

Automatic Tool for Deriving Current and Future IDF Curves and Design Storms

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Latornell 2020



Session overview

Image source: <http://www.metrovancouver.org/about/Pages/default.aspx>

- 1 Background
- 2 Project purpose and objectives
- 3 IDF curves
- 4 Storm analysis
- 5 Spreadsheet tool



Background

Metro Vancouver sewerage services

- Municipal sewers owned by municipalities
- Trunk sewers owned by Metro
- 33 pump stations, 5 wastewater treatment plants
- Parts of the system are combined – to be fully separated by 2075

Metro Vancouver stormwater services

- Municipalities own local stormwater collection services
- Municipalities develop stormwater management by-laws
- Trunk sewers and open channels owned by Metro

Background



Climate change impacts

- Increase in air temperature and precipitation (both intensity and frequency)
- Increase in winter precipitation falling as rain
- Increased summer drought
- Short duration rainfall increasing faster than long duration rainfall

Season	Change in Maximum Air Temperature (2050s, 2080s) (°C)	Change in Minimum Air Temperature (2050s, 2080s) (°C)	Change in Precipitation (2050s, 2080s) (%)
Winter	2.4, 4.4	2.9, 4.9	5, 14
Spring	2.9, 4.7	2.9, 4.6	8, 12
Summer	3.7, 6.0	3.2, 5.2	-19, -29
Fall	2.8, 4.5	2.8, 4.5	11, 20
Annual	2.9, 4.9	2.9, 4.8	5, 11

Background

Climate change litigation is increasing

Municipalities need to incorporate climate change adaptation into their existing planning procedures

Numerous difficulties

- Lack of guidelines
- Large degree of uncertainty
- Cost

Climate Change Litigation Databases

U.S. CLIMATE CHANGE
LITIGATION

NON-U.S. CLIMATE CHANGE
LITIGATION

This site provides two databases of climate change caselaw. Cases in the databases are organized by type of claim and are searchable. In many cases, links are available to decisions, complaints, and other case documents.

Project Purpose and objectives

Client: Metro Vancouver

Purpose:

- Advance knowledge and adapt to the effects of climate change to ensure that adequate levels of service for stormwater and sewerage collection infrastructure are maintained

Objectives:

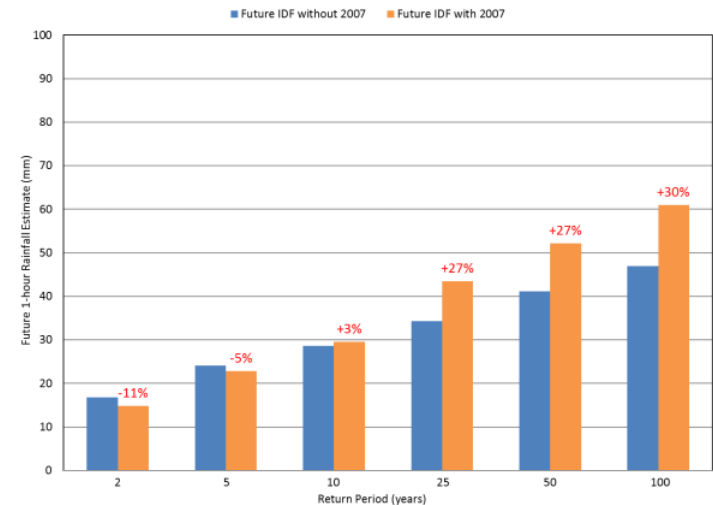
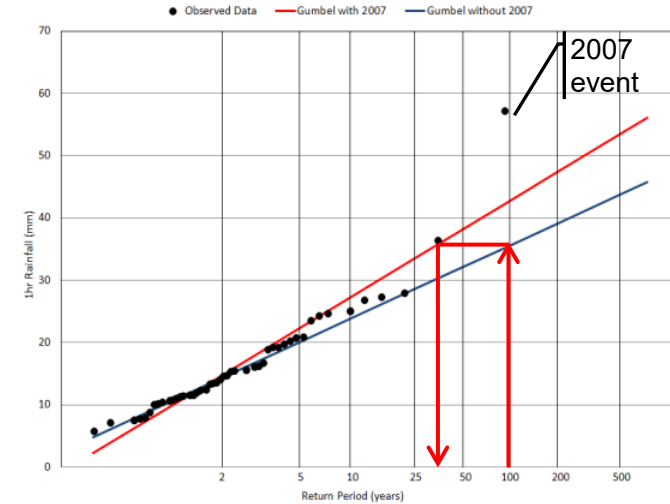
- Update current climate Intensity-Duration-Frequency (IDF) rainfall curves to present day
- Quantify climate change uncertainty and develop future climate IDF curves



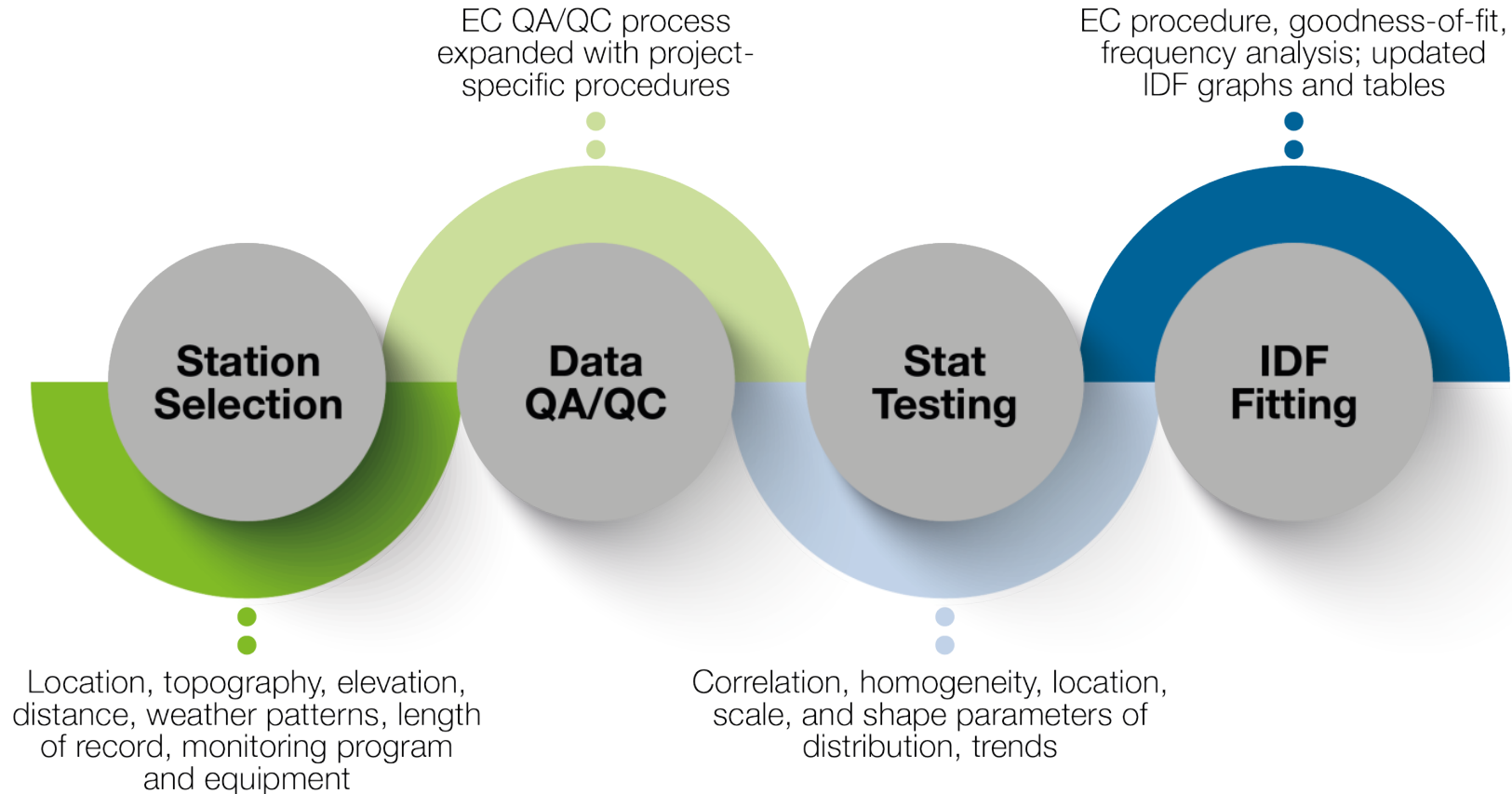
IDF Curve Update

Need for IDF curve update

- Rainfall has already been increasing in some areas – need to capture recent extreme rainfall events
- Future climate IDF curves are based on changes (deltas) from current climate IDF curve



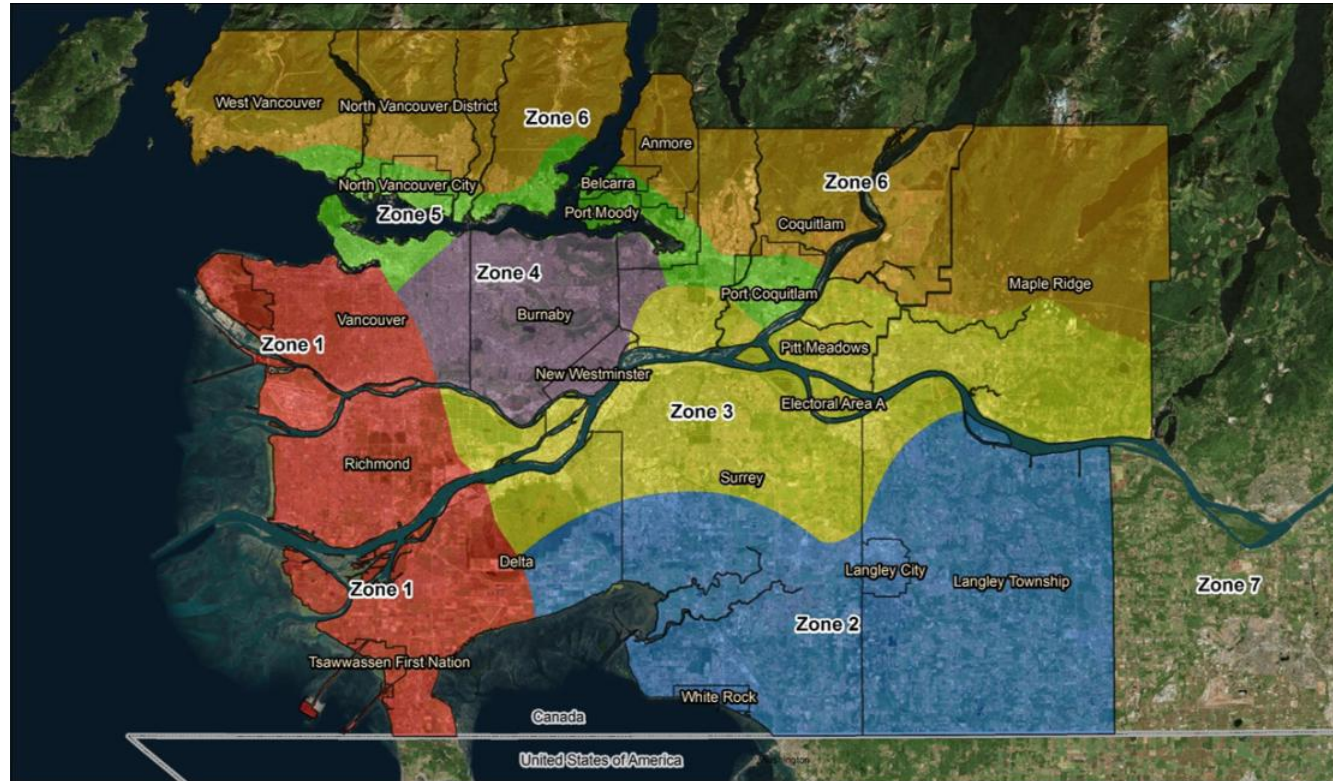
IDF Curve Update



IDF Curve Update

Regional Rainfall Frequency Analysis (RRFA)

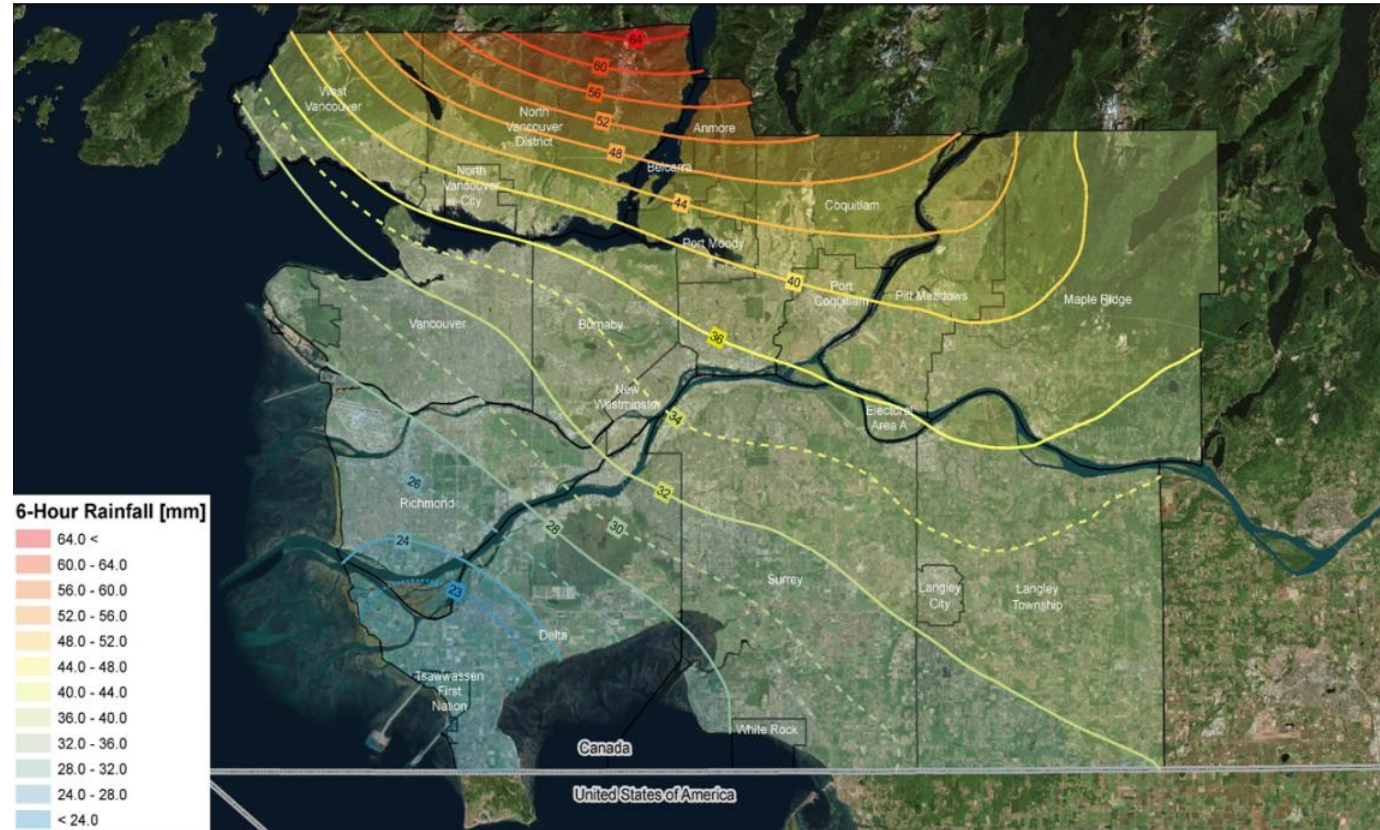
- 74 stations
- 6 rainfall zones
- Homogeneous for durations from 5-min to 24-hr



IDF Curve Update

Index Rain

- Increasing rainfall in northerly direction
- Coastal rainfall characteristics different from stations further inland

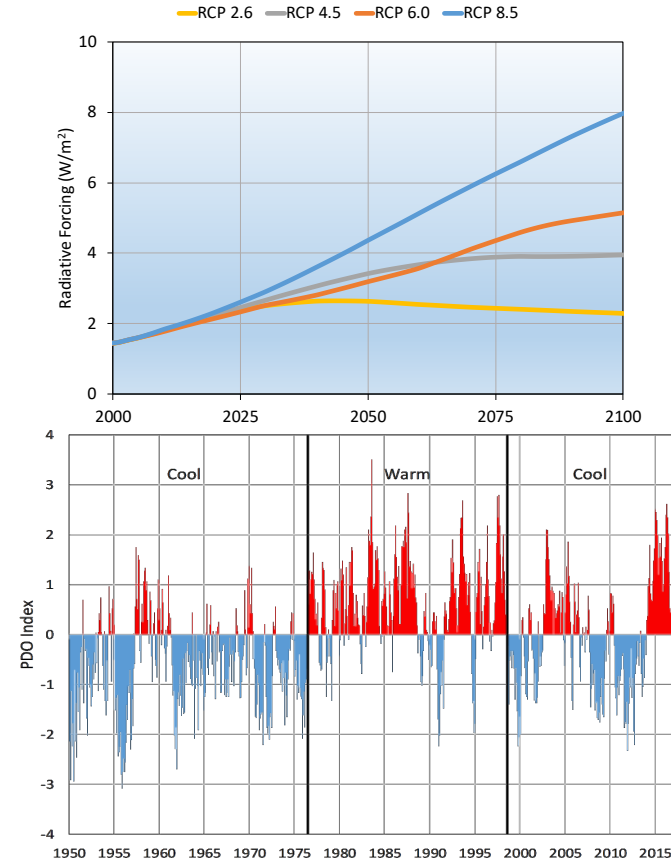


Future Climate IDF Curves

Engineering design need

Challenges

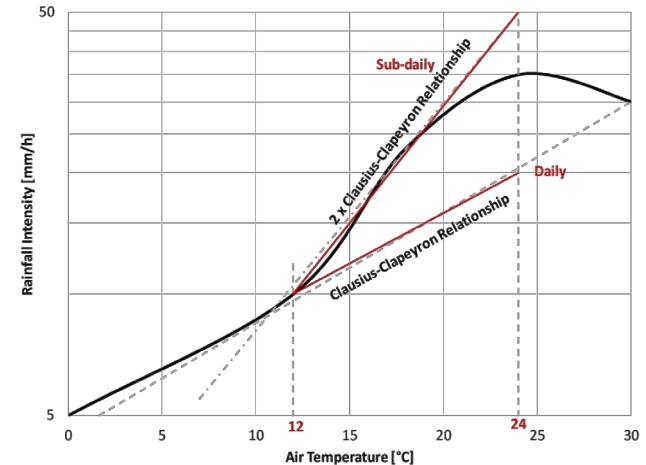
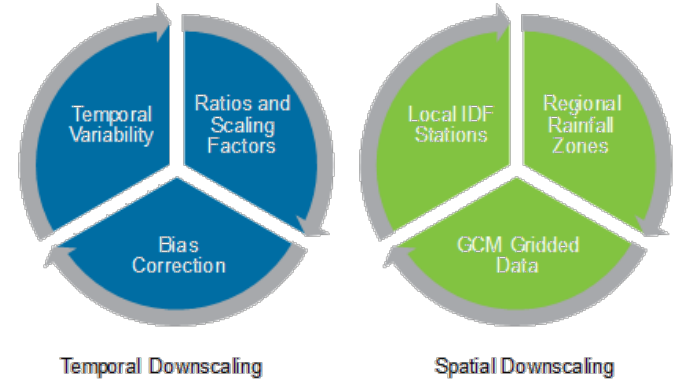
- Numerous uncertainties: different GCMs, future GHG emissions, spatial and temporal resolutions, downscaling methods
- Local climate variability
- No standard or accepted methodology, guidelines, etc.



Future Climate IDF Curves

Developed new methodology

- Collaborated with Pacific Climate Impacts Consortium (PCIC)
- RCP scenarios (5th assessment report IPCC)
- Spatial downscaling (grids to regions)
- Temporal downscaling (daily to sub-daily) with bias correction:
 - Clausius-Clapeyron (C-C) relation
 - Sub-daily scaling ratios
 - Quantile mapping

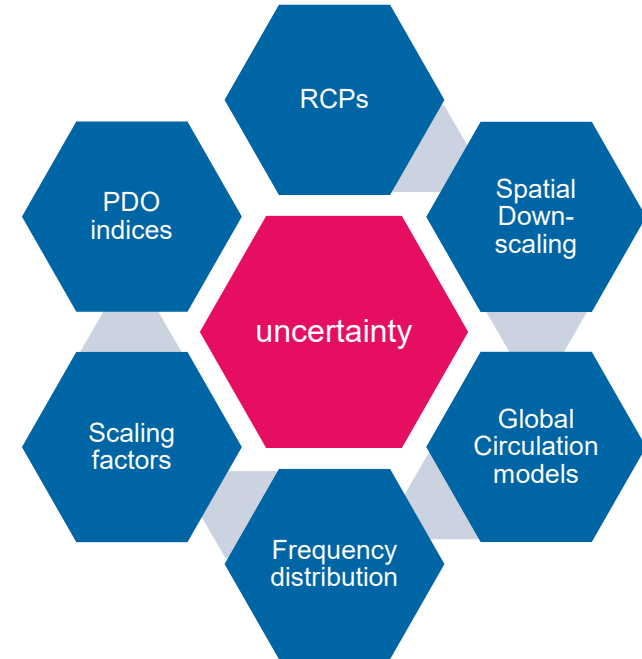


Future Climate IDF Curves

Sensitivity Analysis

- Determine range in future climate IDF curves
- Identified sources of uncertainty
- Simulated all combinations of each type of uncertainty

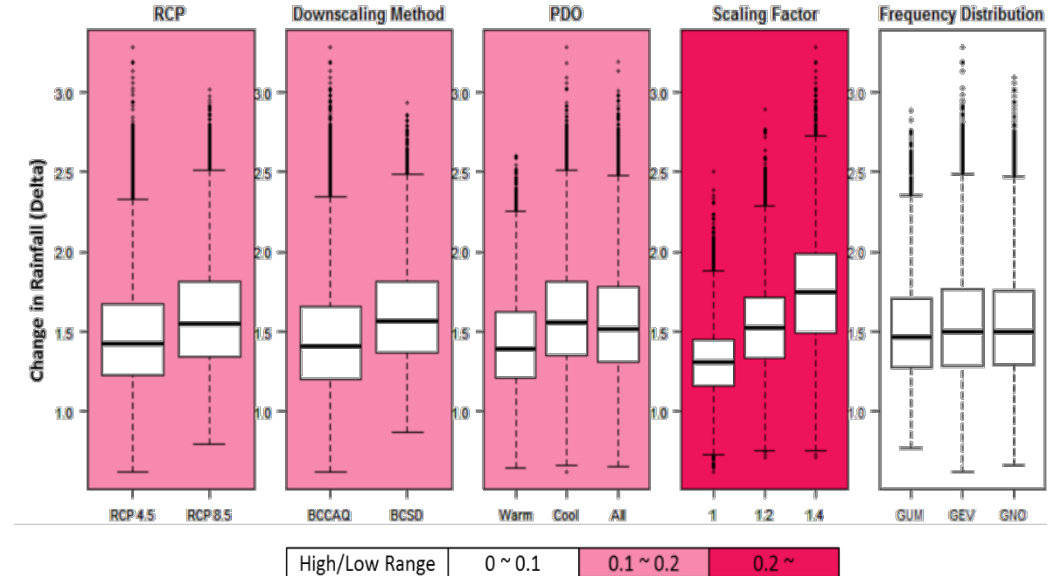
Source of Uncertainty	Number of Levels
GCMs	12
RCP scenarios	2
Spatial downscaling methods	2
Pacific Decadal Oscillation	3
Sub-daily scaling factors	3
Frequency distributions	3
IDF durations	9
IDF return periods	7
Total combinations	81,648



Future Climate IDF Curves

- Scaling factor (from C-C relation) was most sensitive parameter
- Selected parameters for IDF curves

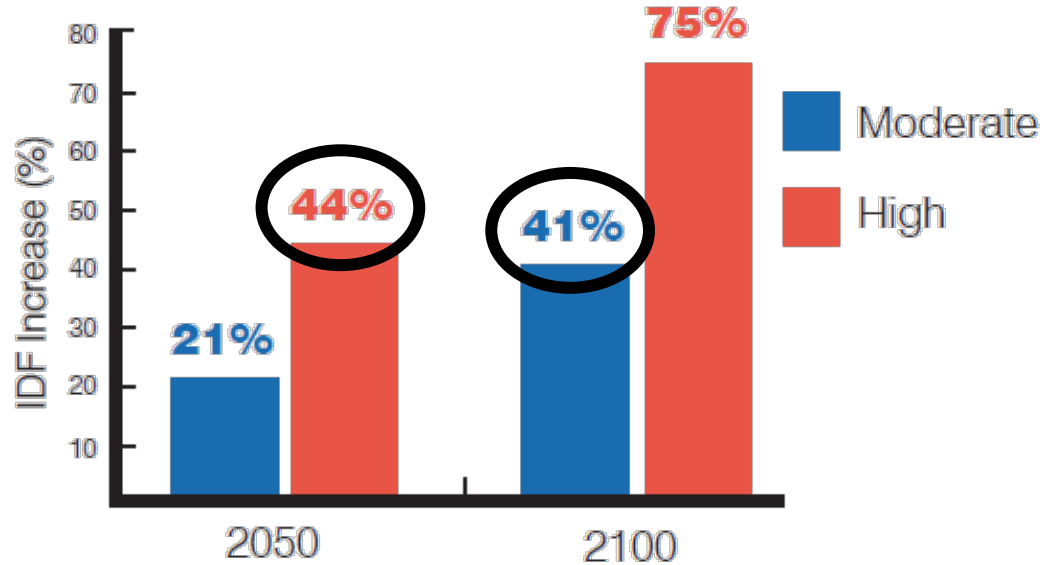
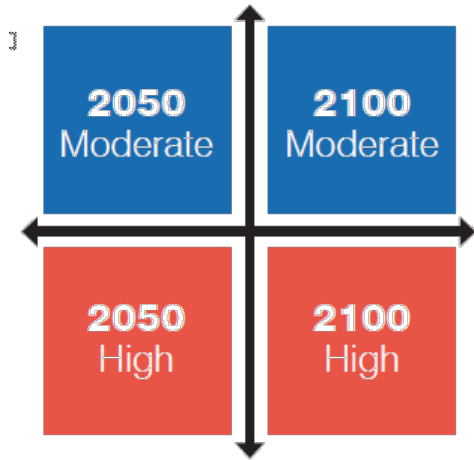
Source of Uncertainty	Selected Value
RCP scenario	RCP8.5
Spatial downscaling method	BCCAQ
Pacific Decadal Oscillation	Both Warm and Cool
Sub-daily scaling factor	1.0
Frequency distribution	Gumbel
Ensemble – Moderate climate change – High climate change	Median 95 th percentile



Future Climate IDF Curves

Moderate = expected (median) projection

High = 95th percentile projection



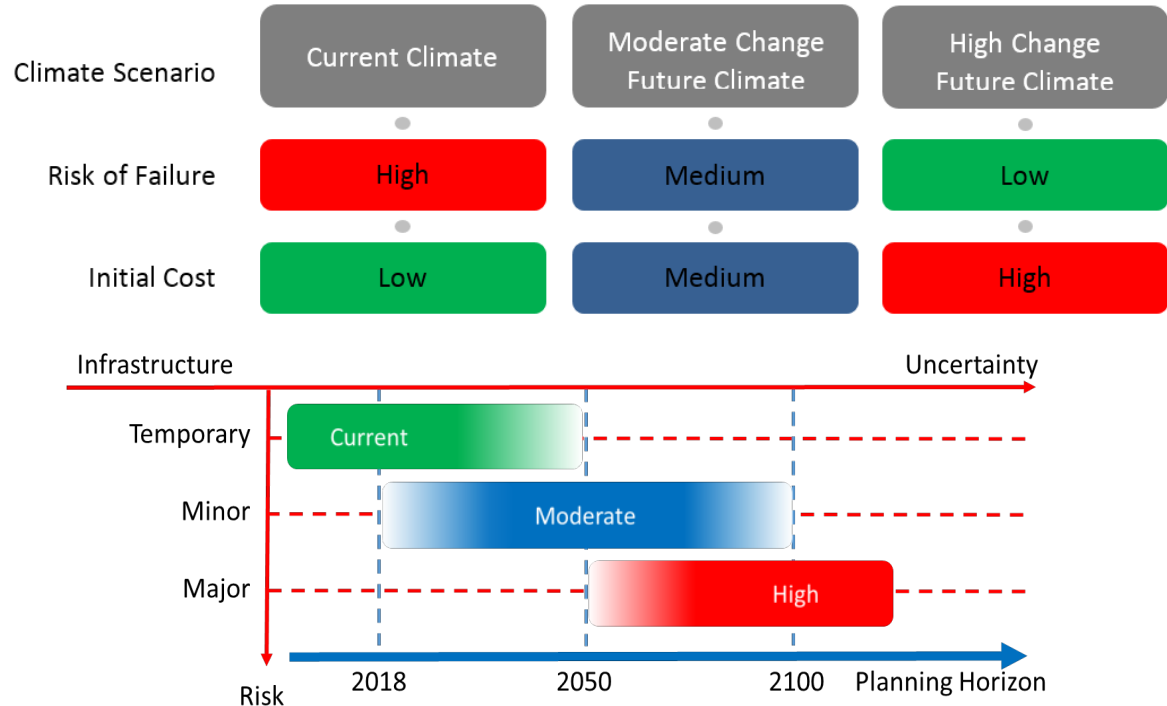
Selection of IDF Curve

Design involves uncertainty

- Design to reduce risk = high cost
- Design to reduce cost = high risk

Select scenarios based on:

- Risk/consequence of failure
- Planning horizon



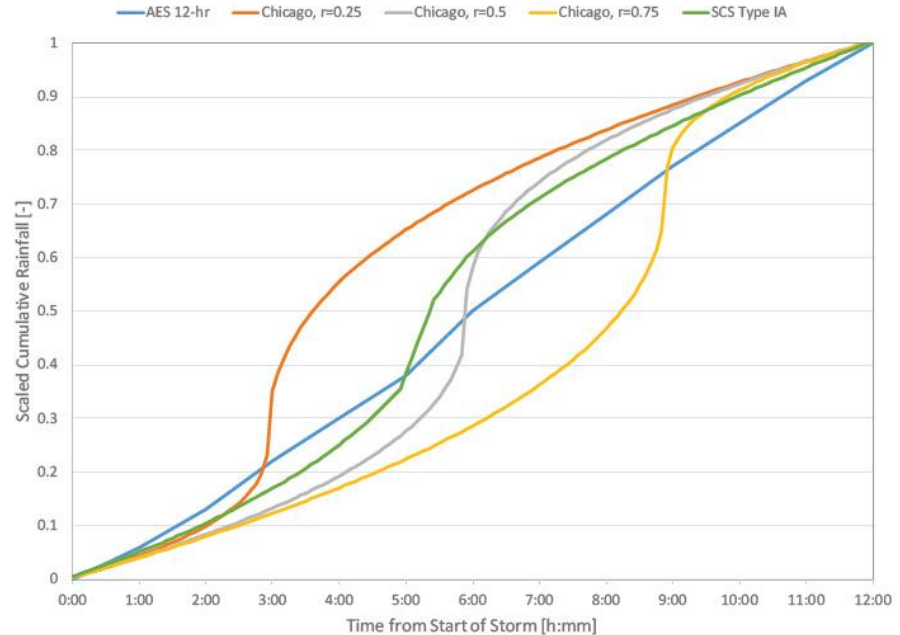
Design Storm Analysis

Purpose

- Determine which design storms are suitable for Metro Vancouver

Candidate Storms

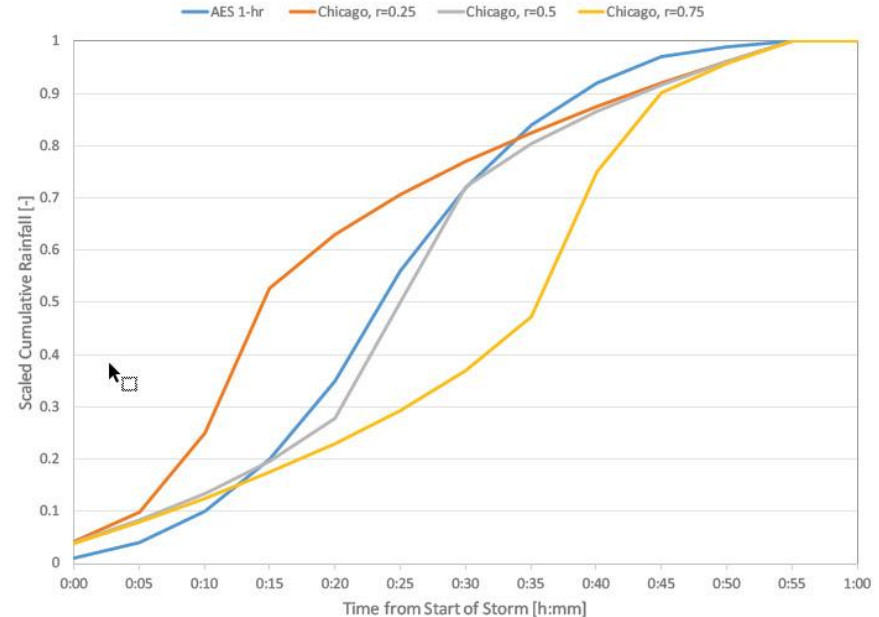
- SCS Type IA: 6-hr, 12-hr, and 24-hr
- AES BC Coast: 1-hr and 12-hr
- Chicago storm: 1-hr to 24-hr



Design Storm Analysis

Methodology

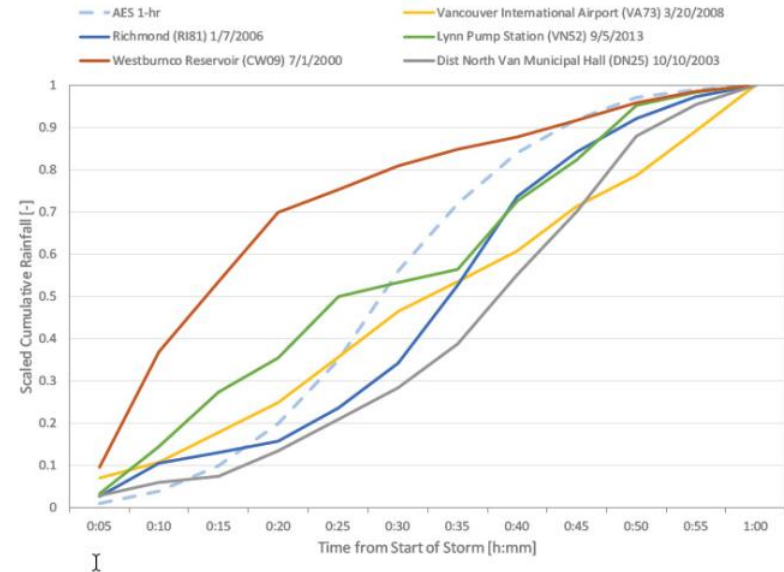
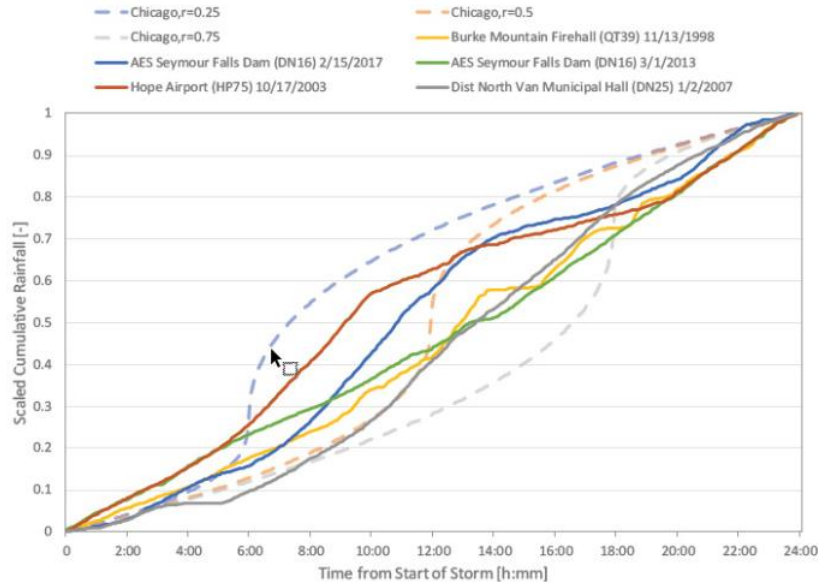
- Review historical storms
- Independent events (not part of a larger storm)
- Durations: 1-hr to 24-hr
- Return Periods: <25 yr, 25-75 yr, >75 yr
- Locations throughout Vancouver
- Scale historical storms and plot cumulative storm pattern
- Compare to candidate storms



Design Storm Analysis

Results

- Short duration events – high intensity
- Long duration events – low intensity



Design Storm Analysis

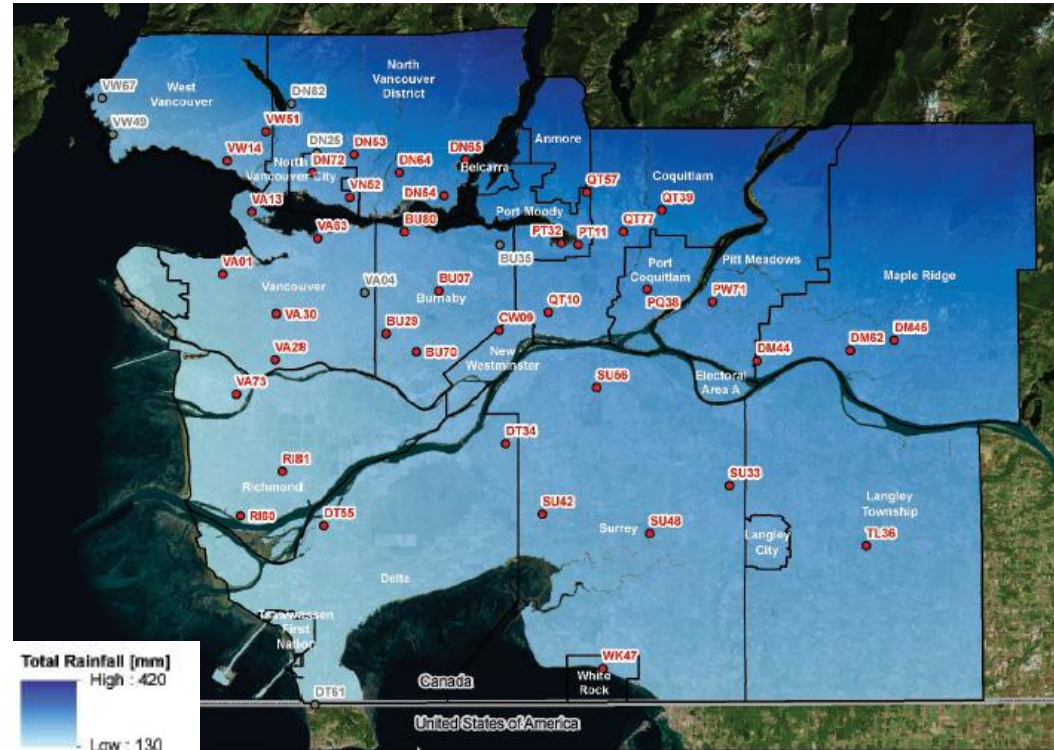
Results

Duration/ Synthetic Storm	1-3 Hours	6-24 Hours
AES	✓	✓
Chicago	✓	✗
SCS Type IA	✗	✓

Historical Storm Analysis

Purpose

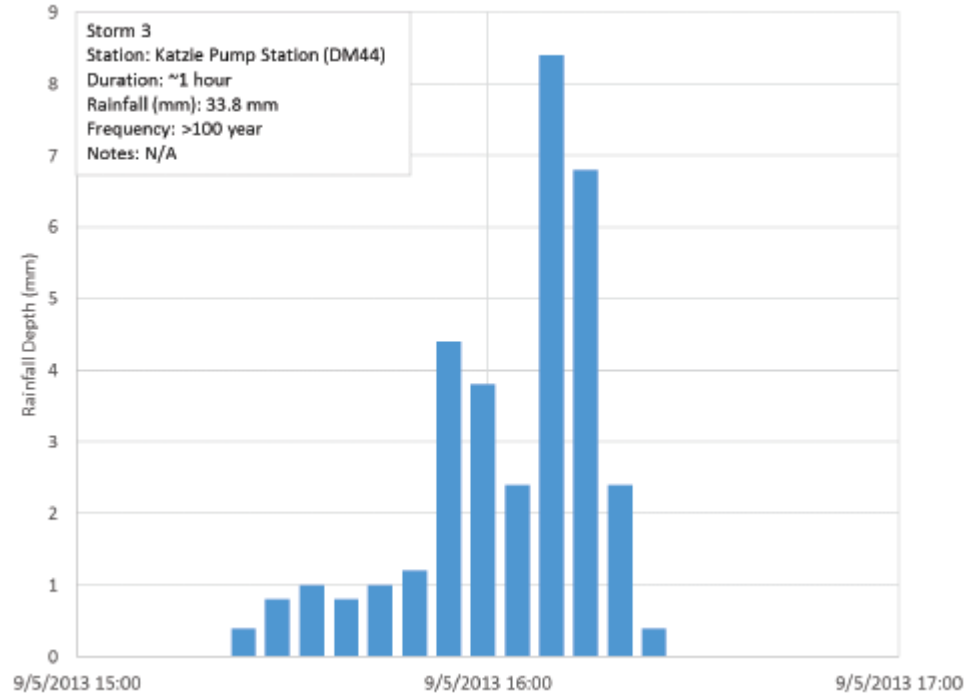
- Identify significant historical storms for Metro Vancouver
 - Short duration (up to 6 hrs)
 - Long duration (up to 96 hrs)
- To be used in addition to design storms
- Develop method for scaling historical storms



Design Storm Analysis

Methodology

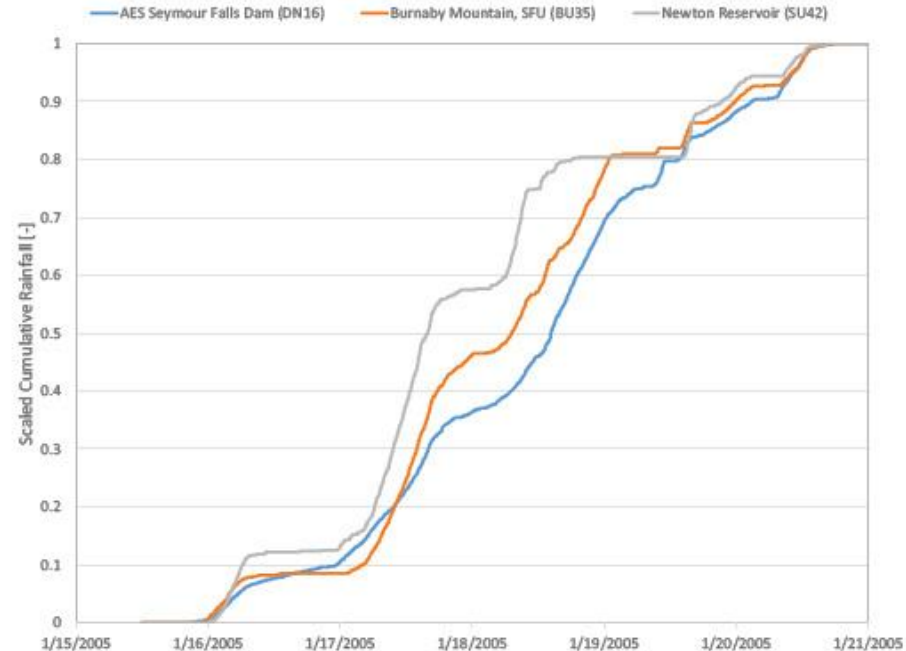
- Identify historical storms
- Selection factors:
 - Duration
 - Intensity
 - Total rainfall
 - Regional applicability
- Scale storms
 - To use with future climate IDF curve rainfall estimates



Design Storm Analysis

Results

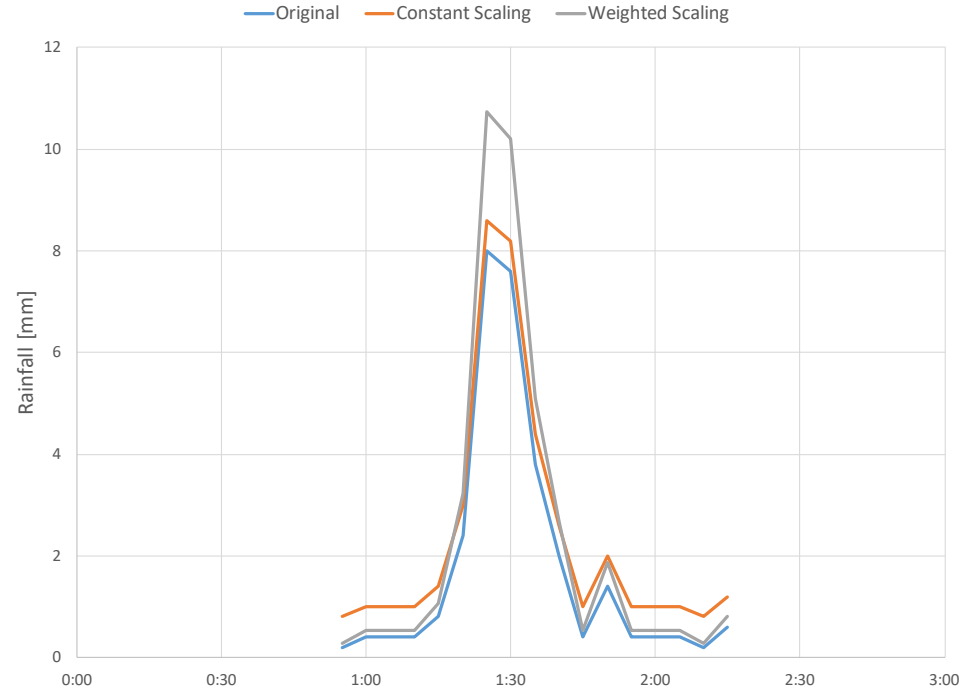
- Short duration events
 - Intense storm
 - Regionally applicable
- Long duration events
 - Atmospheric River (“Pineapple Express”)
 - Last several days
 - High rainfall accumulation



Design Storm Analysis

Scaling

- Scale to Future Climate IDF rainfall totals
- Constant Scaling
 - All timesteps raised by constant amount
- Weighted Scaling
 - Peak rainfall is enhanced
 - Short duration (peak) rainfall is expected to increase faster than long duration rainfall
 - Selected methodology



Spreadsheet Tool

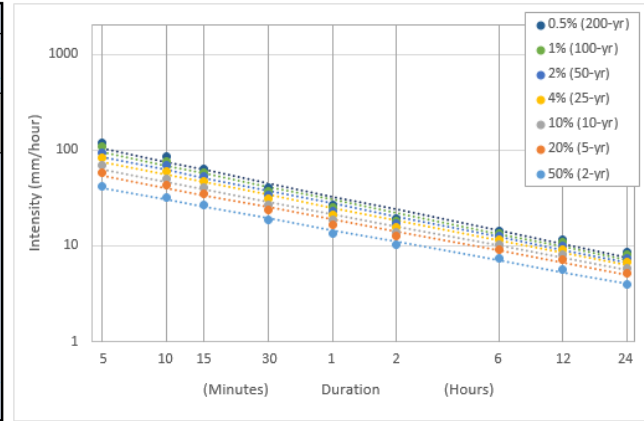
Purpose

- Simplify derivation of IDF Curves
- Generate design storms
- Generate historical storms
- Simple, drop down menus

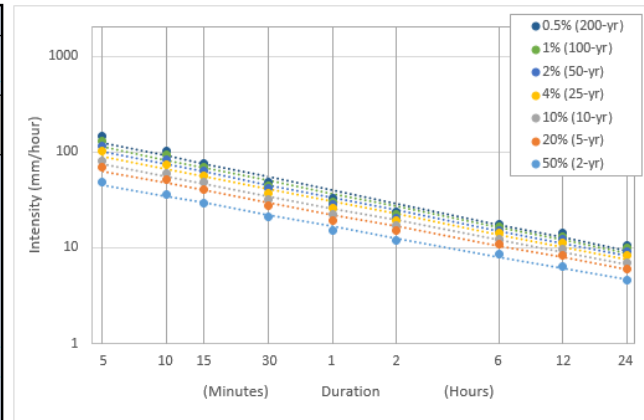
Input Data to Generate Current and Future IDF Curves				
(1) Select from drop-down menu for zone.				
Homogeneous Zone of Study Area				Zone 6
(2) Enter contour map estimates of index rain. If no index rain estimate is provided for a duration, the average index rain for the zone will be used. Note: index rain must be positive, within the range provided, and increase as duration increases. Invalid data are marked in red.				
Duration	Index Rain Values (mm)			
	Average	Valid Range	User-Specified	Error Message
5-min	3.8	3.40 - 3.75	3.70	
10-min	5.7	5.2 - 6.1	6.0	
15-min	7.0	6.3 - 7.3	6.6	
30-min	9.7	8.7 - 10.5	9.0	
1-hr	13.9	12.0 - 16.2	13.0	
2-hr	21.5	17.0 - 28.0	19.0	
6-hr	46.0	31.0 - 66.0	35.0	
12-hr	70.2	44.0 - 98.0	45.0	
24-hr	101.0	63.0 - 135.0	75.0	
(3) Once the data have been input above, the Current and Future Climate IDF curves will be generated to the right.				

Spreadsheet Tool

Current IDF Curve		Total Rainfall in mm							Zone 6
Annual Exceedance Probability	Return Period	50%	20%	10%	4%	2%	1%	0.50%	
$I = AxT^b$	A	14.672	18.873	21.606	25.134	27.662	30.233	32.773	
I in mm/hour, T in hour	B	-0.408	-0.421	-0.429	-0.440	-0.447	-0.455	-0.462	
5-min		3.5	4.8	5.7	7.0	7.9	9.0	10.0	
10-min		5.3	7.2	8.4	10.1	11.4	12.7	14.1	
15-min		6.6	8.7	10.1	11.9	13.2	14.5	15.9	
30-min		9.3	11.8	13.5	15.6	17.1	18.6	20.1	
1-hr		13.3	16.4	18.5	21.2	23.1	25.1	27.0	
2-hr		20.8	25.3	28.1	31.4	33.8	36.0	38.2	
6-hr		44.5	55.2	61.7	69.5	75.0	80.1	85.0	
12-hr		67.4	85.3	96.6	110.3	120.1	129.4	138.4	
24-hr		96.4	123.6	141.1	162.9	178.7	194.1	209.2	



2050 Moderate IDF Curve		Total Rainfall in mm							Zone 6
Annual Exceedance Probability	Return Period	50%	20%	10%	4%	2%	1%	0.50%	
$I = AxT^b$	A	16.710	22.321	25.920	30.375	33.538	36.762	39.959	
I in mm/hour, T in hour	B	-0.405	-0.420	-0.426	-0.438	-0.444	-0.452	-0.460	
5-min		4.0	5.7	6.8	8.5	9.6	10.9	12.2	
10-min		6.0	8.5	10.0	12.1	13.7	15.4	17.1	
15-min		7.4	10.2	12.0	14.2	15.8	17.5	19.2	
30-min		10.5	13.8	16.1	18.7	20.6	22.4	24.3	
1-hr		15.1	19.3	22.2	25.6	28.0	30.5	32.9	
2-hr		24.0	30.2	34.1	38.3	41.4	44.2	47.0	
6-hr		51.3	65.9	74.9	84.9	91.9	98.4	104.7	
12-hr		77.3	101.4	116.7	134.2	146.6	158.3	169.7	
24-hr		110.1	146.5	170.0	197.5	217.4	236.8	255.8	



Spreadsheet Tool

Input Data to Generate Design Storms

- (1) Enter information on Current and Future IDF Curves page
- (2) Select synthetic design storm distribution.

Design Storm Distribution **Chicago**

Notes: GHD expanded/contracted from AES 1-hr and 12-hr distributions to get other AES storm durations. SCS 6-hr and 12-hr were extracted from SCS 24-hr distribution.

- (3) Select duration.

Duration **3-hr**

- (4) Select annual exceedance probability (AEP).

AEP (Return Period) **1% (100-yr)**

- (5) For Chicago distribution, enter ratio to time of peak ($0 < r < 1$).

Ratio **0.35**

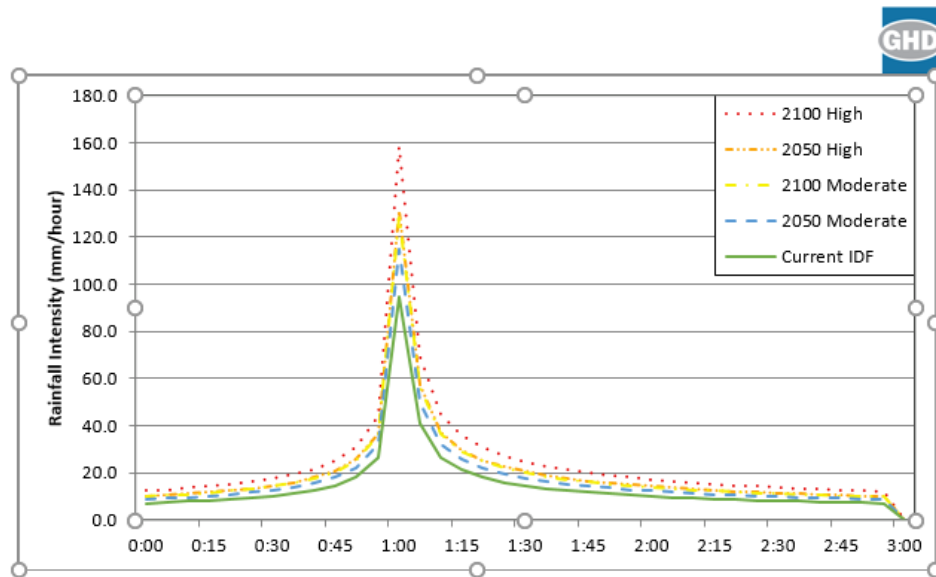
[Click Here to Generate Synthetic Design Storm](#)

[Click Here to Clear Output](#)

Design Storm:

3-hr Chicago
1% (100-yr)
Zone 6

Climate Change Scenarios:
2050 Moderate Future Rainfall
2050 High Future Rainfall
2100 Moderate Future Rainfall
2100 High Future Rainfall



Spreadsheet Tool



Input Data to Generate Design Storms

- (1) Enter information on Current and Future IDF Curves page
- (2) Select duration.

Duration

- (3) If duration ≤ 24 -hr, is scaling required?

Scaling

- (4) If scaling = Yes, select annual exceedance probability.

AEP (Return Period)

[Click Here to Load
Historical Storm](#)

[Click Here to
Clear Output](#)

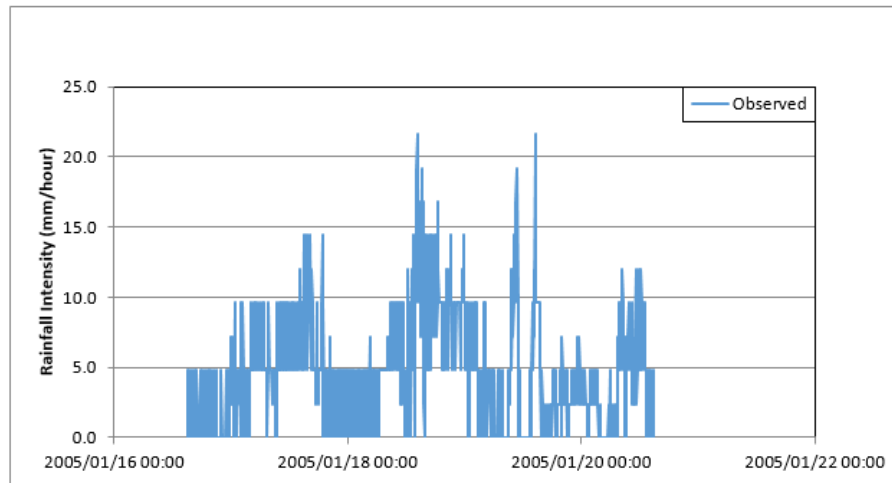
Observed Rainfall Data

Total Depth (mm)
442.8

Date/Time	Intensity (mm/hr)	Depth (mm)
2005/01/16 15:00	4.8	0.4
2005/01/16 15:05	0.0	0.0
2005/01/16 15:10	0.0	0.0
2005/01/16 15:15	4.8	0.4
2005/01/16 15:20	0.0	0.0
2005/01/16 15:25	0.0	0.0

Long Duration Historical Storm:

January 16, 2005
AES Seymour Falls Dam (DN16)
No scaling
Zone 6



Questions

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