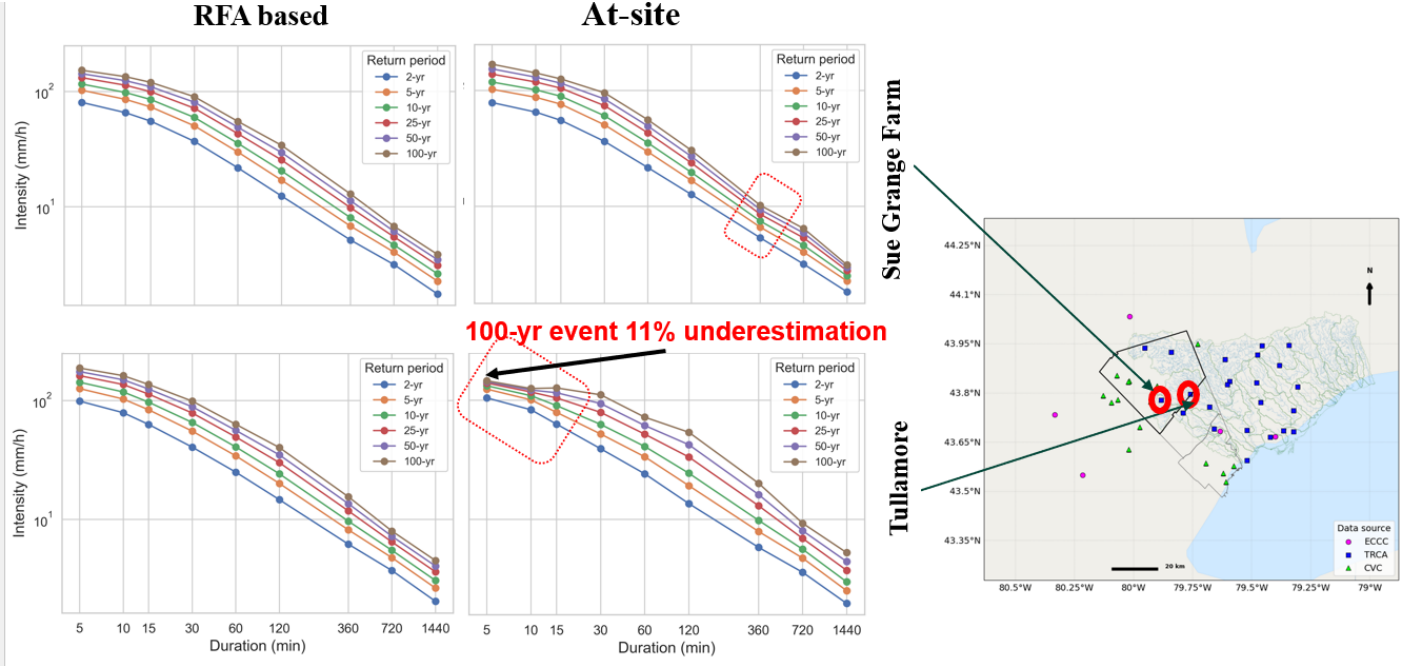


Red circled stations showed a larger difference;

- Have relatively larger variation in rainfall characteristics from the homogenous region
- Located more than 30 km distant from the Caledon
- Have less than 20-year gauge data

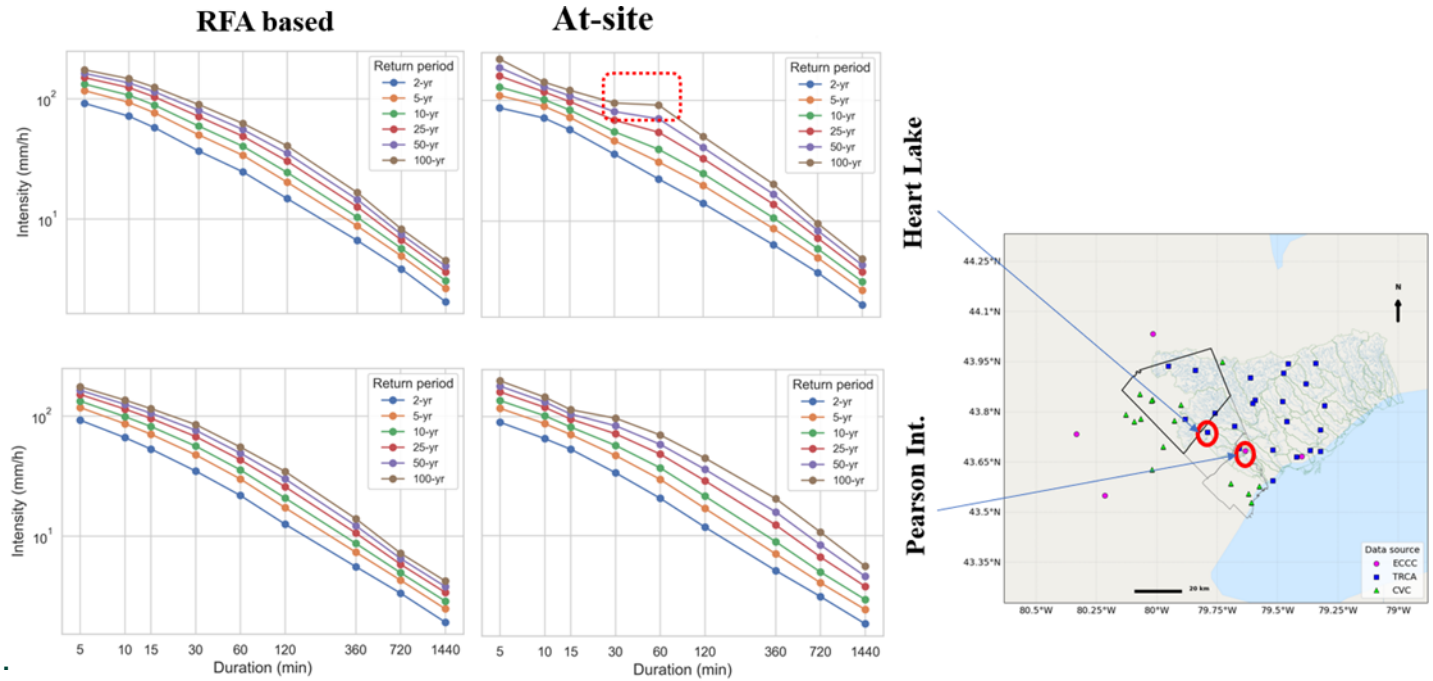
IDF comparison: At-site and Regional Frequency Analysis

- Across most of the durations, both show good agreement
- For some durations, At-site IDF shows a certain degree of inconsistency



IDF comparison: At-site and Regional Frequency Analysis

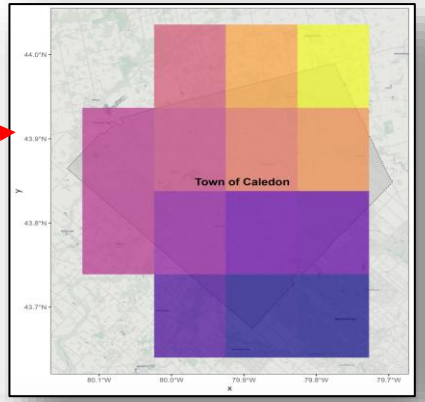
- At-site IDF requires further smoothing
- RFA-based IDF is more consistent across different durations

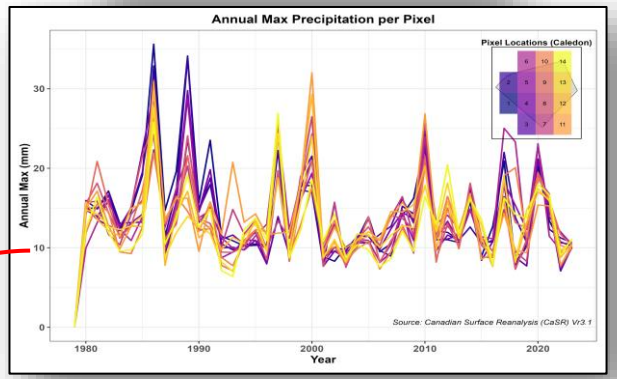


london.

Radar and Satellite Gridded Resources

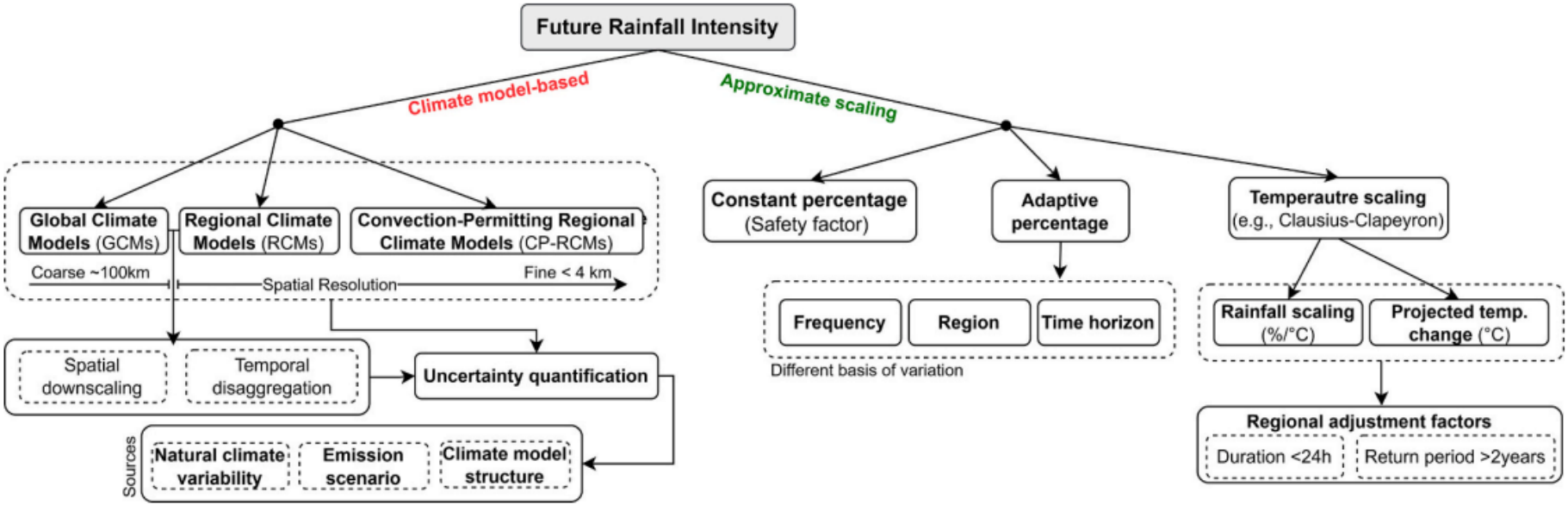
Data Type	Spatial/Temporal Resolution	Use Case
Reanalysis: CaSR*	10km x 10km (hourly)	1980-2023
Satellite: IMERG**	0.1°×0.1° (10 km×10 km) 30 minutes	1998–now
Radar: ECCC Radar	1 km 6 minutes	2004–now





Refining historical IDF curves

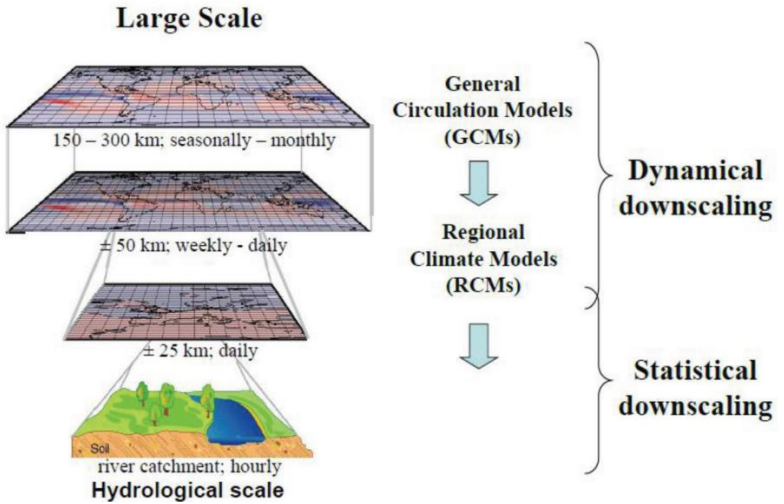
Future Rainfall Intensity Estimation



Future IDF Curve Development

Why use temperature-based scaling?

- Climate models do not reliably resolve short-duration extremes.
- Biases in model precipitation are large, especially for convective storms that dominate IDF curves.
- Temperature projections are more robust and physically constrained
- Observed thermodynamic response is well-established, with extreme rainfall increasing as the atmosphere warms.



Future IDF Curves under climate change

Estimate **future rainfall intensities** based on projected temperature change (temperature scaling).

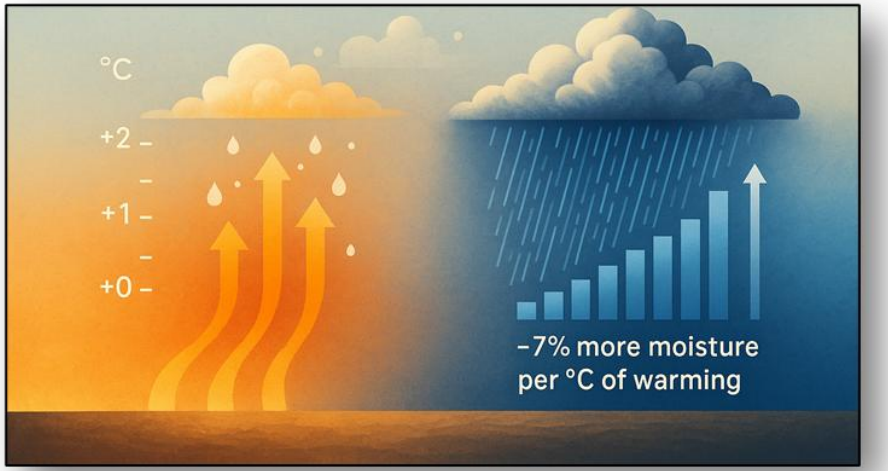
Data:

- Projected mean temperature (extracted from climatedata.ca)
- Derived from an ensemble of 26 CMIP6 General Circulation Models)
- Downscaled by BCCAQv2 using NRCANmet + ECCC historical IDF database.

Two Approaches: Power-law scaling

$RProj = RHist \times (1+\text{scale})^{\Delta T}$

- Clausius–Clapeyron scaling (scale=0.07),
- Based on CONUS II (High resolution climate simulations based on WRF)* (variable scales based on rainfall duration and return period)



*The **Clausius–Clapeyron** relationship describes how the atmosphere's capacity to hold water vapor increases with temperature.*

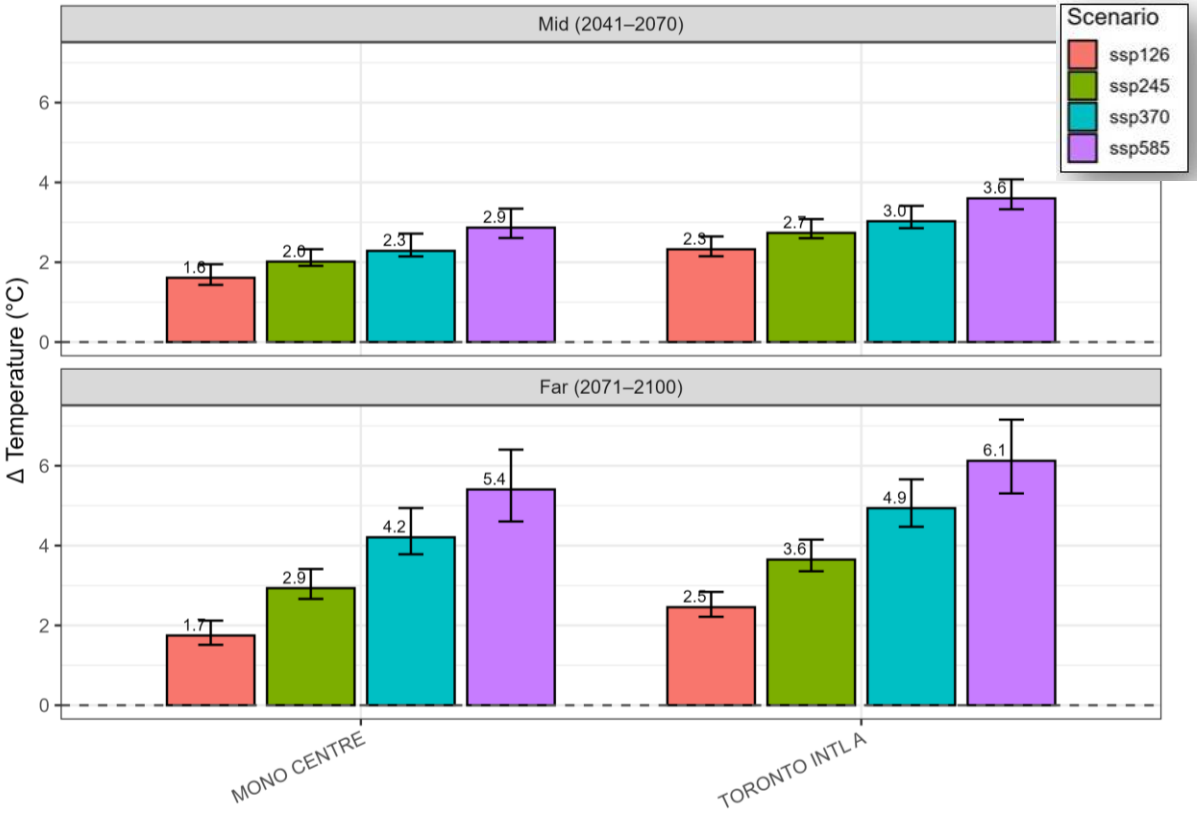
Projected IDF Curves-Temperature change in Ice-free season

Baseline period is different for each station

- Based on the available ECCC historical IDF)

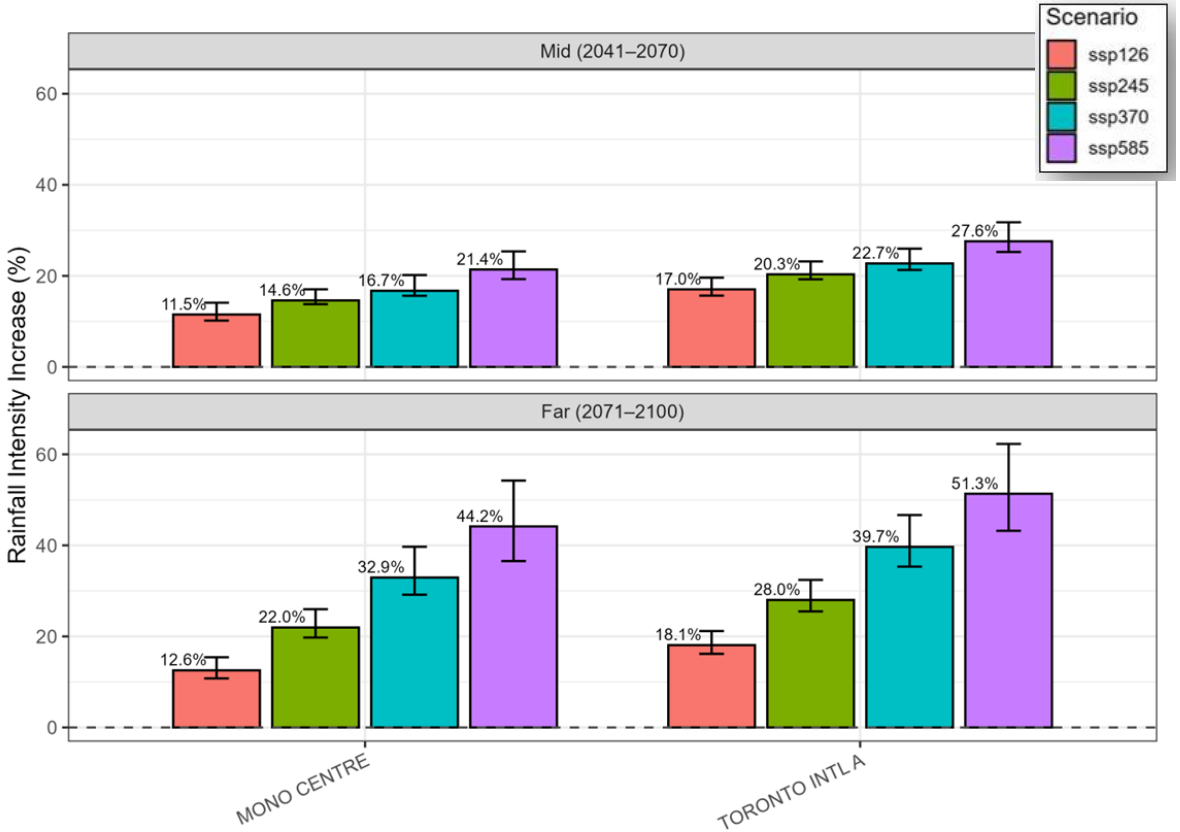
Bars show Median value

- 10th and 90th percentile range representing the uncertainty in climate model projections.



Percentage changes in rainfall extremes

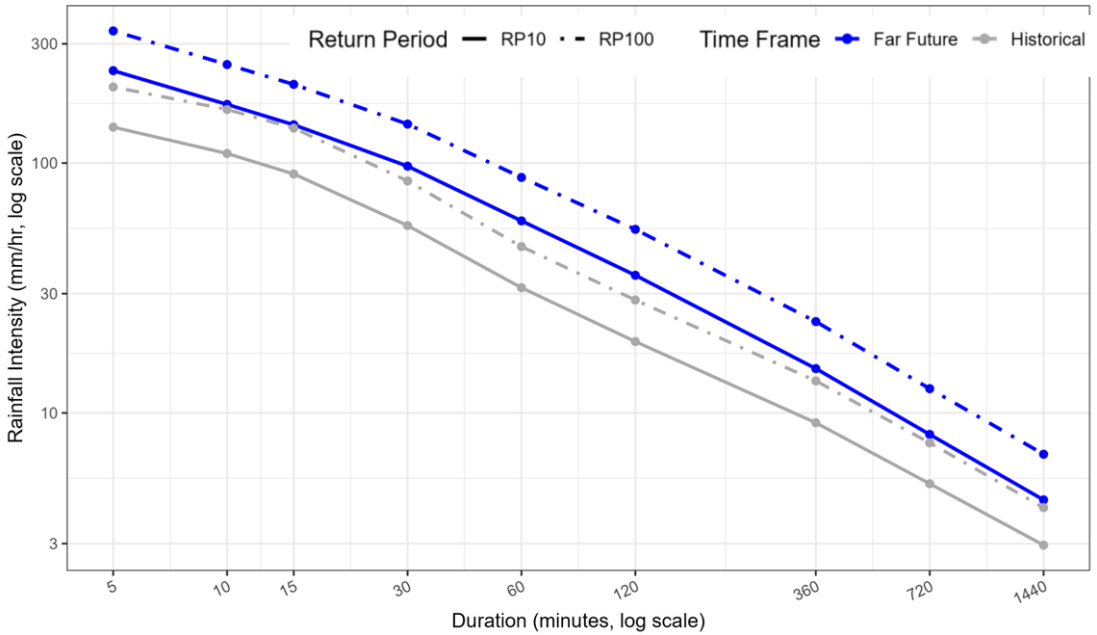
- Clausius–Clapeyron-based scaling using the $(1.07)^{\Delta T}$ rule (temperature-dependent increase).
- Rainfall extremes accelerate faster under stronger warming scenarios (SSP585)



Toronto Int. Historical vs Future IDF

- CONUS II method
  - Variable scaling for different durations and return periods

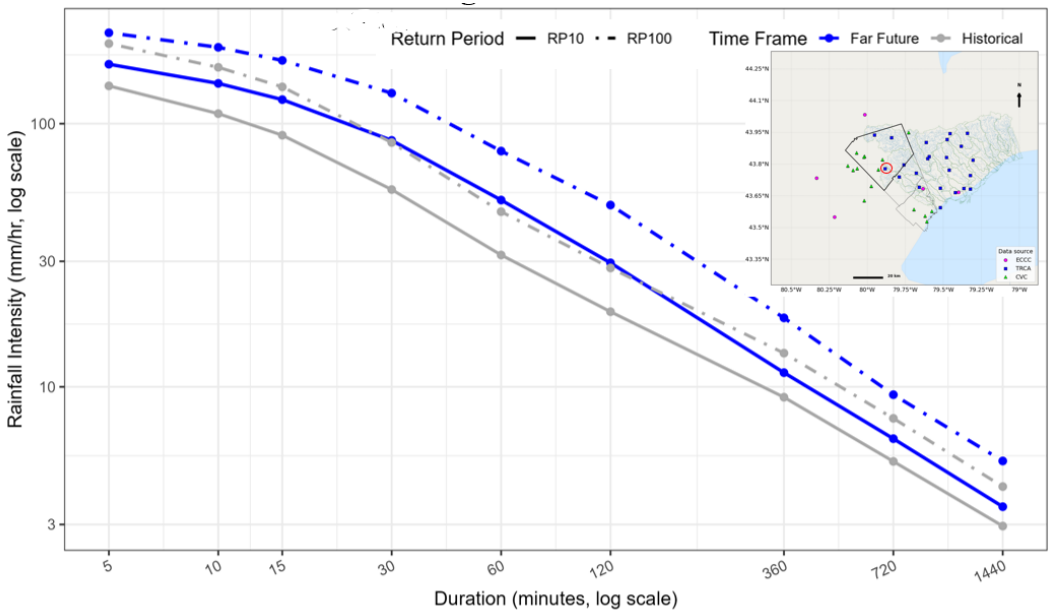
- The historical RP100 curve nearly overlaps with the future RP10, showing temperature change can considerably change the future design storm.



Sue Grange Farm station within Caledon

- Sue Grange Farm has approximately 20 years of local rainfall data.

- Through RFA, the effective record length can be extended to 1990–2020, integrating information from over 500 station–years of data*



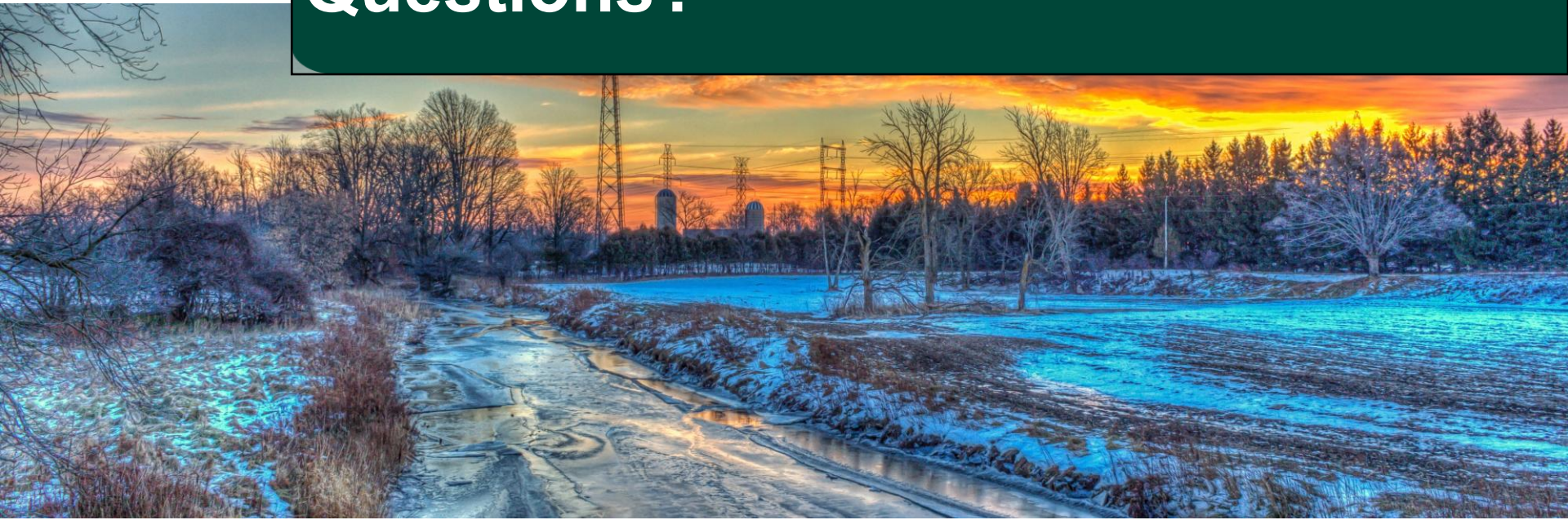
Conclusions

- Combining long-record ECCC stations with nearby TRCA and CVC gauges improves historical IDFs by integrating both temporal depth and local spatial relevance.
- Regional Frequency Analysis strengthens limited station records by pooling hydrologically similar sites, reducing uncertainty in extreme rainfall estimates.
- Warm-season temperature increases are robust across CMIP6 scenarios and may reach about +6 °C under SSP5-8.5 by late century.
- Future rainfall intensification follows the Clausius–Clapeyron relationship (~7% per °C), with additional refinement from CONUS II scaling rates that vary by duration and return period.
- At-site projections indicate a major shift in design storms, with the historical 100-year event approaching the intensity of a future 10-year event.
- A combined at-site and regional approach offers the most reliable climate-adjusted IDFs by balancing local accuracy with regional statistical stability.

Acknowledgements

- Dr. Reza Javidi Sabbaghian, University of Western
- Robiul Islam, University of Western
- Dr. Mohammad Fereshtehpour, NRCan
- Alex Cannon (CRD ECCC)

Questions?



Appendix

❖ Guideline for IDF Analysis:

CSA GROUP™

CSA W231:25
National Standard of Canada

Developing and interpreting intensity-duration-frequency (IDF) information under a changing climate

scc ccn

Legal Notice for Standards

Canadian Standards Association (operating as "CSA Group") develops standards through a consensus standards development process approved by the Standards Council of Canada. This process brings together volunteers representing varied viewpoints and interests to achieve consensus and develop a standard. Although CSA Group administers the process and establishes rules to promote fairness in achieving consensus, it does not independently test, evaluate, or verify the content of standards.

Disclaimer and exclusion of liability

This document is provided without any representations, warranties, or conditions of any kind, express or implied, including, without limitation, implied warranties or conditions concerning this document's fitness for a particular purpose or use, its merchantability, or its non-infringement of any third party's intellectual property rights. CSA Group does not warrant the accuracy, completeness, or currency of any of the information published in this document. CSA Group makes no representations or warranties regarding this document's compliance with any applicable statute, rule, or regulation.

IN NO EVENT SHALL CSA GROUP, ITS VOLUNTEERS, MEMBERS, SUBSIDIARIES, OR AFFILIATED COMPANIES, OR THEIR EMPLOYEES, DIRECTORS, OR OFFICERS, BE LIABLE FOR ANY DIRECT, INDIRECT, OR INCIDENTAL DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES, HOWSOEVER CAUSED, INCLUDING BUT NOT LIMITED TO SPECIAL OR CONSEQUENTIAL DAMAGES, LOST REVENUE, BUSINESS INTERRUPTION, LOST OR DAMAGED DATA, OR ANY OTHER COMMERCIAL OR ECONOMIC LOSS, WHETHER BASED IN CONTRACT, TORT (INCLUDING NEGLIGENCE), OR ANY OTHER THEORY OF LIABILITY, ARISING OUT OF OR RESULTING FROM ACCESS TO OR POSSESSION OR USE OF THIS DOCUMENT, EVEN IF CSA GROUP HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES.

In publishing and making this document available, CSA Group is not undertaking to render professional or other services for or on behalf of any person or entity or to perform any duty owed by any person or entity to another person or entity. The information in this document is directed to those who have the appropriate degree of experience to use and apply its contents, and CSA Group accepts no responsibility whatsoever arising in any way from any and all use of or reliance on the information contained in this document.

CSA Group is a private not-for-profit company that publishes voluntary standards and related documents. CSA Group has no power, nor does it undertake, to enforce compliance with the contents of the standards or other documents it publishes.

Intellectual property rights and ownership

As between CSA Group and the users of this document (whether it be in printed or electronic form), CSA Group is the owner, or the authorized licensee, of all works contained herein that are protected by copyright, all trade-marks (except as otherwise noted to the contrary), and all inventions and trade secrets that may be contained in this document, whether or not such inventions and trade secrets are protected by patents and applications for patents. Without limitation, the unauthorized use, modification, copying, or disclosure of this document may violate laws that protect CSA Group's and/or others' intellectual property and may give rise to a right in CSA Group and/or others to seek legal redress for such use, modification, copying, or disclosure. To the extent permitted by licence or by law, CSA Group reserves all intellectual property rights in this document.

Patent rights

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. CSA Group shall not be held responsible for identifying any or all such patent rights. Users of this standard are expressly advised that determination of the validity of any such patent rights is entirely their own responsibility.

Authorized use of this document

This document is being provided by CSA Group for informational and non-commercial use only. The user of this document is authorized to do only the following:

If this document is in electronic form:

- load this document onto a computer for the sole purpose of reviewing it;
- search and browse this document; and
- print this document if it is in PDF format.

Limited copies of this document in print or paper form may be distributed only to persons who are authorized by CSA Group to have such copies, and only if this Legal Notice appears on each such copy.

In addition, users may not and may not permit others to

- alter this document in any way or remove this Legal Notice from the attached standard
- sell this document without authorization from CSA Group or
- make an electronic copy of this document.

If you do not agree with any of the terms and conditions contained in this Legal Notice, you may not load or use this document or make any copies of the contents hereof, and if you do make such copies, you are required to destroy them immediately. Use of this document constitutes your acceptance of the terms and conditions of this Legal Notice.

CSA GROUP™

View access copy/voir la copie d'accès for/par Alex Cannon, alex.cannon@ec.gc.ca, provided by/par CSA Group/Groupe CSA on/le 10/29/2025. Storage, copying, distribution or use on network prohibited. Le stockage, reproduction, la distribution ou l'utilisation sur le réseau est interdit.