Climate Data Training Session for Municipal and Conservation Authority Engineers, Planners and Decision Makers
Ontario Science Centre - April 26, 2017

Evidence-Based Policy, Programs and Design Standards in Municipal Engineering to Adapt to Extreme Weather and Climate Change

Robert J. Muir, M.A.Sc., P.Eng.

Manager, Stormwater, City of Markham

Blogger in Chief: www.CityFloodMap.com

Contributor: Open During Construction Podcast on iTunes

Twitter: @RobertMuir_PEng

Outline

- **Data-driven, Evidence-based Risk Management:**
  - **Policy, Programs, Priorities for Remediation**
  - **Design Practices & Resiliency for New Development**
- **Responding to Non-technical Reports & Media**
- **Quantifying Risk Factors and Design Practice Adaptation**
  - **Hydrology – intensification, return period safety factors**
  - **Meteorology – critical hyetographs selection, past IDF trends & climate change projections (safety factors & stress tests)**
- **Stress Tests for System Resiliency Future IDF**
  - **PCSWMM minor and major system hydrologic/hydraulic assessment**
  - **InfoWorks sanitary surcharge / basement back-up assessment**
- **Adaptation Measures (municipal & private)**

History of Flooding & Known Design Limitations Drive Policy, Programs and Priorities for Risk Reduction

MARKHAM
FLOOD CONTROL
PROGRAM

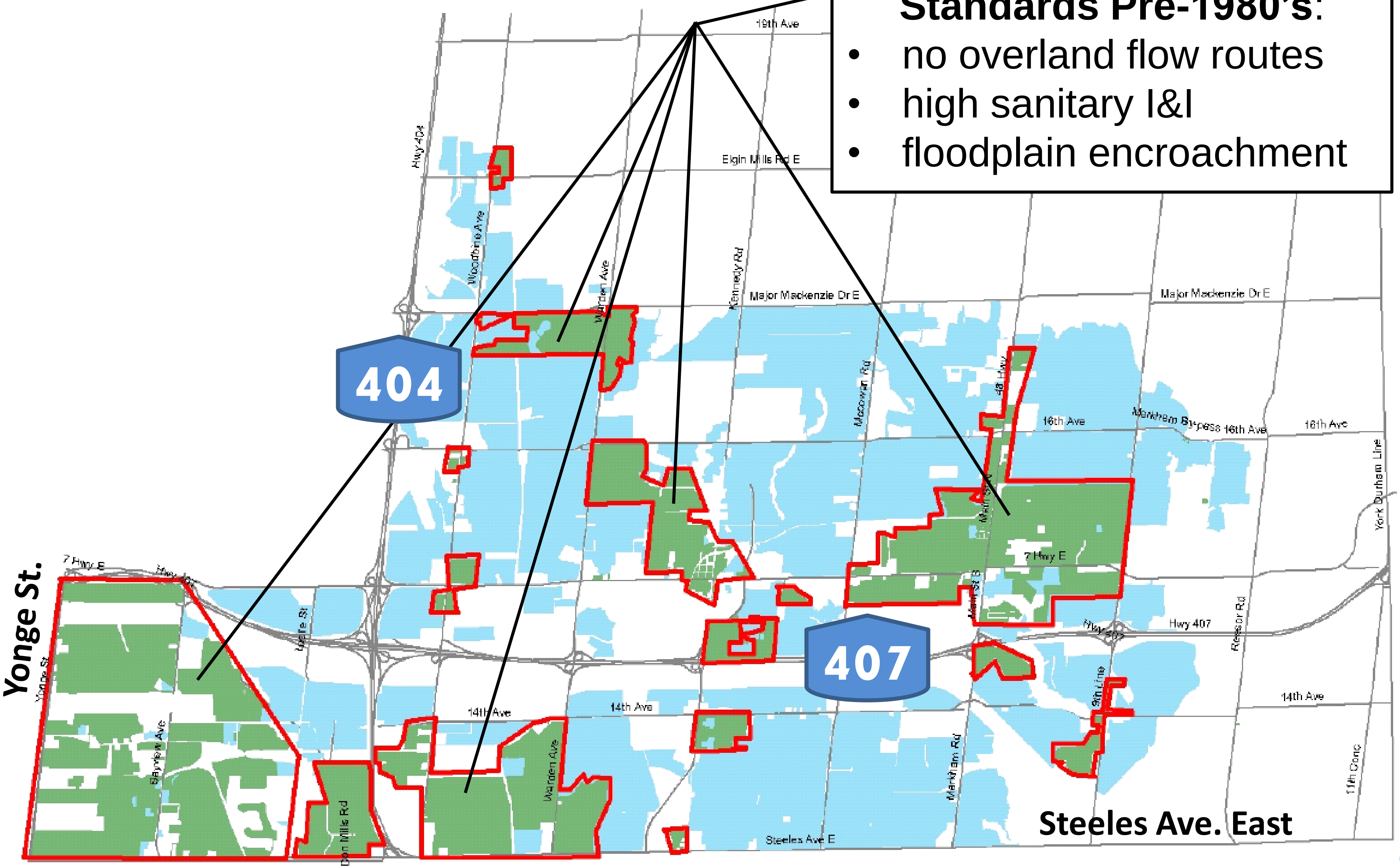
West Thornhill – August 19, 2005 (> 100 year)

Don Mills Channel
August 19, 2005

Where Priorities for Risk Mitigation ?

Potentially Limited Design Standards Pre-1980's:

- no overland flow routes
- high sanitary I&I
- floodplain encroachment



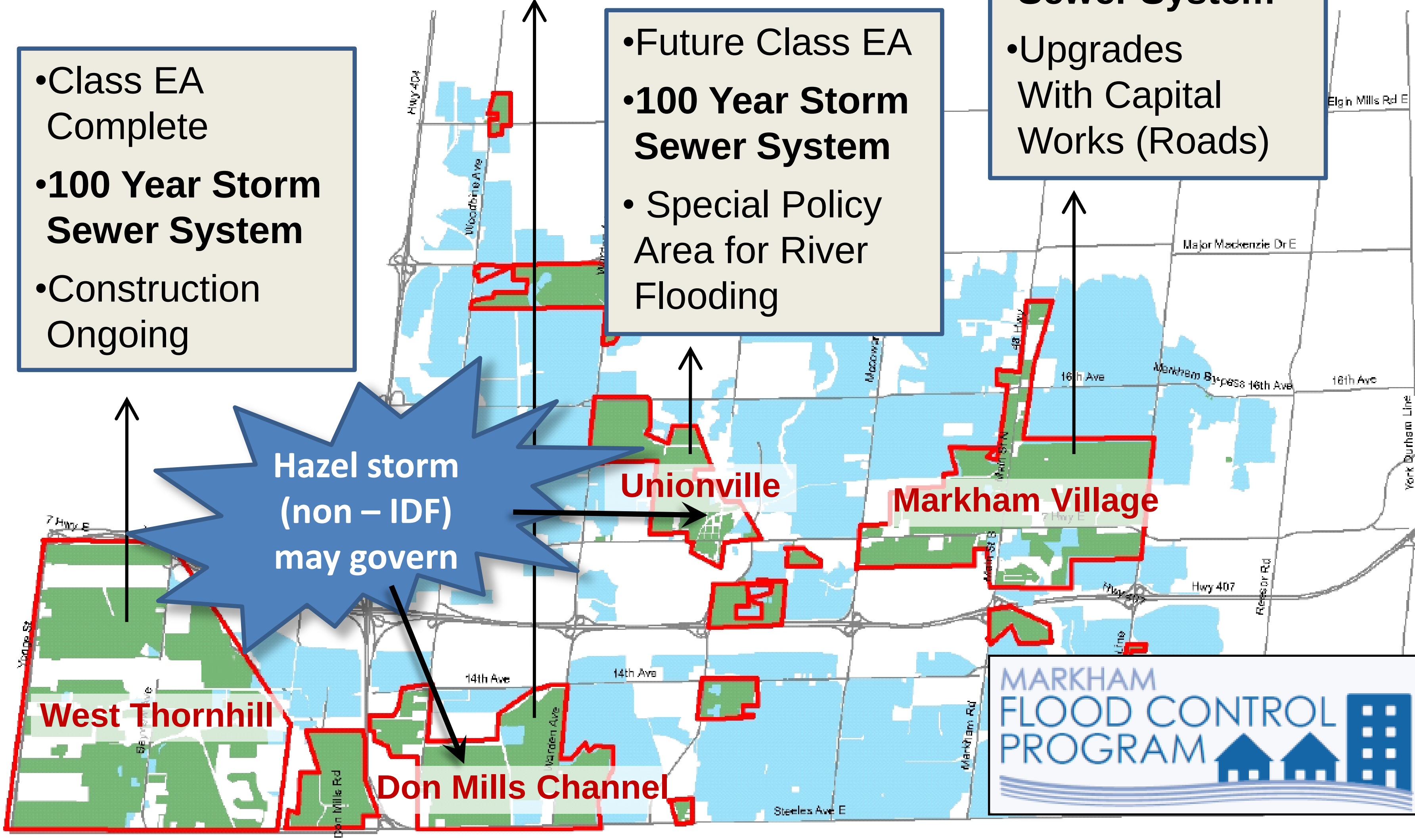
What Are Program Level of Service Targets ?

- Class EA Complete
- **100 Year Storm Sewer System**
- Construction Ongoing

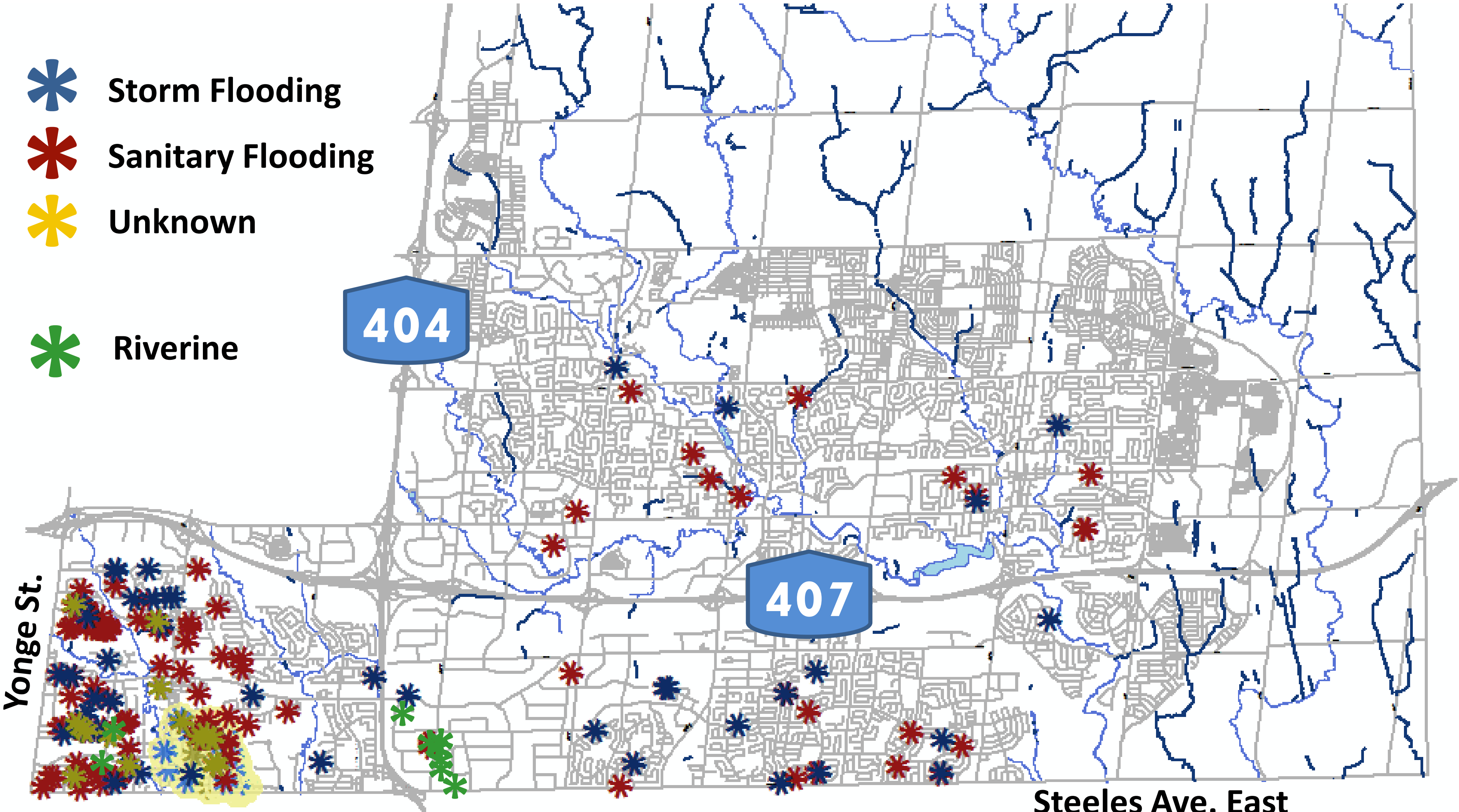
- Class EA Initiated
- **5+ Year Private Channel**

- Future Class EA
- **100 Year Storm Sewer System**
- Special Policy Area for River Flooding

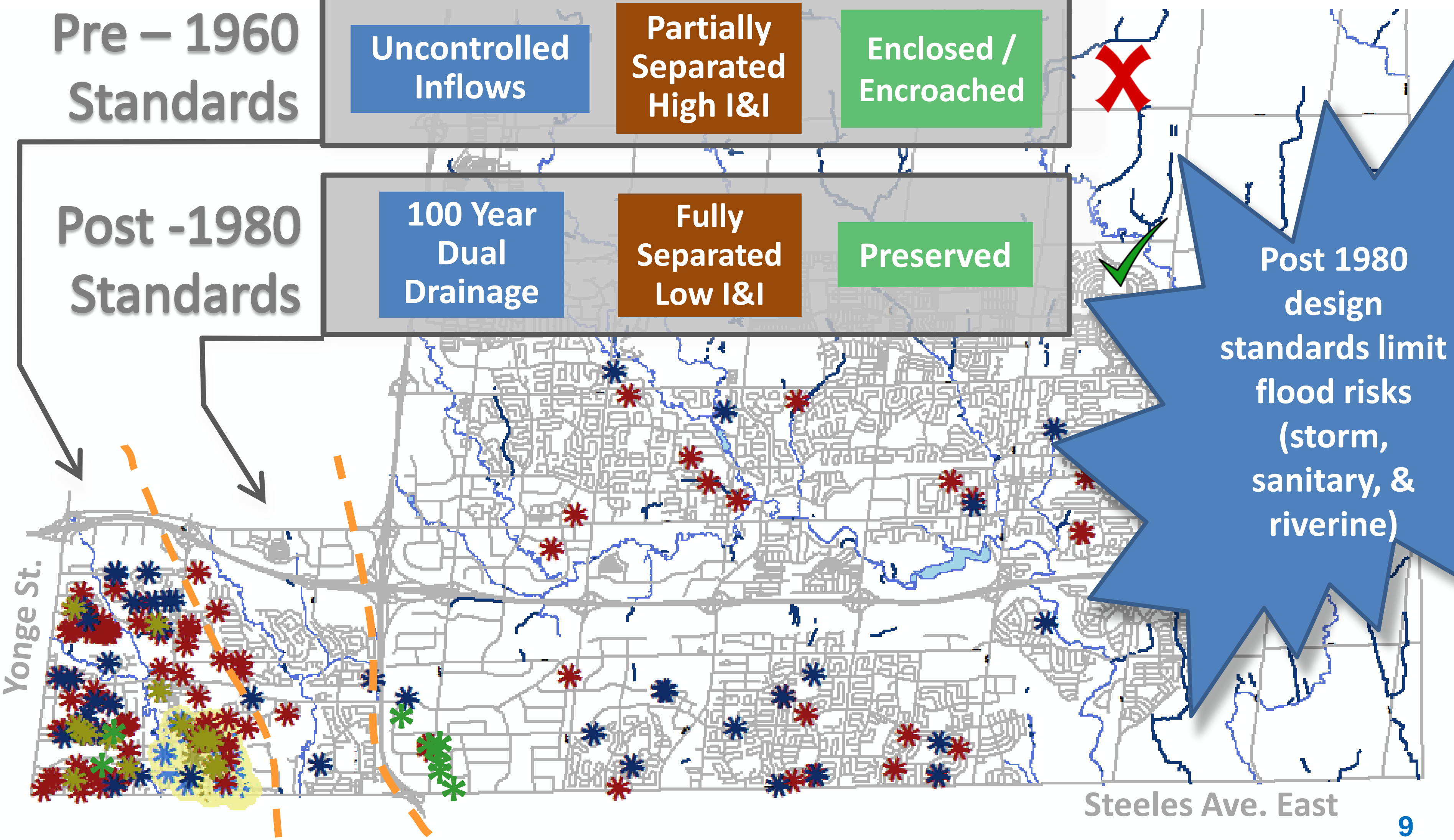
- Future Class EA
- **100 Year Storm Sewer System**
- Upgrades With Capital Works (Roads)



Various 2005 Flooding Types in Pre-1980 Areas

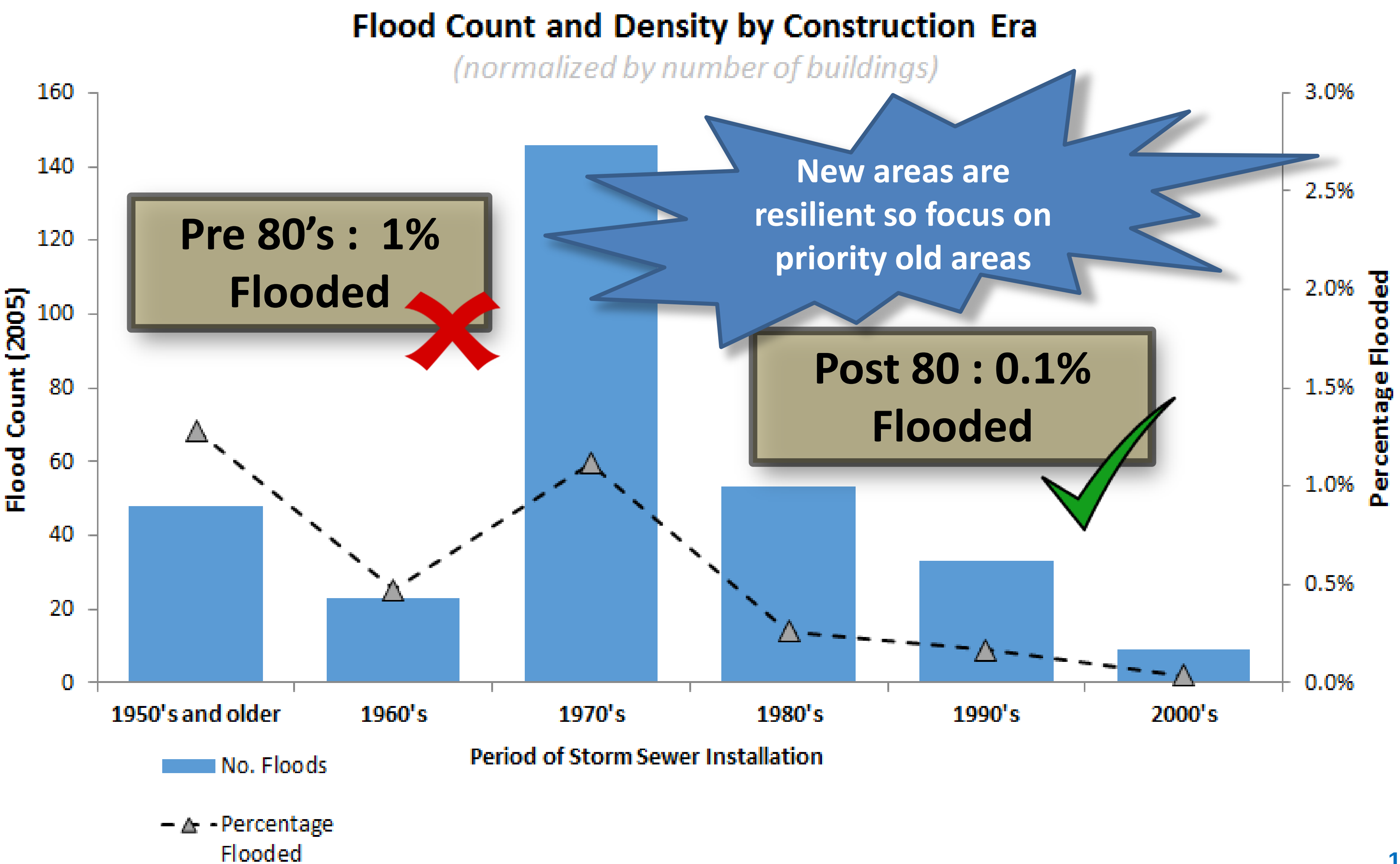


	Overland Drainage	Sanitary	Flood Plains
Pre – 1960 Standards	Uncontrolled Inflows	Partially Separated High I&I	Enclosed / Encroached
Post -1980 Standards	100 Year Dual Drainage	Fully Separated Low I&I	Preserved



Post 1980 design standards limit flood risks (storm, sanitary, & riverine)

Post-1980's Design Standards Are Effective



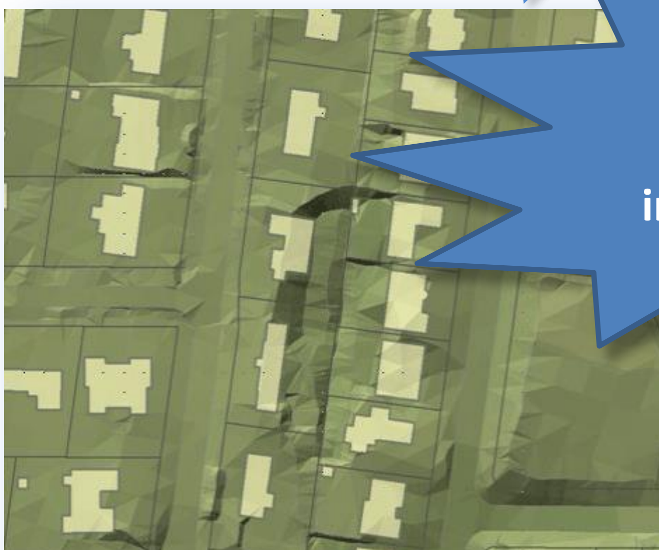
Overland Drainage

Sanitary

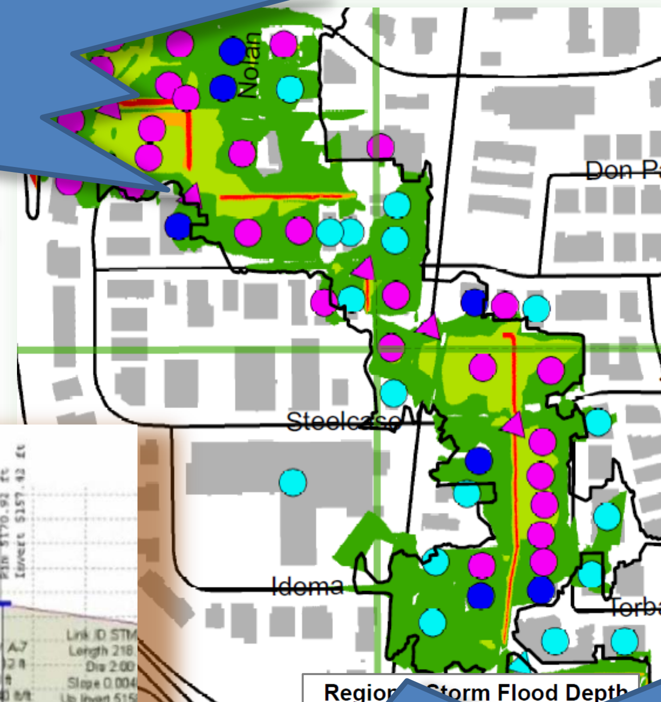
Flood Plains

InfoWorks Dual Drainage & GIS ArcHydro Screening

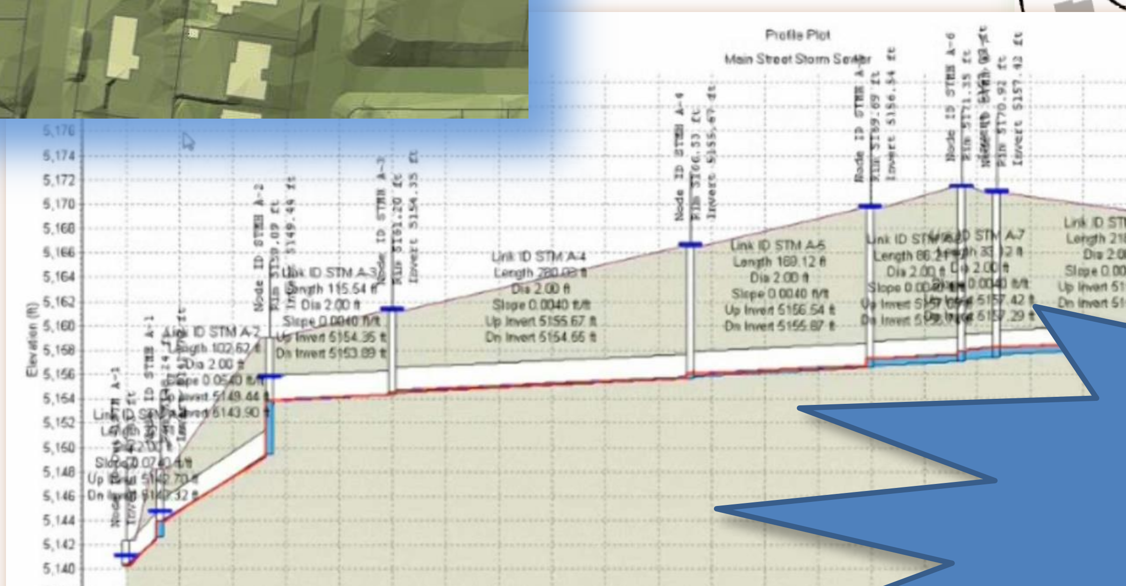
HEC-RAS, GeoRAS PCSWMM 2D



Hyetograph simulated is <u>more</u> critical than IDF input to performance



InfoWorks CS / ICM

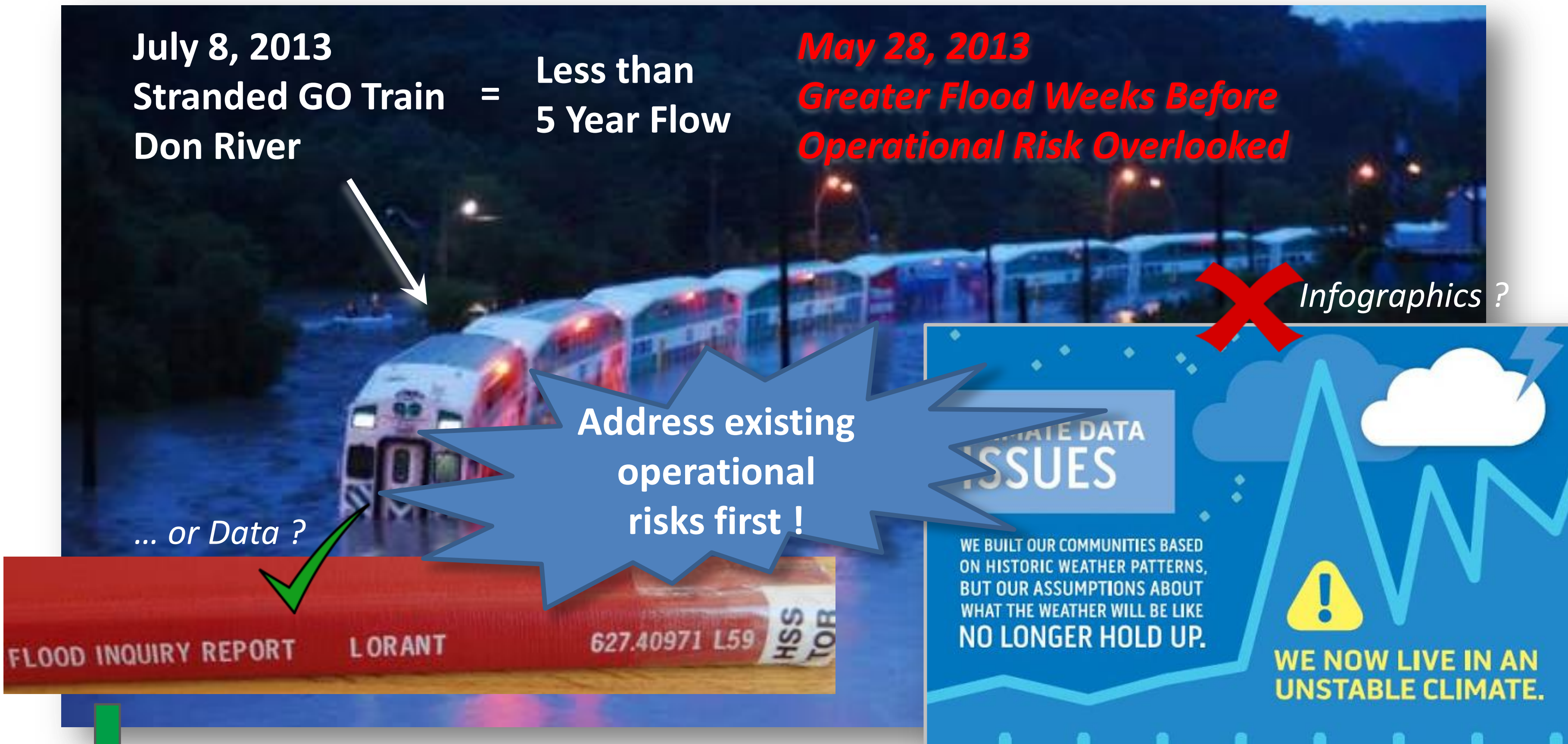


Quantitative methods are required to identify specific local risks and remediation.

Responding to Non-Technical Reports & Media

Media & Government Data Gaps

- Operational issues mis-characterized as a climate change-induced event.
- Reported “unprecedented” conditions contradict past data & reports.



http://www.cityfloodmap.com/2015/12/stranded-metrolinx-go-train-avoidable.html

Insurance Industry Data Gaps

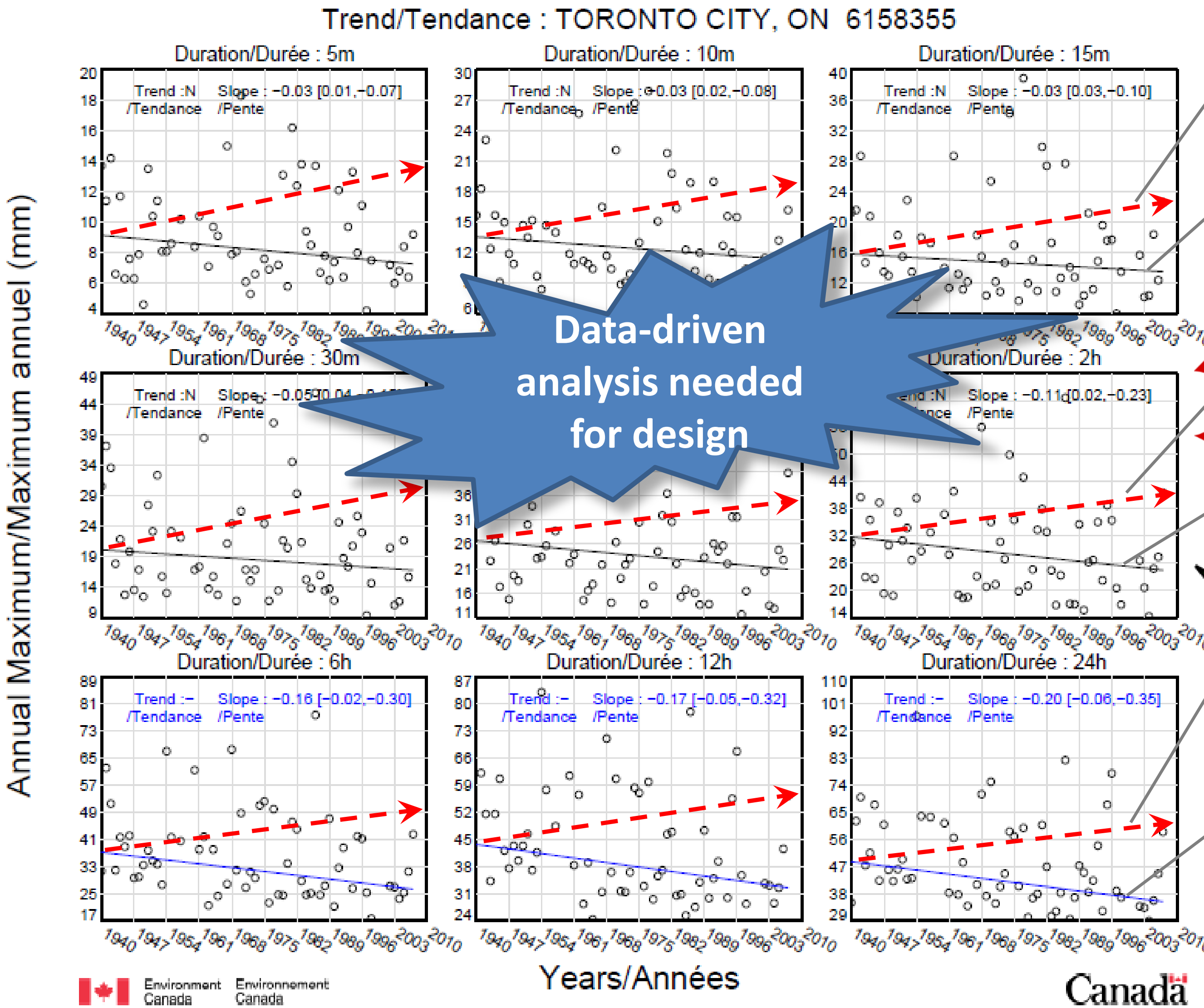
Confused arbitrary prediction with real observed trend data

CBCnews · Calgary Sun · TD · thestar.com · CivicAction · intact INSURANCE · AVIVA · ICLR · IBC · RSA

[Telling the Weather Story - Gordon McBean - Empire Club presentation - YouTube]

http://www.slideshare.net/RobertMuir3/storm-intensity-not-increasing-factual-review-of-engineering-datasets

Comparing Data Facts With "Alternative Facts"



IBC "Weather Story" Intensity Increase

Environment Can. Intensity Decrease

IBC "Weather Story" Intensity Increase

Environment Can. Intensity Decrease

IBC "Weather Story" Intensity Increase

Environment Can. Intensity Decrease (statistically significant over 6 - 24 hrs, 2x as common as increases in S. Ontario)

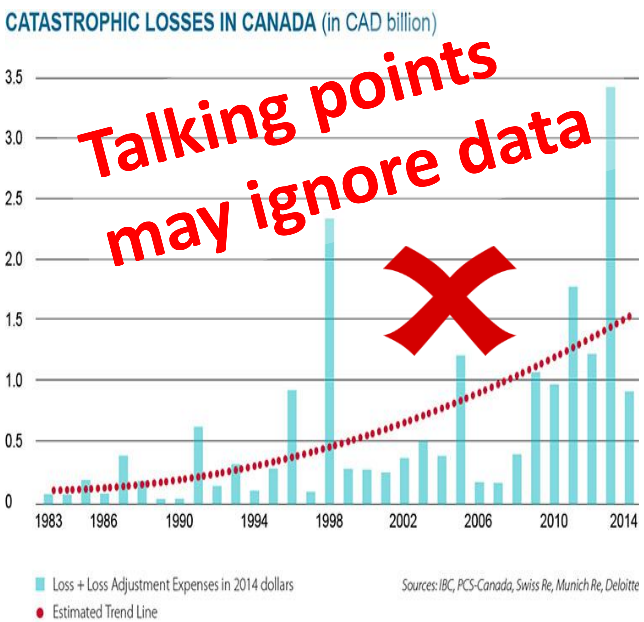
BUILDING MARKHAM'S FUTURE TOGETHER 2015-2019 Strategic Plan

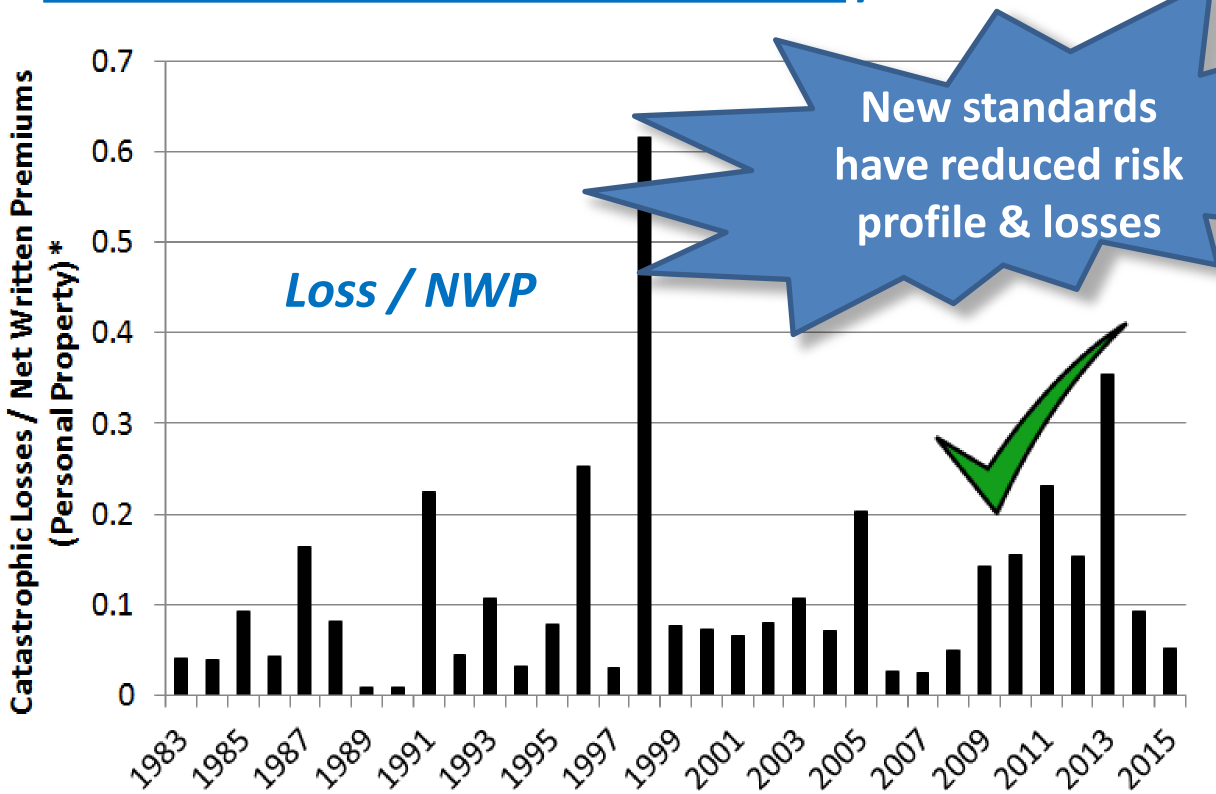
MARKHAM

Economic Growth Ignored in Damage-Cost Data

Losses normalized by net written premiums peaked in '98

Catastrophic losses are up but ...





* Catastrophic Losses in 2015 Dollars and NWP (1992-2015) per IBC 2016 Fact Book, NWP (1990-1991) per IBC 2013 Fact Book, NWP 1983-1989 extrapolated assuming 2% growth per year.

link: Net Written Premiums to 2015
link: NWP 1990-1991

http://www.cityfloodmap.com/2016/12/book-review-rightful-place-of-science.html

Quantifying Risk Factors and Design Practice Adaptation

Markham Imperviousness Trends

1952 32 %

1971 45 %

1981 56 %

2002 70 %

Rational Method Peak "Instant" Flow

Q	=	**k**		**C**		**i**		**A**
Peak Flow	α			**Runoff Coefficient**	x	**Rain Peak Rate**	x	**Area**

Return Period Factor (e.g., +25% 100-yr)

- **C** values required updates based on densities
- **i** values did not require updates for current IDF
- **Q** may require "stress test" for *some* future IDF **i**
- **Return Period Factor** for extreme storms increases resiliency / conservatism for extreme events

Markham Standards

Rational Peak Safety Factor

Q	=	C		i		A
Peak Flow	α	Runoff Coefficient	x	Rain Peak Rate	x	Area

Add Return Period Factor (+ 25% for 100 year)

Increase Residential C from 0.5 to 0.7

Keep higher, older Toronto IDF rate of 275 vs 219 Local IDF at Buttonville

Return period factor, higher C, and old higher rain intensity **adds 120 %** to old standards and local IDF approach (new resilient systems).

New:

$Q_{100\ resid.} = 1.25 \times 0.70 \times 275 \times 1.0 = 240.6$ L/s

+ 25 % + 40 % + 26 % + 120 %

Old:

$Q_{100\ resid.} = 1.0 \times 0.50 \times 219 \times 1.0 = 109.6$ L/s

IDF Trends – Lower in Southern Ontario (Safety Factor)

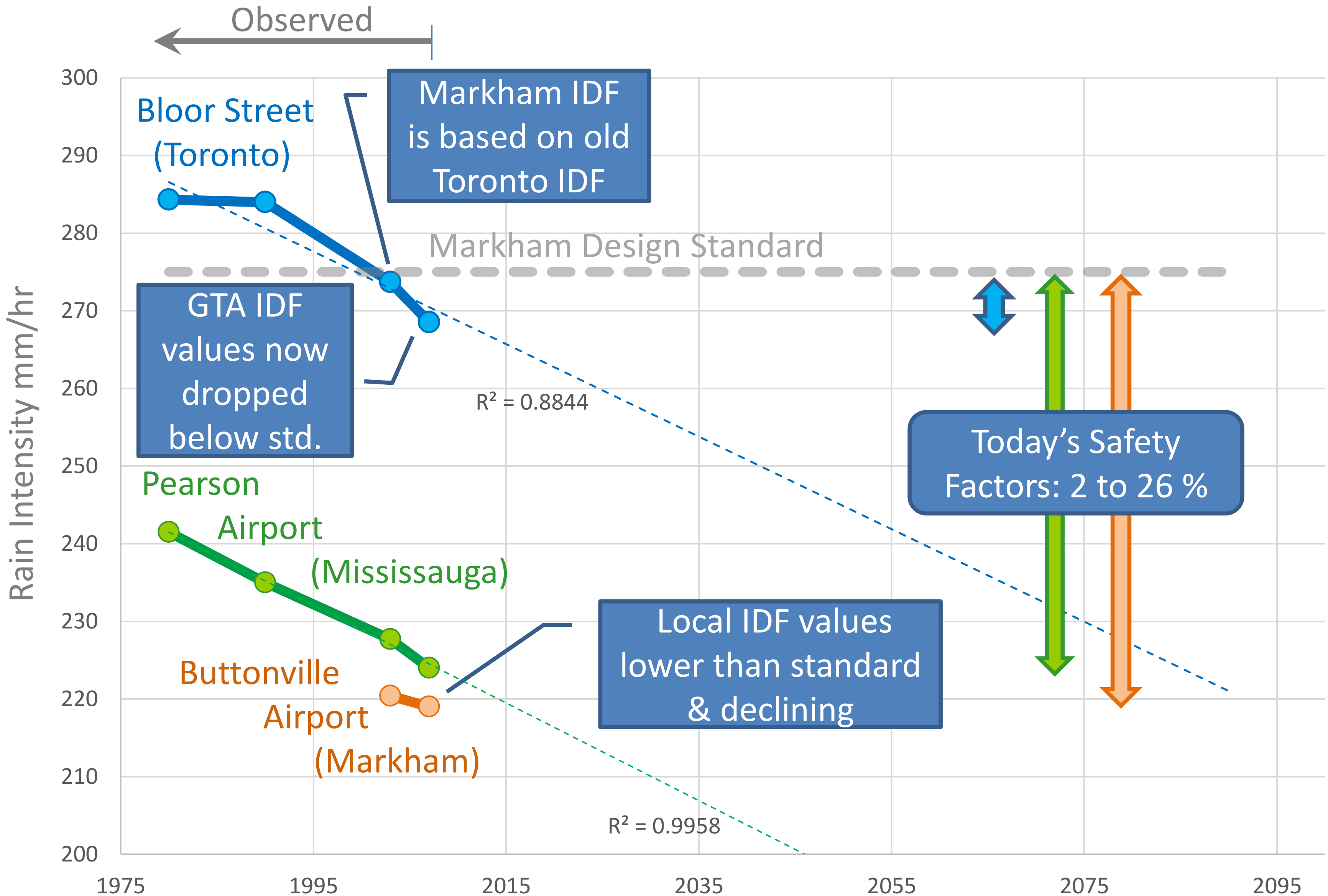
- As annual maximum values trend lower, extreme IDF intensities **decrease** as well.
- Toronto City "Bloor Street" trends **are lower for all durations and for all return periods**.
- Design standard IDF is conservative.

Toronto Extreme Rainfall Trends Environment Canada Climate Station 6158355 (Toronto City)				
Return Period (Years)	5 Minute Rainfall Intensity (mm/hr)			Change in Rainfall Intensity
	1990	2003	2007	1990 - 2007
2	113.9	110.8	109.2	-4.1%
5	159.4	154.4	151.9	-4.7%
10	189.6	183.3	180.1	-5.0%
25	227.7	219.8	215.8	-5.2%
50	256	246.8	242.3	-5.4%
100	284	273.7	268.5	-5.5%
			Overall:	-5.0%

Source:
Environment Canada Engineering Climate Dataset
ftp://ftp.tor.ec.gc.ca/Pub/Engineering_Climate_Dataset/IDF/
Up to 2007 per Dataset v2.3, to 2003 per Dataset v1, to 1990 per hardcopy records

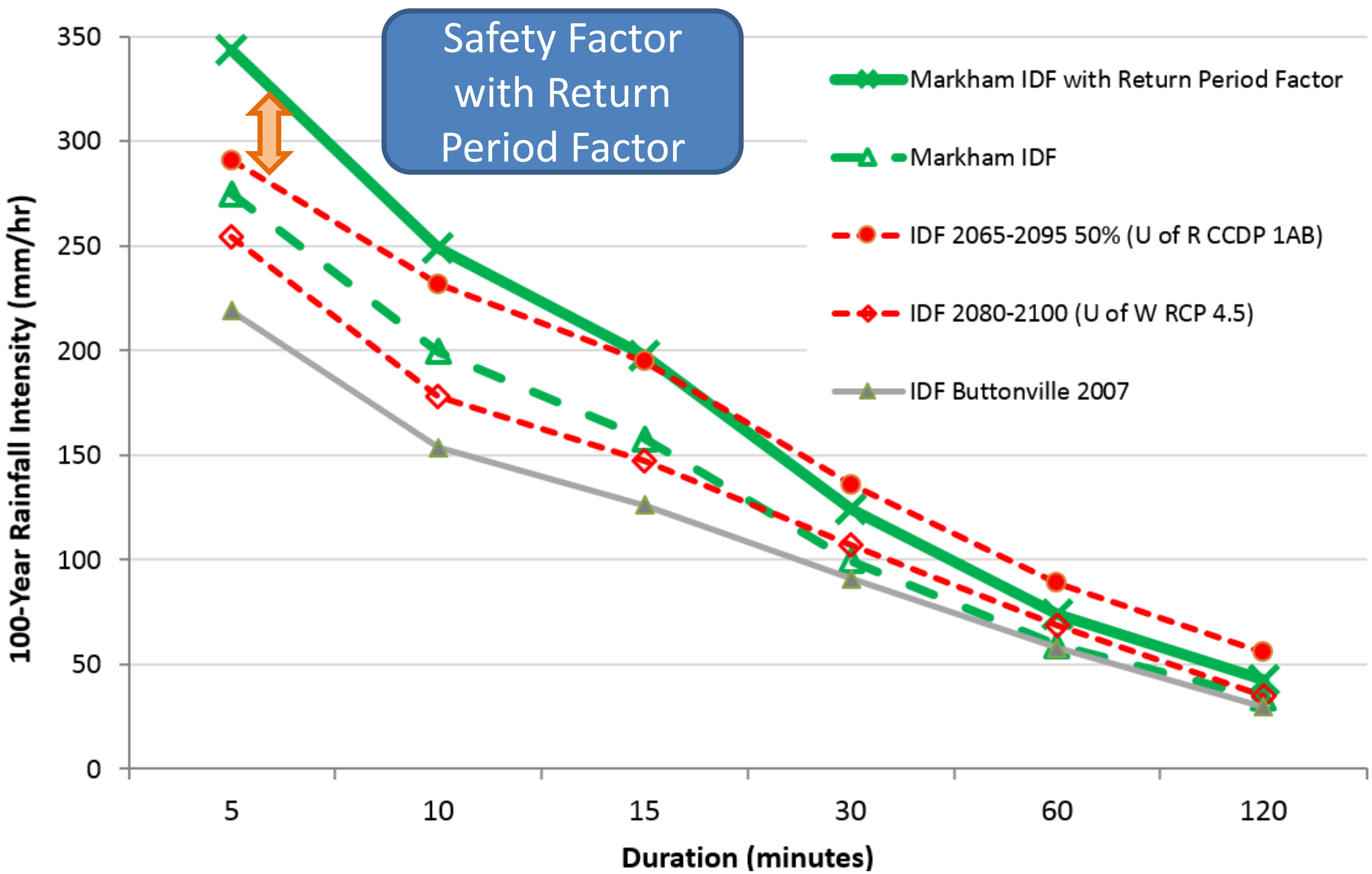
http://www.cityfloodmap.com/2016/01/toronto-climate-change-extreme-rainfall.html

5 Minute 100-Year Intensity Past Trends / Safety Factors



Design IDF May be Above or Below Future IDF Depending on the Scenario Before Return Period Factor Applied

- Design IDF values are above local IDF values.
- Design IDF above UofW RCP 4.5 & below UofR A1B values.
- Factored design IDF values can exceed future IDF for shortest durations (adds resiliency).



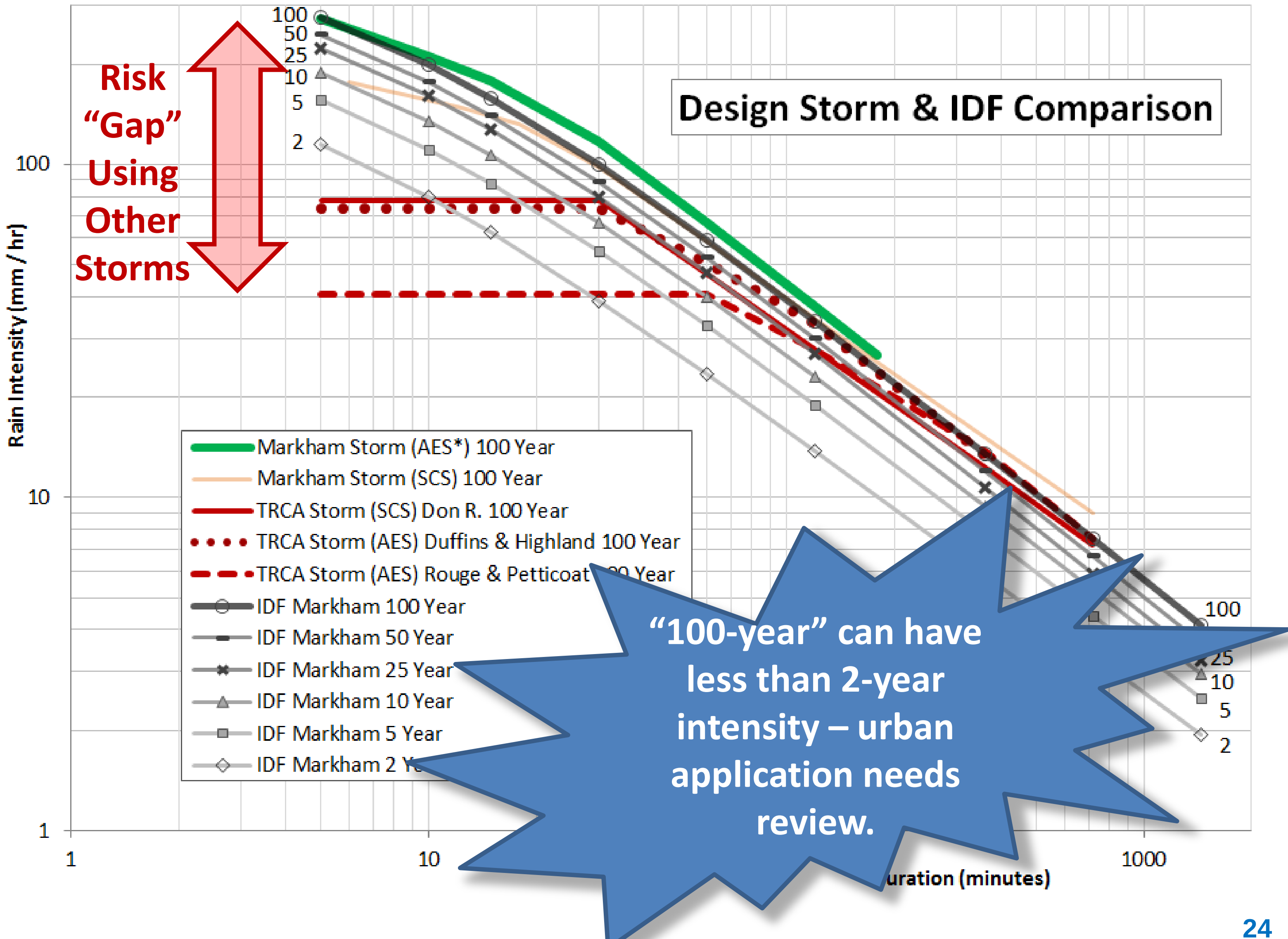
Simulation Flow Time Series

Q (t)	:	**Land Use / Soil**	<- transformation	**Hyetograph**	
Hydro-graph	:	**Catchment Parameters**	<-	**Rain Pattern**	**Storm System**
Wet Weather Flow	:	**Groundwater & Inflow Response** ('black box')	<-	**Rain Pattern / Vol.**	**Sanitary System**

- **Runoff parameters** based on soil & development
- **Rain pattern** may be conservative or unconservative & require review, and/or updates for current IDF
- **Q(t)** may require "stress test" for future IDF **i** especially where hyetograph is unconservative or where safety factors for resiliency are not incorporated in the infrastructure system

Some Hyetographs Have 'Risk Gap' For Flashy Urban Areas

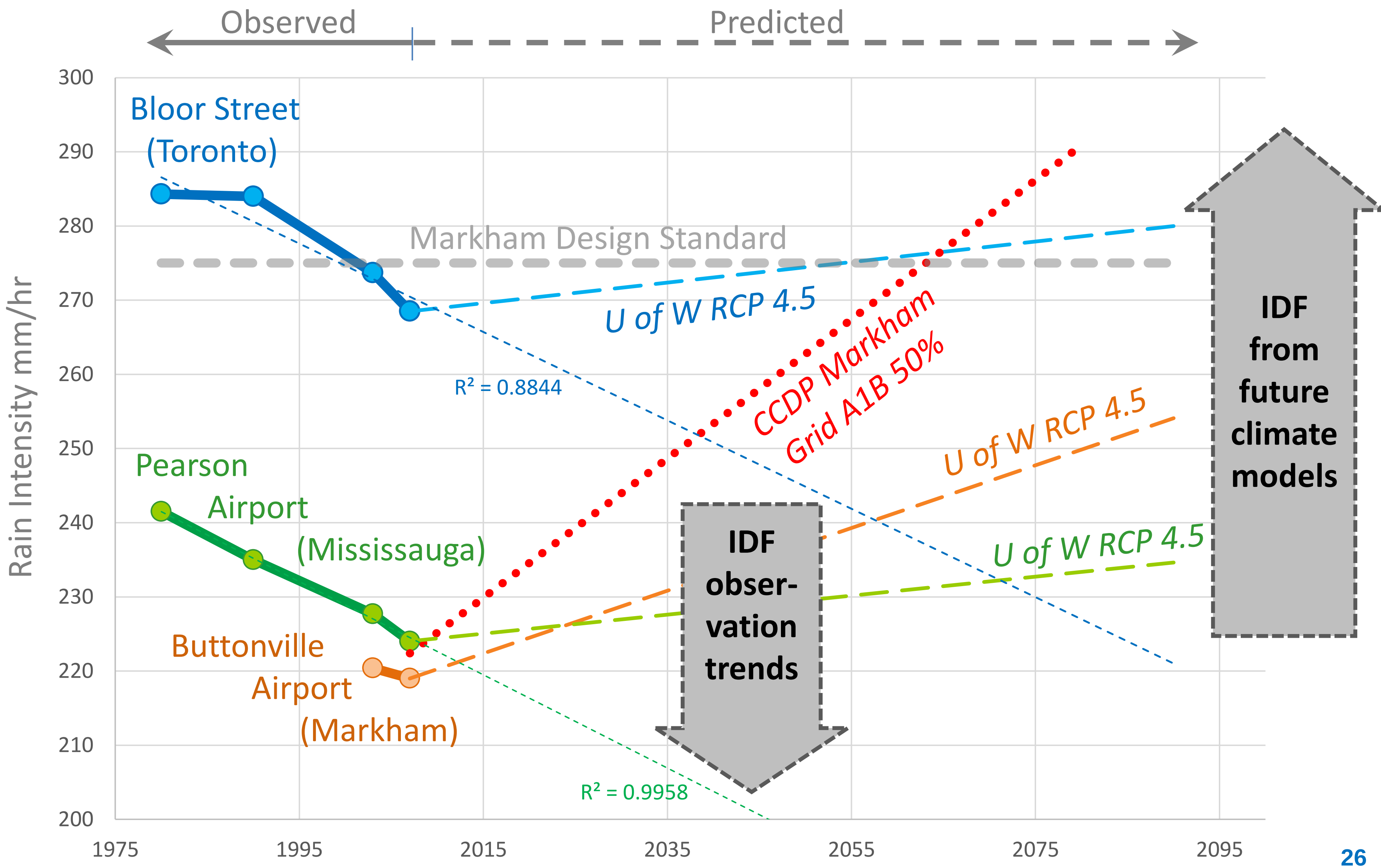
- IDF data show some watershed storms do not reach the short duration design intensities.
- Markham 3hr AES* storm is conser-vative (above IDF values).



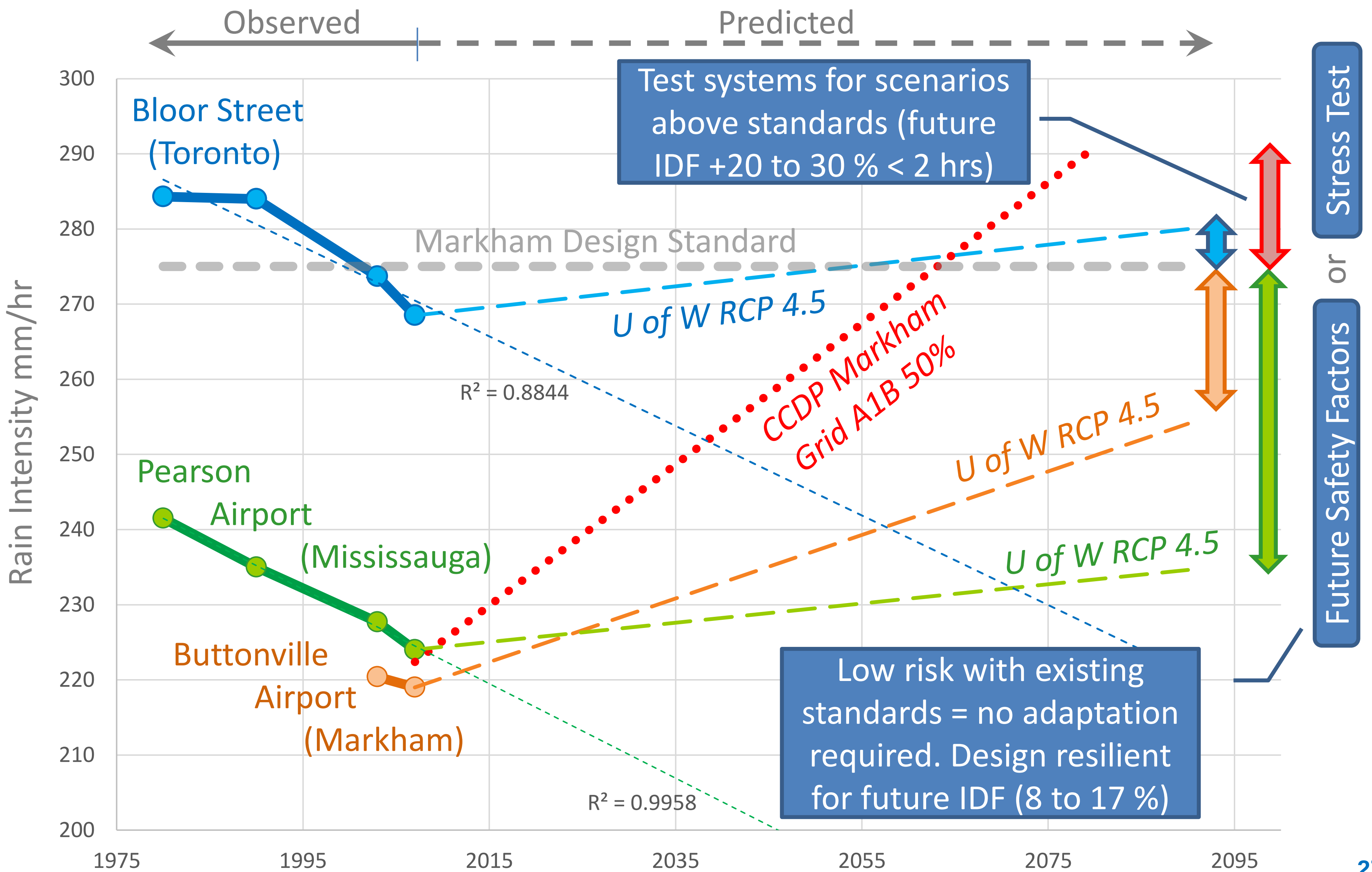
Stress Tests for System Resiliency Future IDF

Storm & Sanitary Sewer Systems

5 Minute 100-Year Intensity Projections

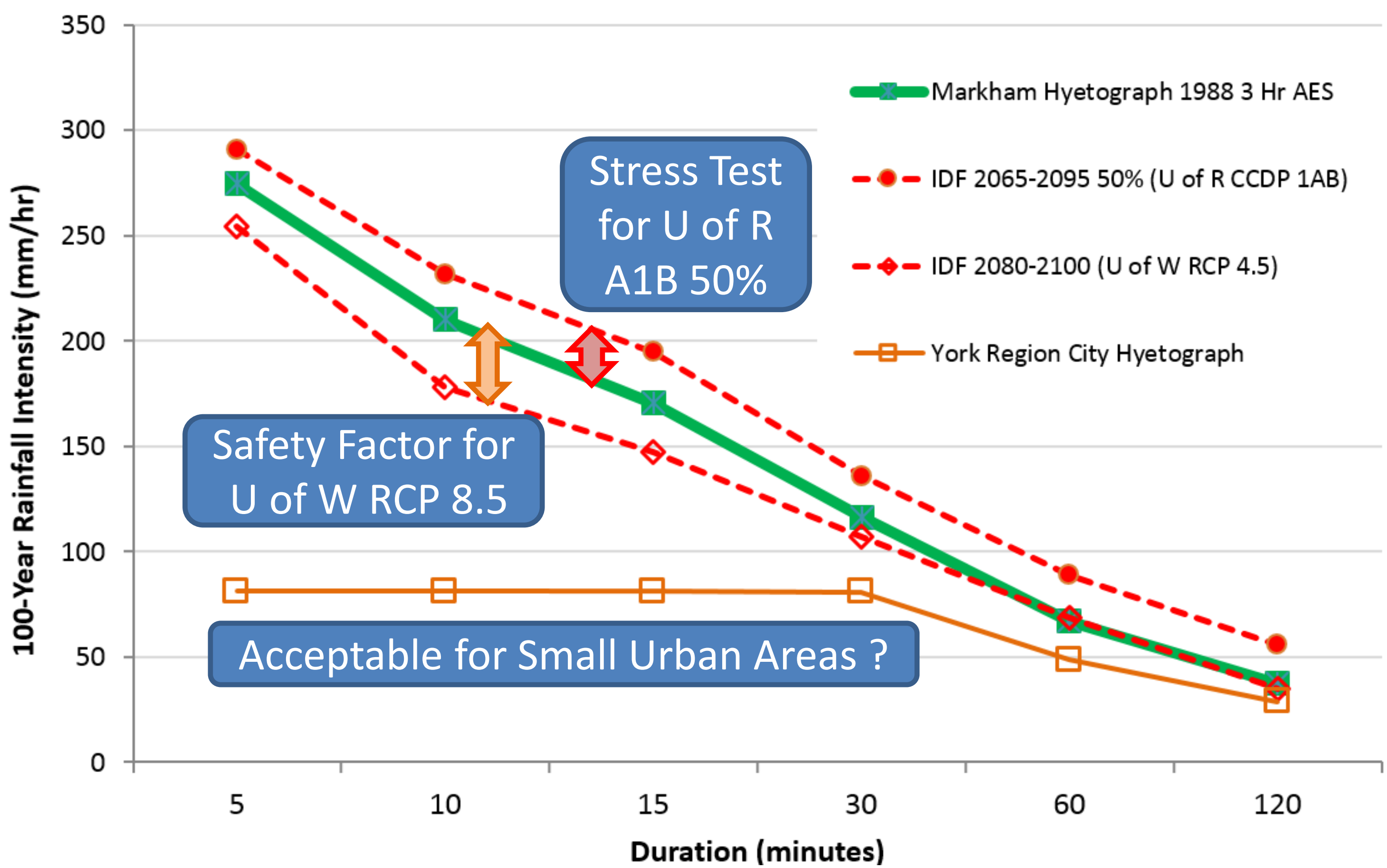


Short Duration Rain Intensity Adaptation Requirements



Hyetographs Intensities Above & Below Future IDF (< 2hrs) (systems have safety factors <u>or</u> require stress test)

- Markham 3hr AES design storm intensities above above UofW RCP 4.5, below UofR A1B values.
- Other study design storm intensities may under-estimate short duration intensities.



Future IDF 'Stress Test' – Minor & Major Storm System (PCSWMM)

IDF Data → Hyetograph Pattern → Runoff Transformation → Dual Routing & Hydraulic Capture → Hydraulic Performance / Freeboard → Damages / Risk – Assess Need for Adaptation

- Evaluate worst case +20% U. of R. A1B 50% 2065-2095 avg. shift over 2Hrs.
- Markham 3-hr AES (base intensities > local IDF values by 29% over 2 hrs).
- Assume existing hydrology parameters.
- Inlet capture devices in 50%+ of CBs limit minor system flow impacts.
- Unsteady, gradually varied flow model (PCSWMM).
- Storm system HGL exceeds freeboard of 0.5 m to reach lowest basement elevation.

Baseline Performance

Peak flow 255 L/s local storm sewer (ID 12)

Maximum major overland flow depth 248 mm.

Foundation drain back-up risk impact remains nil with future IDF (ICD's limit capture), overland impact negligible.

Future Performance

Peak flow 257 L/s local storm sewer (ID 12) **+1%**

Maximum major overland flow depth is 265 mm.
+17 mm IDF Impact

Future IDF 'Stress Test' – Sanitary Sewer System (InfoWorks)

IDF Data

Hyetograph Pattern

Dry Weather Sanitary Flow

I&I Transformation (Extraneous Flow)

Hydraulic Performance / Freeboard

Damages / Risk – Assess Need for Adaptation

- Evaluate worst case +30% U. of R. A1B 50% 2065-2095 avg. shift over 2Hrs.
- Chicago (per Master Plan base intensities > local IDF values by 22% over 2 hrs).
- Use calibrated/monitored values.
- Apply existing calibrated parameters for inflow and infiltration response.
- Dynamic / gradually varied flow model (InfoWorks).
- Sanitary system HGL less than 2.0 m below grade (near basement elevations).

Baseline Performance

7.4 % surcharged pipes.

1.8 % MH's less than 2.0 m of freeboard with sanitary basement back-up risk.

Basement back-up risk impact negligible with future IDF – risk varies significantly by design storm pattern

Future Performance

12.1 % surcharged pipes.

3.5 % MH's less than 2.0 m of freeboard with back-up risk **+1.7 % IDF impact**

Conclusions

- **System vulnerability varies with design standards:**
  - **Current standards have significantly decreased extreme weather risk (riverine, storm, and sanitary systems).**
  - **Historical land use practices with limited design standards drive <u>specific, local</u> remediation priorities.**
  - **Riverine flood risks not readily addressed (Special Policy)**
- **Design practice adaptation adds resiliency**
  - **Hydrology – higher runoff coefficients and return period factors**
  - **Meteorology – conservative hyetographs selection for urban areas**
- **Stress tests demonstrate system resiliency for those future IDF scenarios above design standard intensities**
  - **Negligible minor and major system impacts where common ICDs are in place (limit minor systems capture, use major freeboard)**
  - **Sanitary surcharge / basement back-up assessment shows negligible change in surcharge in system with future IDF**

Conclusions

- **Adaptation Measures (municipal & private)**
  - **Cost effective / timely:**
    - Sanitary downspout disconnection
    - Sanitary manhole sealing
    - Storm ICDs
    - Commercial flood-proofing, Special Policies
    - Minor system upgrades
  - **Costly / partially effective or ineffective**
    - Floodplain system upgrades
    - Catchment-wide green infrastructure (cost constraint)
    - On-site runoff over-control (timing constraint)

Thank You

Questions ?