Rainfall Weighting Factors for Stormwater Control Measure (SCM) Sizing

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- Founder/Owner of Hydroworks for past 22 years in New Jersey
- Stormceptor (Imbrium)
  - US General Manager (2000-2001)
  - Canadian Director of Engineering (1995-1999)
- Marshall Macklin Monaghan (WSP) (1986-1994)
  - Primary Author of 1994 MOE SWM Manual
- University of Guelph 1984, 1986

Rainfall Weighting Factors for Stormwater Control Measure (SCM) Sizing

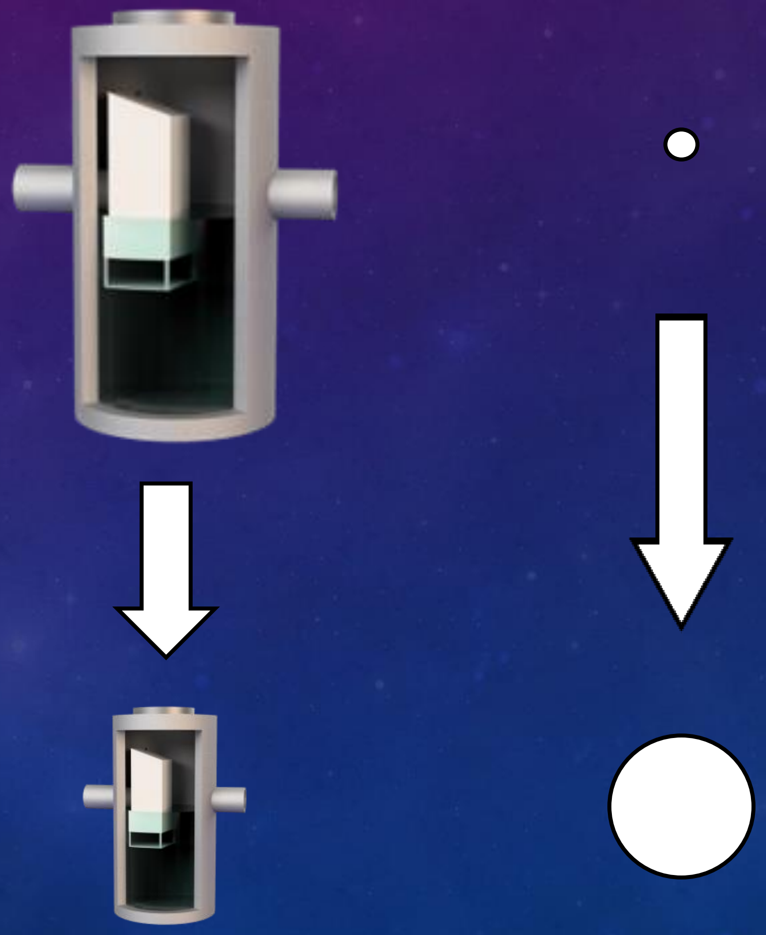
Key Issues for SCM Sizing

- Hydrology
- Particle Size Distribution

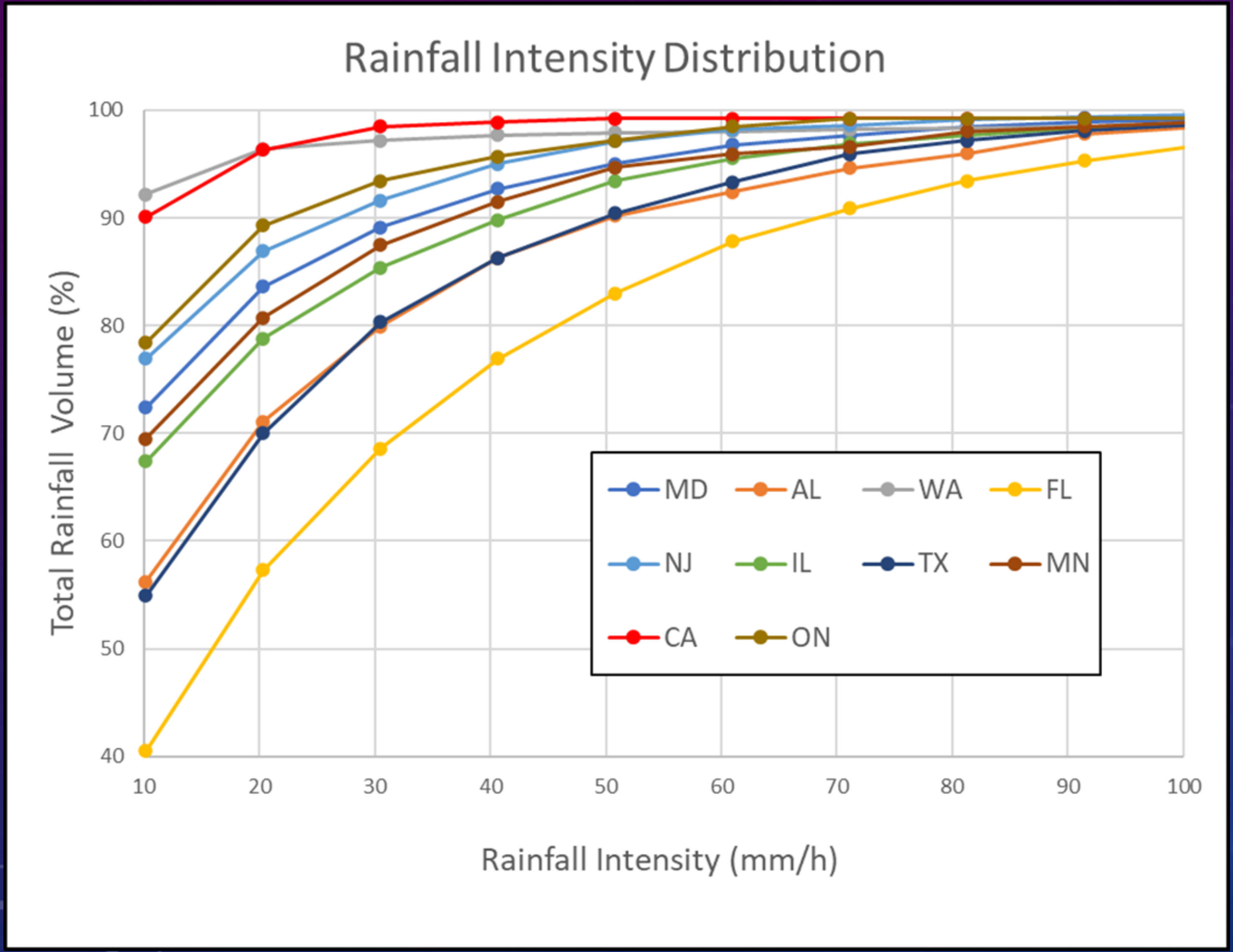
Particle Size Distribution (PSD)

- Defined in Laboratory Test Protocols
  - NJDEP HydroDynamic Separator
  - NJDEP Filter
  - TRCA OGS (ETV Canada)
- Undefined in Field Testing (TAPE, TARP)
  - You get what you get
  - Varies with site
  - Varies with storm
  - Creates inequitable verifications
- Design PSD <> Test PSD in all cases
  - Designs vary with agency acceptance

Size of MTD | Size of Particles



Hydrology



- Varies geographically and annually
- Long term precipitation records can be used to define the frequency distribution of precipitation intensities or weighting factors.
- The frequency distribution / weighting factors can be used in conjunction with lab testing to determine annual performance

Application of Weighting Factors

1. Define relationship between rainfall intensity and percentage of annual rainfall volume that occurs at each intensity.
2. Calculate flow rate for drainage area and imperviousness based on rainfall intensities
3. Determine pollutant removal at each flow rate based on verified testing
4. Multiply pollutant removal by % of annual rainfall volume that occurs at each flow rate /rainfall intensity (weighting factor)
5. Sum up pollutant removals for entire distribution of rainfall intensities (annual removal)

History of Weighting Factors

- Computer Model and Spreadsheet Sizing
- NJDEP laboratory protocol weighting factors (2002)
  - Weighting factors are incorrect for NJ hydrology
- ASTM E64 Subcommittee on Rainfall Weighting Factors (2022)
- City of Toronto Rainfall Weighting Factors (2023)
  - Hydroworks provided data to MECP/TRCA/Toronto demonstrating the design variability in Ontario with respect to precipitation intensity frequency distributions in 2022

Issues with Weighting Factors

- Weighting Factors Vary Based on:
  - Data Resolution of Precipitation (0.25 mm / 2.5 mm)
  - Temporal Resolution of Precipitation (5 min, 15 min, hourly)
  - Conversion of Precipitation to Runoff
  - Climate Change Adjustment of Historical Data
  - Pollutograph vs Hydrograph Timing
  - Precipitation Data Verification
- ASTM Standard
  - Provides a Standard Method to derive Weighting Factors

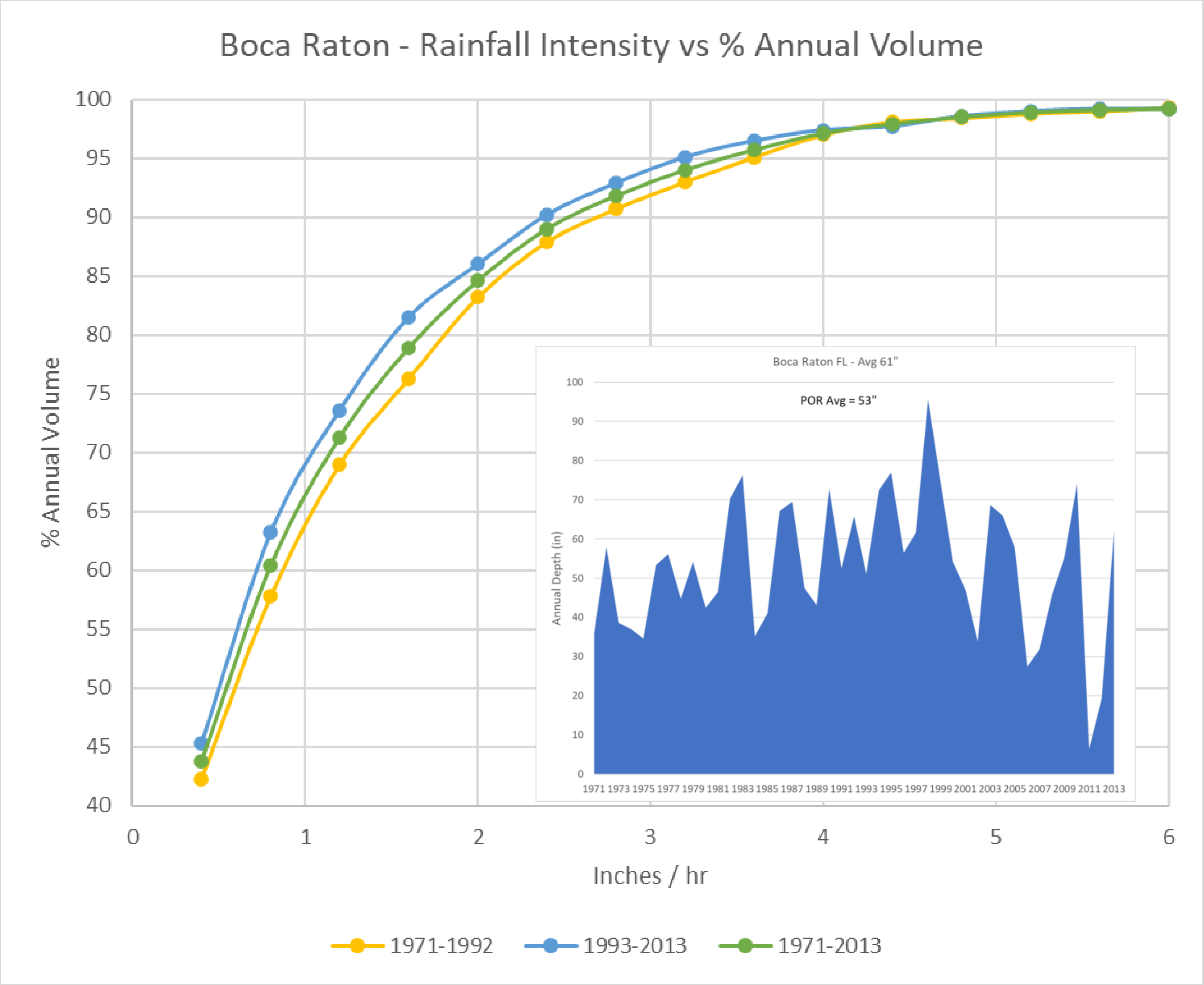
ASTM Standard Parameters

1. Data resolution
   - 0.01” (0.25 mm) data should be used if possible
   - 0.1” (2.5 mm) resolution = 0.4”/hr (10 mm/h) for the smallest 15 min rainfall intensity
2. Temporal resolution
   - Based on Tc of site (15 min or Hourly)
   - Hourly Data can be used if no 15 min data available
     - If Tc < 30 min hourly data must be discretized into 15 min based on seasonality

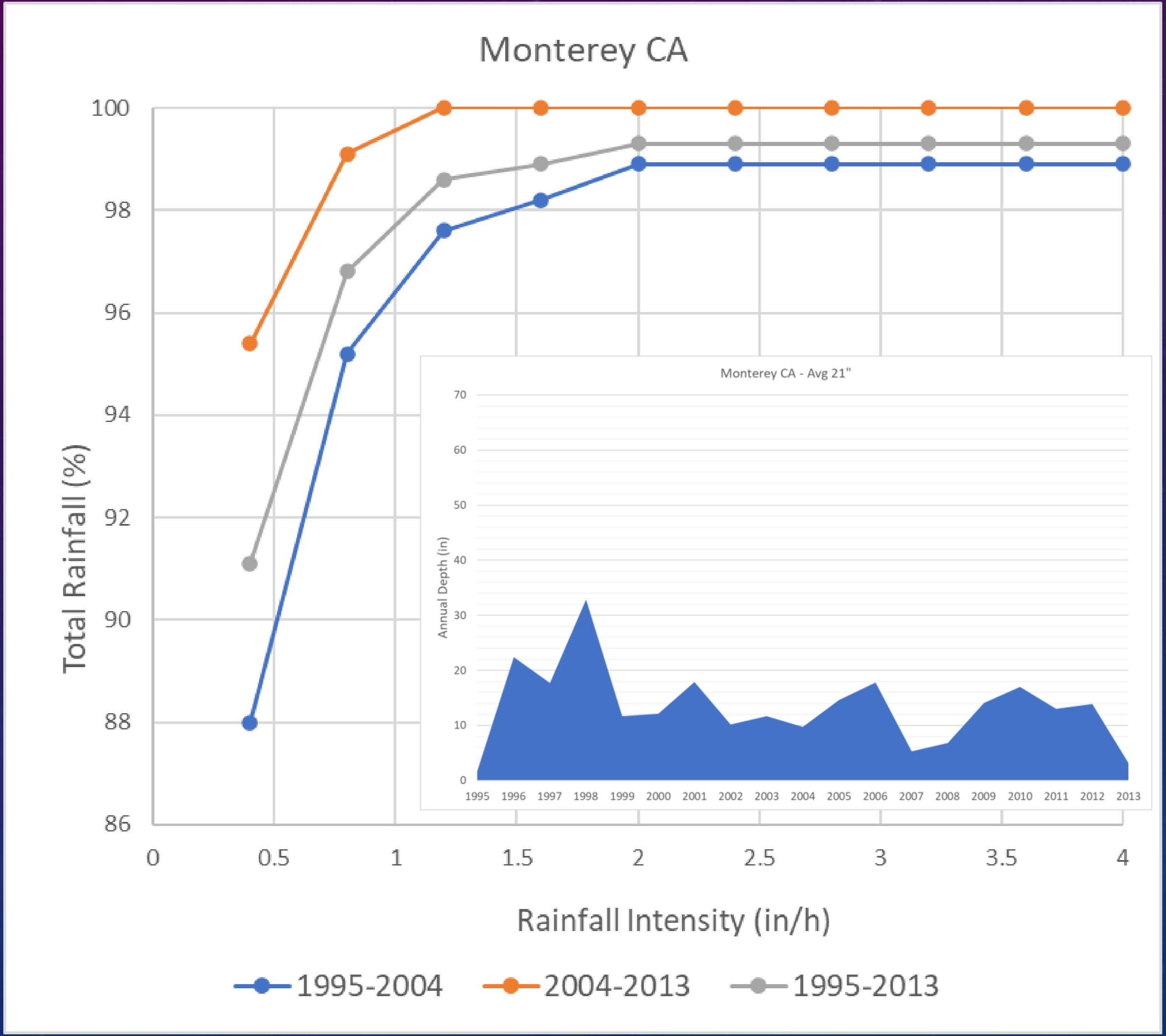
ASTM Standard Parameters

3. Conversion of Precipitation to Runoff
   - Initial abstraction of 2.54 mm
   - Initial abstraction depletes with initial precipitation and replenishes after 24 h of zero precipitation
4. Climate Change Adjustment
   - Reviewed several stations to determine trend over time
   - No consistent change due to many factors
     - Period of record, geographic location, changes in extremes, lack of most recent years data
     - Does not support a constant multiplication factor
   - Topic for future discussion/inclusion in this standard

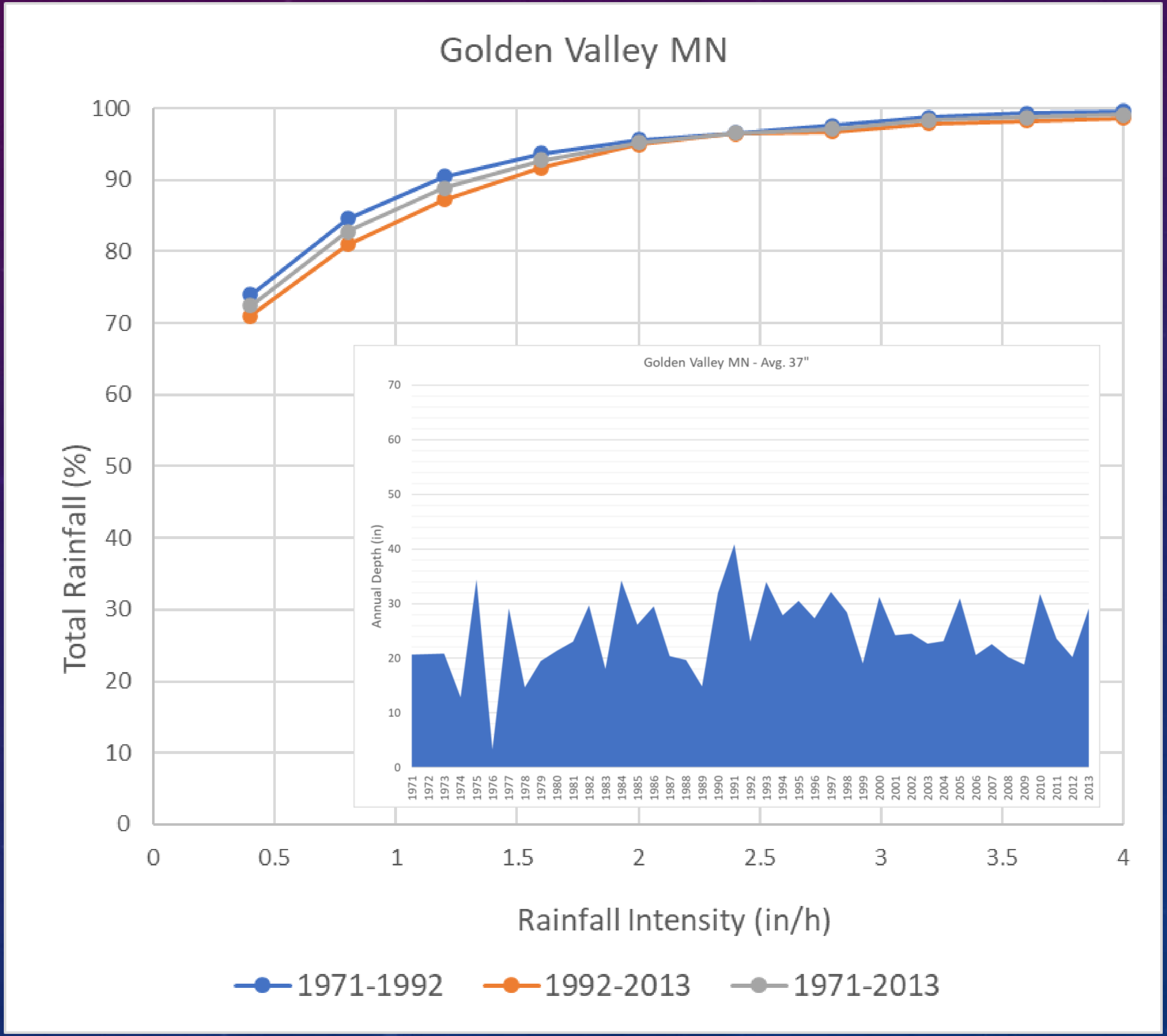
Precipitation Becoming Less Intense



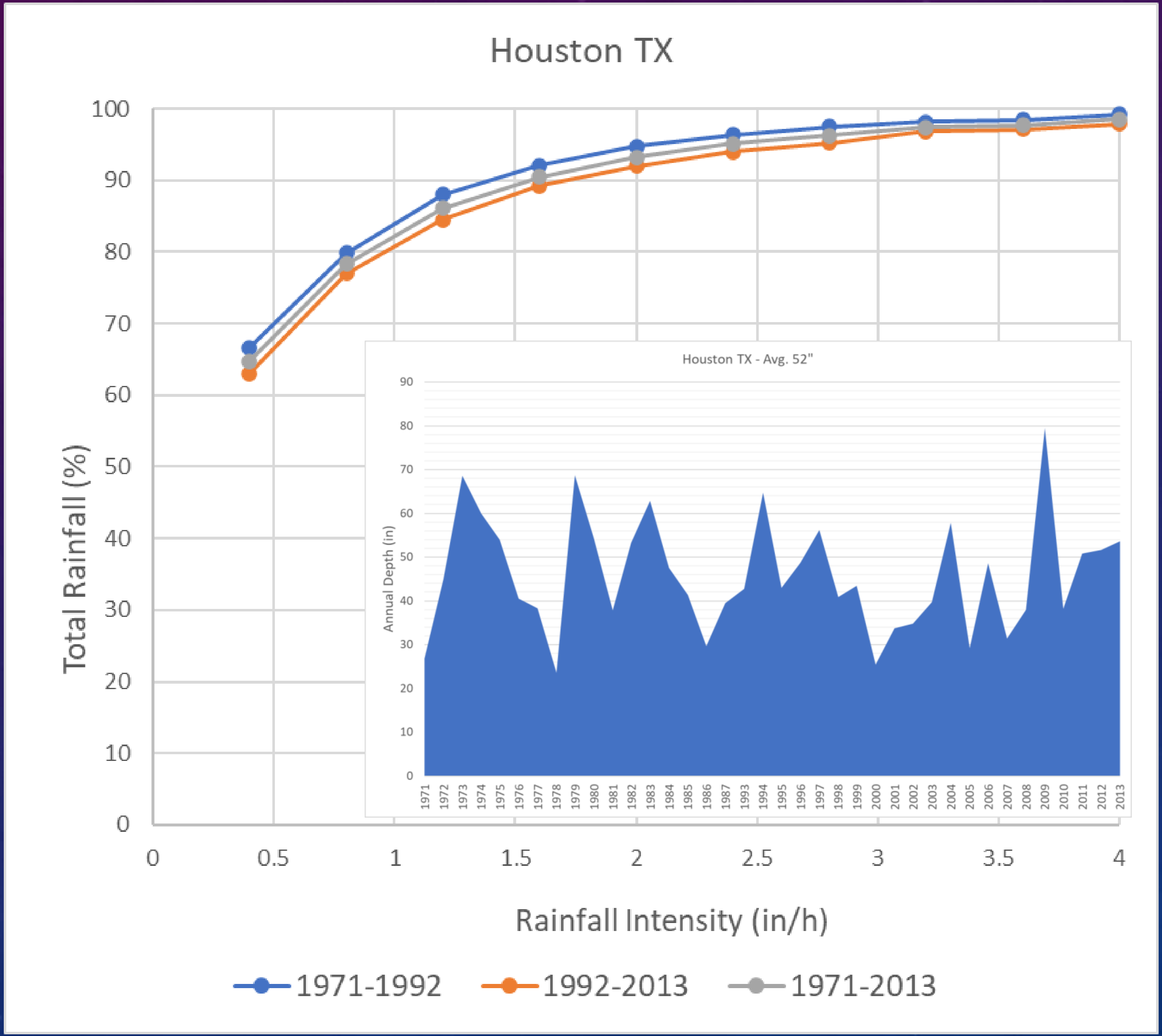
Precipitation Becoming Less Intense



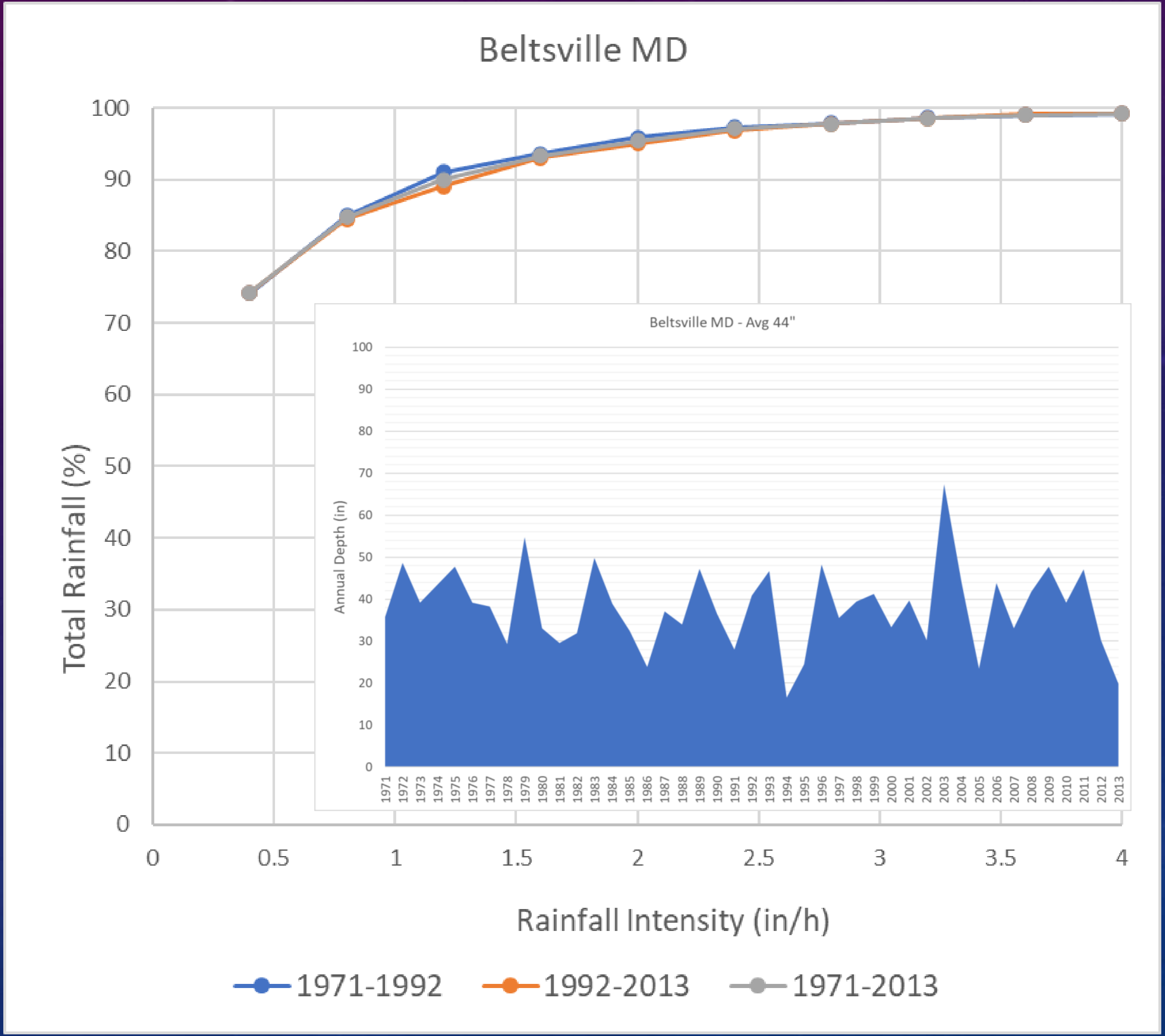
Precipitation Becoming More Intense



Precipitation Becoming More Intense



Precipitation Has Not Really Changed

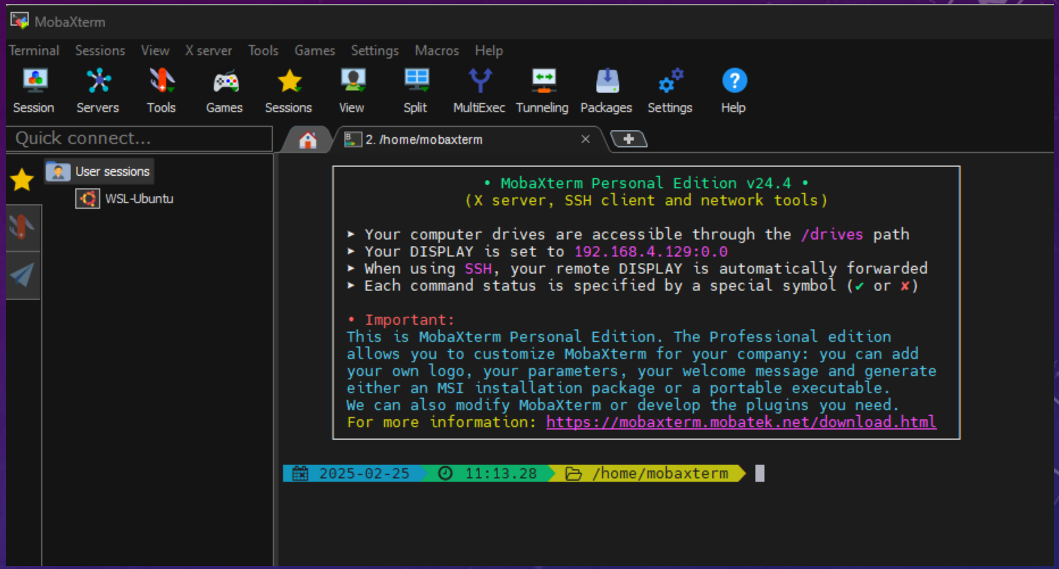


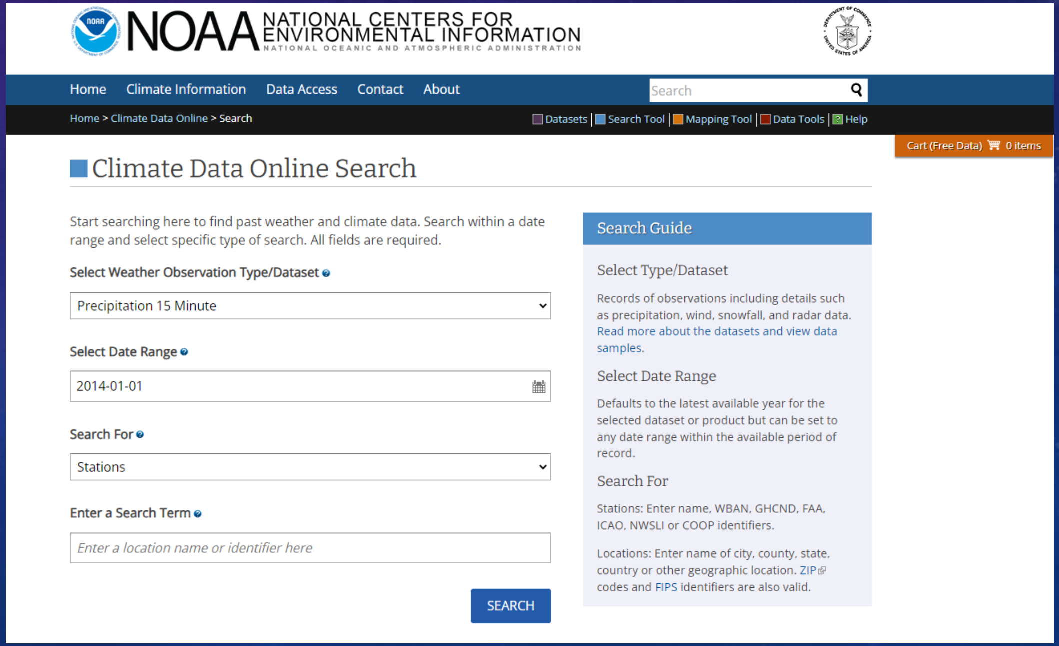
Precipitation Issues

5. Snow vs Rain
    - Current standard ignores difference and treats all precipitation as rain
6. Pollutograph vs Hydrograph
    - Have to assume EMC in spreadsheet calculations
    - Computer Models can use different buildup/washoff methods
        - ASTM Standard assumes EMC
        - More conservative than first flush

Precipitation Data

- Environment Canada
  - MobaXterm
    - Terminal line commands
    - Only hourly data
    - 15min must be requested
- NOAA
  - Web access





Have to review Precip Data

HoustonTX.err - Notepad

File Edit View

```
YEAR  MON  DAY  DEPTH (IN)

1996   3    7        2.80
1996   3    7        1.80
1996   3    7        1.60
2002   2    1        2.00
2002   2    1        4.00
2002  12    9        2.00
2003   3    3       80.00
2003   8    1        2.00
2003  10    6        5.70
2008  10   10        2.30
2012   3   19        2.40

# OF MISSING DAYS OF DATA        21
```

6.2" in one day ????

Ln 1, Col 1   100%   Windows (CRL

29.63 °N, 95.25 °W

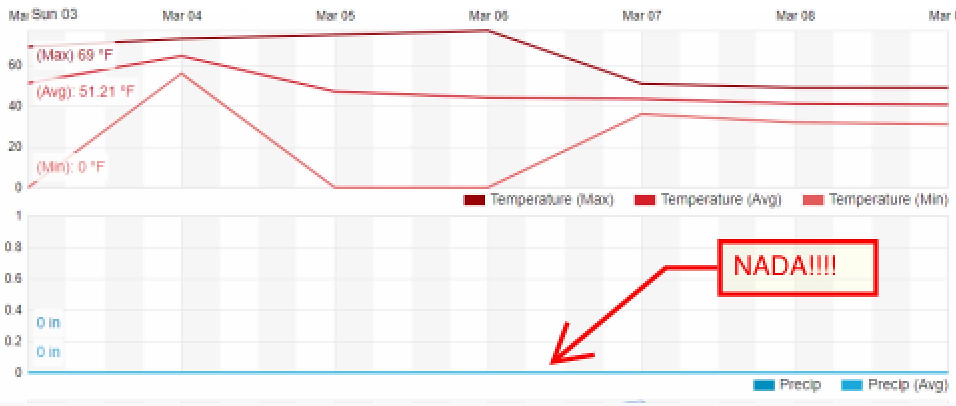
Houston, TX Weather History

65° WILLIAM P. HOBBY AIRPORT STATION | CHANGE

TODAY HOURLY 10-DAY CALENDAR HISTORY WUNDERMAP

Daily Weekly Monthly

March 7 1996 View



HoustonTX.txt - Notepad

File Edit View

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COOP:224265    HOUSTON MS US 19960307 14:15 0.10       HT   -9999
COOP:224265    HOUSTON MS US 19960307 14:45 0.16       HT   -9999
COOP:224265    HOUSTON MS US 19960307 15:15 0.59       HT   -9999
COOP:224265    HOUSTON MS US 19960307 15:30 0.96       HT   -9999
COOP:224265    HOUSTON MS US 19960307 18:00 1.12       HT   -9999
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COOP:224265    HOUSTON MS US 19960318 17:15 0.47       HT   0.10    HT
COOP:224265    HOUSTON MS US 19960318 17:30 0.48       HT   0.10    HT
COOP:224265    HOUSTON MS US 19960318 17:45 0.49       HT   0.10    HT
```

Ln 7769, Col 32   100%   Unix (LF)

Proposed Methodology

- Use 15 min or hourly rainfall files to determine rainfall intensity frequency curves
    - Based on time of concentration
    - Can use hourly if 15 min not available
        - Discretize into 15 min segments based on seasonality
- Include 0.1” (2.54 mm) initial abstraction to develop frequency curves
- Develop weighting factors for the annual rainfall volume
- Number of weighting factors varies by station
    - Add factors for every intensity that represents 2.5% or more of the annual rainfall volume
    - Maximum intensity increment is 10 mm/h for < 2.5% change in annual rainfall volume
- Do not adjust for snow vs rain
- Do not adjust for first flush
- Do not adjust for global warming
    - Can update weighting factors with more data in the future

Example of ASTM Standard

- City of Toronto 15 min data (.25 mm resolution)
- Years 1982-1999
- Initial Abstraction of 2.54 mm
- 24 h dry period reset for initial abstraction

- Fortran program
  - Reads in rainfall records
  - Modifies rainfall for initial abstraction values
  - Converts remaining runoff causing rainfall into rainfall intensities
  - Categorizes intensities into frequencies every 1 mm/h
  - Calculates the volume of stormwater per intensity frequency
  - Calculates the percentage of annual runoff per frequency by dividing the frequency volume by total volume of stormwater runoff

Toronto Central Full Distribution

mm/h	% Vol	Cum %Vol		mm/h	% vol	Cum %Vol
0.00	0.00	0.00		27.43	0.56	92.60
1.02	18.48	18.50		28.45	0.35	92.90
2.03	16.56	35.00		29.46	0.24	93.20
3.05	11.86	46.90		30.48	0.25	93.40
4.06	9.91	56.80		31.50	0.26	93.70
5.08	6.85	63.70		32.51	0.53	94.20
6.10	4.79	68.40		33.53	0.28	94.50
7.11	3.45	71.90		34.54	0.43	94.90
8.13	2.17	74.10		35.56	0.44	95.30
9.14	1.96	76.00		36.58	0.00	95.30
10.16	2.38	78.40		37.59	0.31	95.60
11.18	1.79	80.20		38.61	0.32	96.00
12.19	1.75	82.00		39.62	0.00	96.00
13.21	1.52	83.50		40.64	0.00	96.00
14.22	1.05	84.50		41.66	0.00	96.00
15.24	0.94	85.50		42.67	0.18	96.10
16.26	0.74	86.20		43.69	0.00	96.10
17.27	0.85	87.10		44.70	0.00	96.10
18.29	0.53	87.60		45.72	0.38	96.50
19.30	0.64	88.20		46.74	0.19	96.70
20.32	1.17	89.40		47.75	0.00	96.70
21.34	0.70	90.10		48.77	0.00	96.70
22.35	0.18	90.30		49.78	0.00	96.70
23.37	0.48	90.80		50.80	0.63	97.30
24.38	0.40	91.20		51.82	0.00	97.30
25.40	0.52	91.70		52.83	0.00	97.30
26.42	0.33	92.00		53.85	0.22	97.60

Consolidate Results

- Add values for every 2.5% change, and/or 10 mm/h
  - Ensures accurate definition of weighting table
  - Ensures no large gaps of rainfall intensity in weighting table for higher rainfall intensities
  - Reduces amount of calculations

mm/h	% Vol	Cum %Vol		mm/h	% vol	Cum %Vol
0.00	0.00	0.00		27.43	0.56	92.60
1.02	18.48	18.50		28.45	0.35	92.90
2.03	16.56	35.00		29.46	0.24	93.20
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5.08	6.85	63.70		32.51	0.53	94.20
6.10	4.79	68.40		33.53	0.28	94.50
7.11	3.45	71.90		34.54	0.43	94.90
8.13	2.17	74.10		35.56	0.44	95.30
9.14	1.96	76.00		36.58	0.00	95.30
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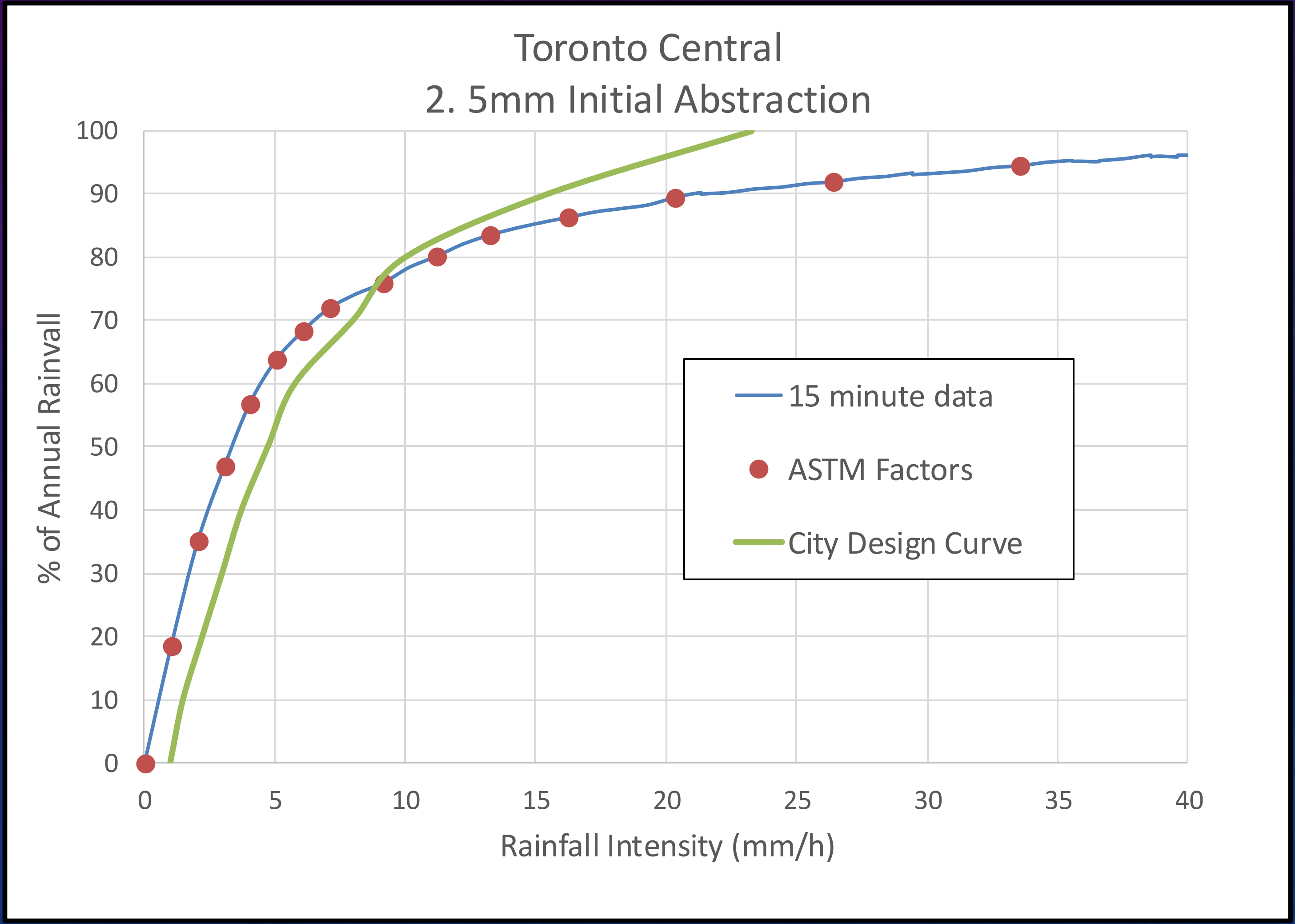
11.18	1.79	80.20		38.61	0.32	96.00
12.19	1.75	82.00		39.62	0.00	96.00
13.21	1.52	83.50		40.64	0.00	96.00
14.22	1.05	84.50		41.66	0.00	96.00
15.24	0.94	85.50		42.67	0.18	96.10
16.26	0.74	86.20		43.69	0.00	96.10
17.27	0.85	87.10		44.70	0.00	96.10
18.29	0.53	87.60		45.72	0.38	96.50
19.30	0.64	88.20		46.74	0.19	96.70
20.32	1.17	89.40		47.75	0.00	96.70
21.34	0.70	90.10		48.77	0.00	96.70
22.35	0.18	90.30		49.78	0.00	96.70
23.37	0.48	90.80		50.80	0.63	97.30
24.38	0.40	91.20		51.82	0.00	97.30
25.40	0.52	91.70		52.83	0.00	97.30
26.42	0.33	92.00		53.85	0.22	97.60

Final Table for Toronto

mm/h	Wt. Factor
1.0	0.185
2.0	0.166
3.0	0.119
4.1	0.099
5.1	0.069
6.1	0.048
7.1	0.035
9.1	0.041
11.2	0.042
13.2	0.033
16.3	0.027
20.3	0.032
26.4	0.026
33.5	0.025
43.7	0.016
53.8	0.015
65.0	0.014
75.2	0.006
106.7	0.004

TORONTO RAINFALL WEIGHTING FACTOR COMPARISON

- City Factors slightly different – Why?
- City combined data into hourly intensities
  - City less intense than ASTM at high intensities (hourly averaging)
- City set all hourly values <= 1 mm equal to zero
  - City more intense than ASTM at low intensities (deleted all low intensities)



SUMMARY

- ASTM is developing a standard to allow testing results from standardized testing protocols to predict annual removal based on local hydrology
- Pros
  - Simple
  - Standardized
- Cons
  - Simple
- Current Standard is a draft being sent to ballot
  - ASTM standards never pass on first ballot
  - Join ASTM E64 if you would like to collaborate /contribute to this standard or other stormwater standards currently being developed by ASTM