KEY ASPECTS OF CLIMATE ADPATATION AND INFRASTCRUTURE RELATED SUB-SECTORS

Ephrat Yovel

Workshop on Climate Adaptation
15 Feb, 2021

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DISCUSSION

- Shared understanding
- Infrastructure and climate change
- Infrastructure vulnerability

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A SHARED UNDERSTANDING

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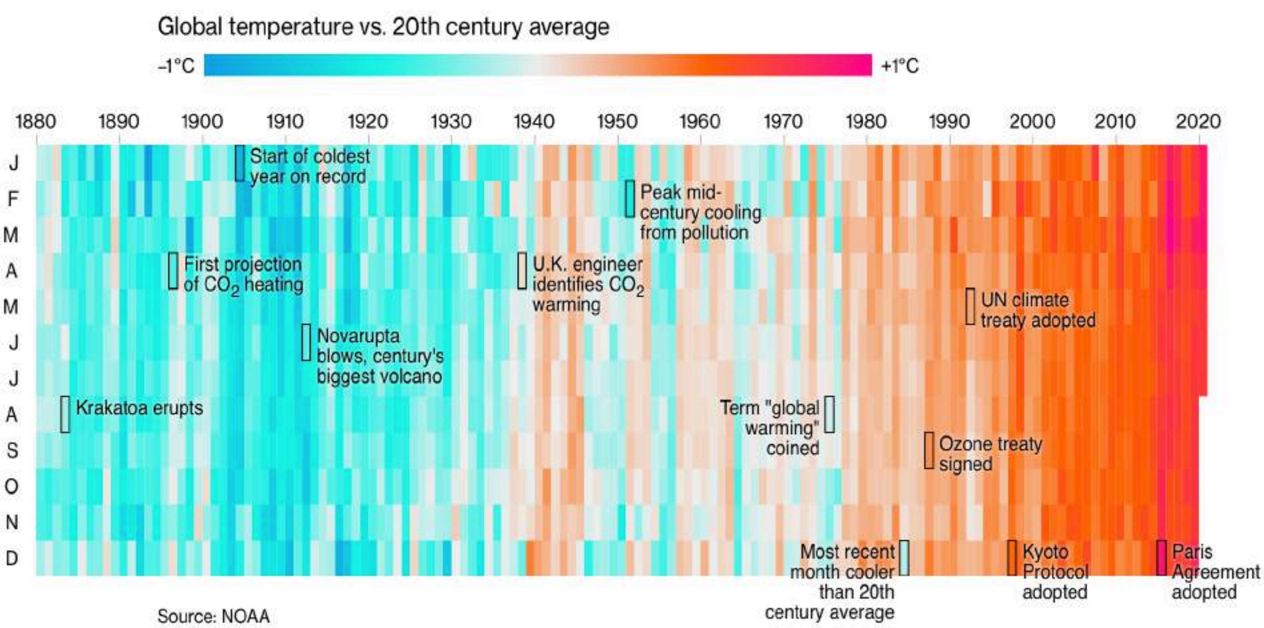
GLOBAL TEMPERATURES ARE INCREASING



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WE HAVE A GOOD IDEA OF HOW CERTAIN TYPES OF CLIMATE EVENTS ARE BEING AFFECTED

Stronger and more frequent heat waves

Stronger rainfall and winter storms

Rising sea level and stronger hurricanes

Larger wildfires in the West

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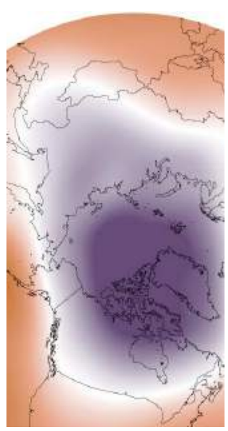
OTHERS, WE'RE STILL FIGURING OUT

Droughts: stronger, but more or less frequent?



Polar Vortex: related to Arctic warming?

Derechos: Hard enough to predict, let alone project!

Tornadoes, hail-storms: stronger, but more or less frequent?

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CHANGING CLIMATE IS A RISK MULTIPLIER

Uncertain impacts on existing systems

Uncertain politics and social reactions

Changing composition of populations

Uncertainty of changing costs and funding flows

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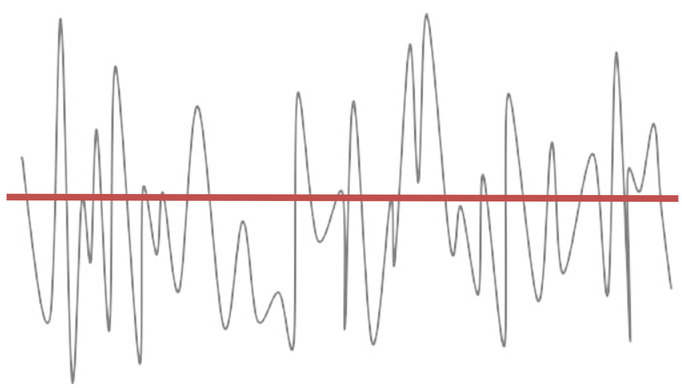
IMPACTS ARE HERE. TIME TO PREPARE

We used to assume that the long-term climate will remain stable and can be predicted based on past climate normals



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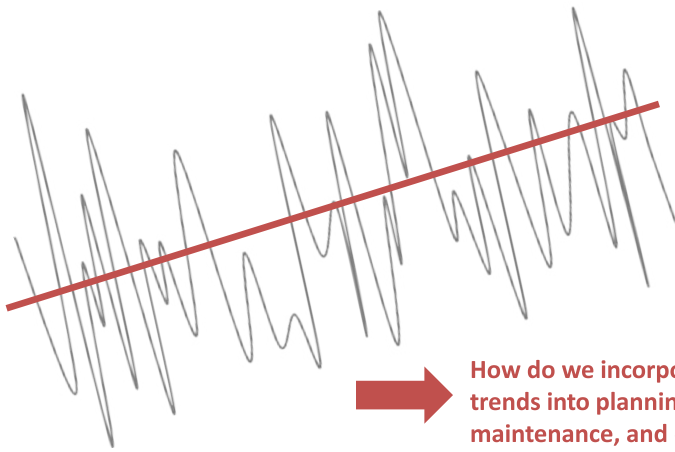
IMPACTS ARE HERE. TIME TO PREPARE

Today, climate is manifestly non-stationary: Past is no longer a reliable indicator of present or future conditions



How do we incorporate changing climate trends into planning for operations, maintenance, and design?

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INFRASTRUCTURE & CLIMATE CHANGE

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THE SERVICES PROVIDED BY CIVIL INFRASTRUCTURE WORKS SUPPORT SOCIETY IN MANY WAYS…

Services

- Shelter
- Safety and security Aesthetics
- Heat, Light and Power
- Mobility for people, goods and services
- Health and recreation Wealth creation

Categories

- Homes & Buildings
- Transportation networks
- Energy networks
- Water, Waste, & Storm water networks
- Industrial structures
- Communications networks
- Landfills and waste depots
- Culture and recreational facilities

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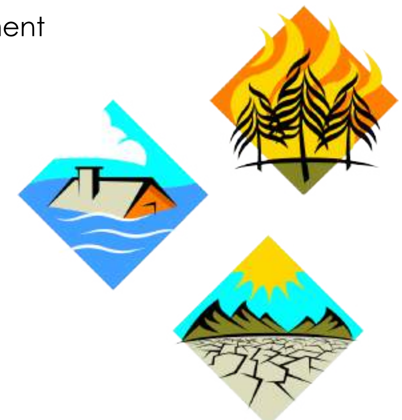
WHY ADDRESS INFRASTRUCTURE RISKS?

- Minimize service disruptions
- Protect people, property and the environment
- Optimize service
- Manage lifecycle
- Manage operations
- Avoid surprises
- Reduce costs
- First step in planning adaptation



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SOME CLIMATE IMPACTS ON INFRASTRUCTURE

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SOME CLIMATE IMPACTS ON INFRASTRUCTURE






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AUGUST 2005 STORM – TORONTO, CA

Photos courtesy Jane-Finch.com

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THE CONCERN WITH INFRASTRUCTURE IN A CHANGING CLIMATE

- Increasing occurrence of extreme weather events causing damage with high cost to repair and replace
  - Existing infrastructure has been designed using historical climate data
  - Infrastructure will not be sufficiently resilient for its service life in the future climate
- Climate change threatens the ability of engineers to safely and effectively design resilient infrastructure
  - Design, operation and maintenance practices must adapt
  - Need for updated and improved codes, standards and practices
- Climate change engineering vulnerability assessment contributes to adaptation process

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CHANGING CLIMATES, CHANGING LOADINGS…

- Changing temperatures
- Changes in seasonality and type of precipitation
- Changes in extreme loadings
- Intensity of precipitation
- Earlier freshet
- Sea level rise and storm surge
- More freeze-thaw cycles
- Melting permafrost
- . . .

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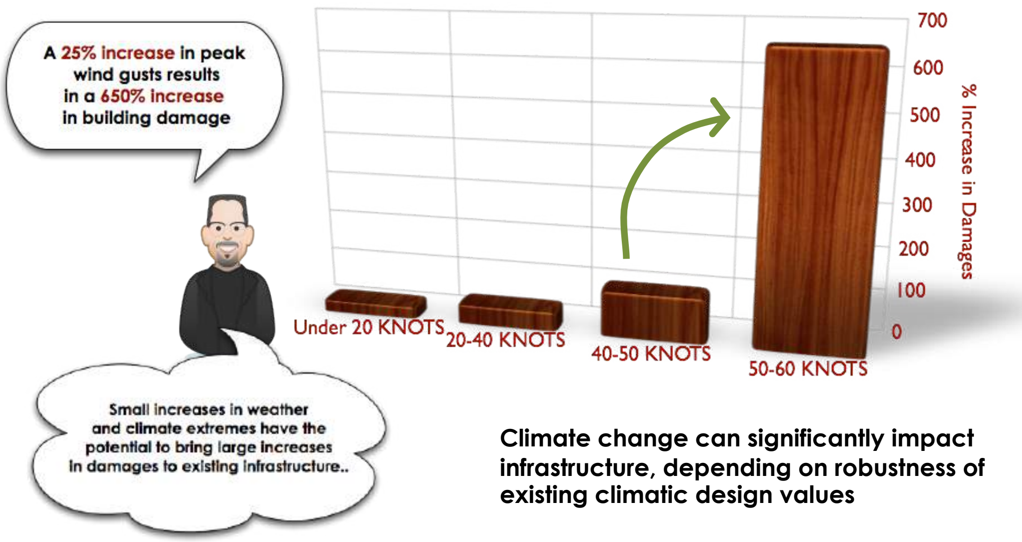
SMALL INCREASES = ESCALATING INFRASTRUCTURE DAMAGE



Climate change can significantly impact infrastructure, depending on robustness of existing climatic design values

Coleman, 2002

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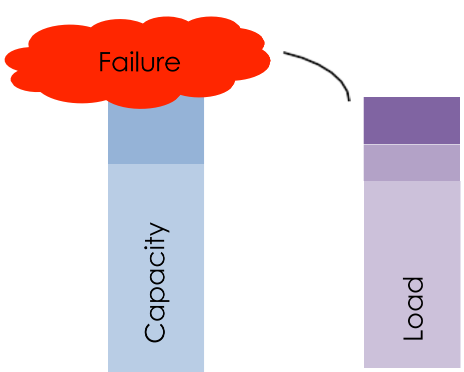
HOW DO SMALL CHANGES LEAD TO CATASTROPHIC FAILURE?



Design Capacity
- Safety Factor
- Impact of age on structure
- Impact of unforeseen weathering

Design Load
- Change of use over time
  e.g., population growth
- Severe climate event

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SMALL CHANGES CAN MAKE A BIG DIFFERENCE

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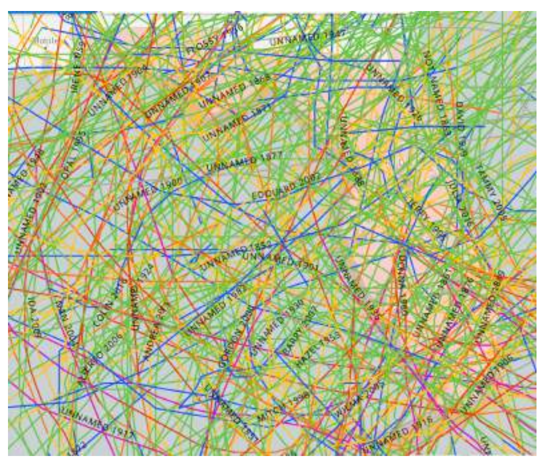
HURRICANE "ANDREW" (1992)

- First hurricane level storm to hit South Florida since hurricane "Donna" in 1960
  - Andrew a category 5 storm when it hit Florida
  - Category 3 when it hit Louisiana
- Most of the damage caused by wind
- Considered one of the costliest disasters in the US
- Affected suburban and rural area south of Miami
  - 1.4 million people
  - Homestead Air Reserve Base became "severely damaged or unusable" and has since been abandoned
  - In Everglades and Biscayne National Parks and other parks and open areas more than 25% of trees were destroyed



Tracks of hurricanes that have threatened or struck Florida since 1886

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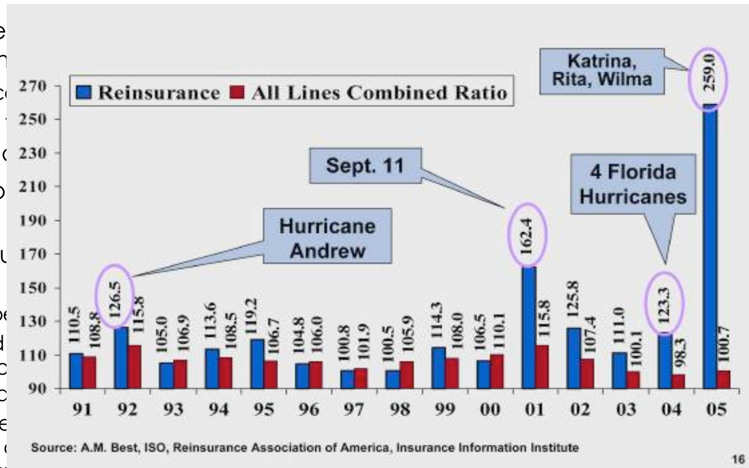

Tracks of hurricanes that have threatened or struck Florida since 1886

Historic Insurance Losses
A.M. Best / ISO / Reinsurance Association of America / Insurance Information Institute

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CHANGES IMPLEMENTED AFTER "ANDREW"

- Improved land use planning
- Restricting development areas
- Increasing open space requirements
- Building code improvements & stringent code enforcement
- Building costs in S. FL now at least 15% higher than other states
- Improved construction techniques
- Required set of non-structural mitigation measures
  - e.g., hurricane shutters, impact windows
- Promotion of other mitigation measures
- Annual public awareness campaigns
- Risk-based insurance rates*

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IMPROVED CONSTRUCTION

Damage after Hurricane Jeanne (2004), Vero Beach, FL

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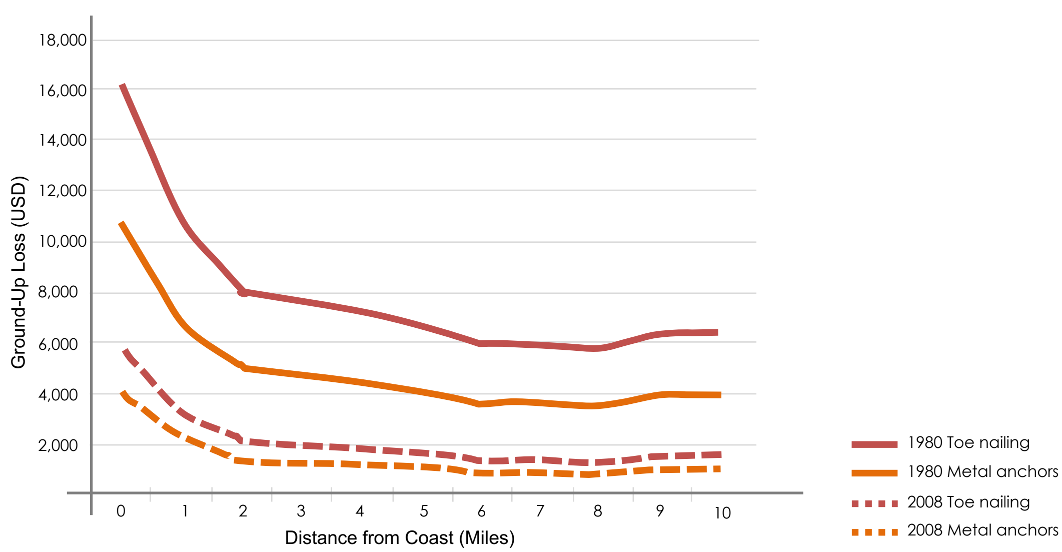
CHANGES TO THE ROOF REQUIREMENTS IN THE SOUTH FLORIDA BUILDING CODE



Munich Re / RMS RiskLink Output

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INFRASTRUCTURE VULNERABILITY ANALYSIS

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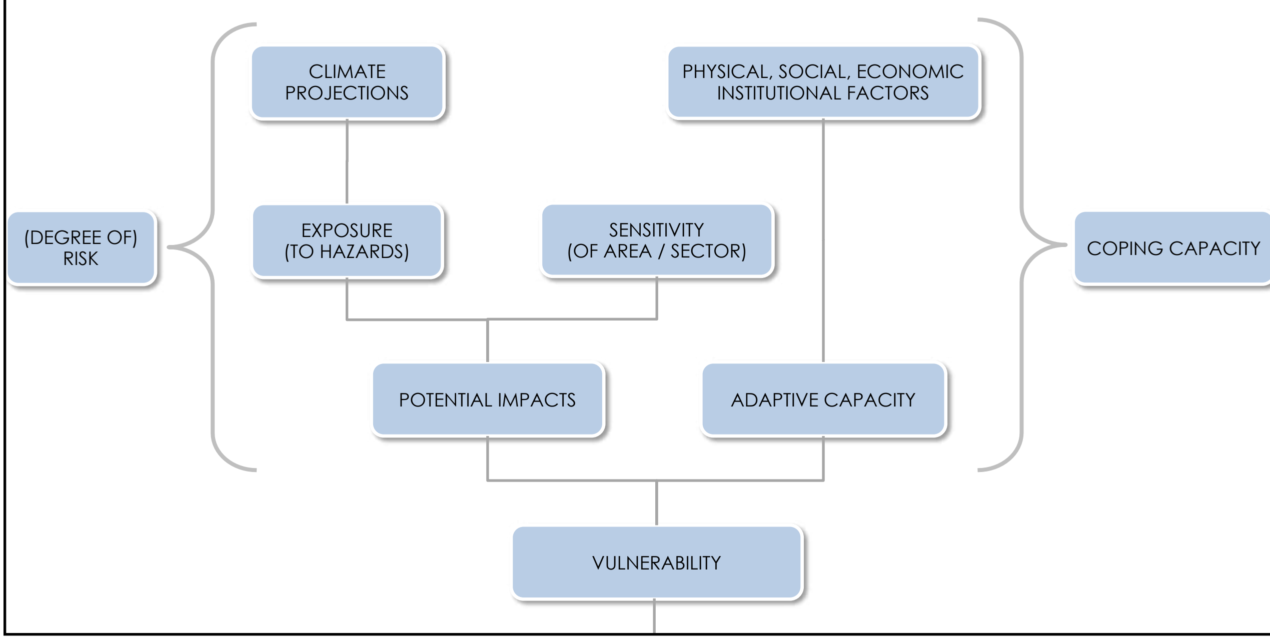
COMPONENTS OF VULNERABILITY AND CAPACITY



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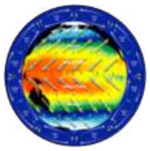
INFRASTRUCTURE VULNERABILITY ANALYSIS PROCESS



Climatic conditions
Character, magnitude and rate of change in climate conditions for exposed infrastructure

Sensitivities of infrastructure
How sensitive is the infrastructure to climate change?

Built-in capacity of infrastructure
What level of built-in capacity of infrastructure exists to absorb consequences of a changing climatic?

Vulnerability assessment needs to consider all 3!

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DESIGN LIFE-APPROPRIATE ASSESSMENT

- Design life varies
- Component-based vulnerability assessment
  - Safety / economics / technical
- There is adaptive capacity because of maintenance & rehabilitation
- Conversely, poor maintenance and lack of rehabilitation contributes to vulnerability

Structures	Expected Lifecycle
Houses / Buildings	Retrofit/alterations 15 – 20 years Demolition 50 – 100 years
Storm / Sanitary Sewer	Base system 100 years Major upgrade 50 – years Components 25 – 50 years
Dams / Water Supply	Base system 50 – 100 years Refurbishment 20 – 30 years Reconstruction 50 years
Roads & Bridges	Road surface 10 – 20 years Bridges 50 – 100 years Maintenance annually Resurface concrete 20 – 25 years Reconstruction 50 – 100 years

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RESILIENCE - A GUIDING PRINCIPLE FOR IMPLEMENTING PRACTICES AND POLICIES FOR CLIMATE CHANGE

- Resilience - The capacity to tolerate disturbance, undergo change, and retain the same essential functions, structure, identity and feedbacks

- Resilience to climate change is a by-product of a well-planned and efficiently executed process of risk assessment, damage prevention, adaptation to change, and effective mitigation measures to remedy damages and learn to better deal with the risks that threaten our complex infrastructure systems

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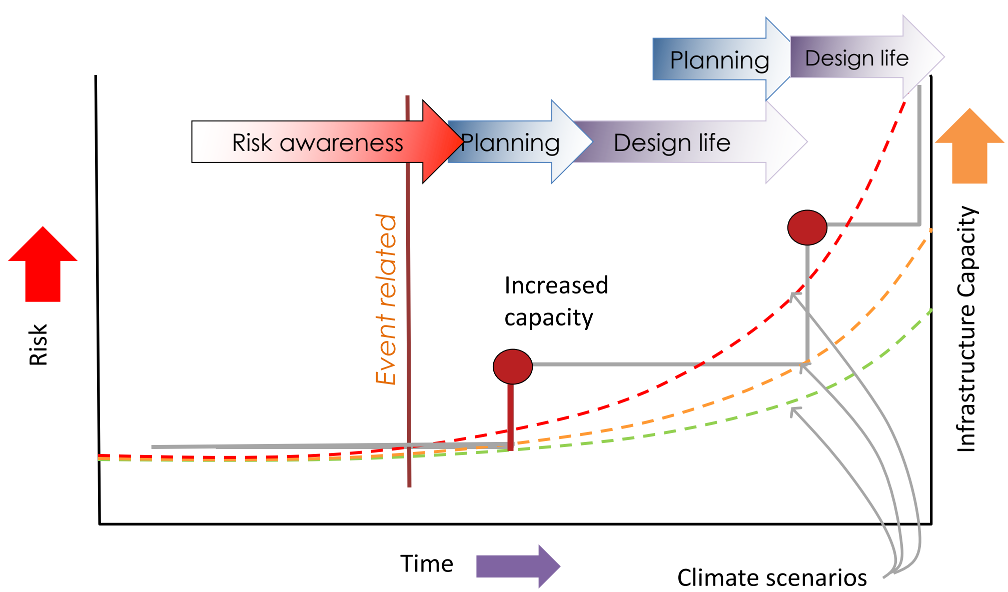
CONCEPTUAL ADAPTIVE RESILIENCE MODEL



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LESSONS LEARNED FROM INFRASTRUCTURE CLIMATE RISK ASSESSMENTS

- Intensity – short duration precipitation is almost always a concern
- Infrastructure systems are almost always vulnerable to interruptions in power supply
- Combinations of events can have more impact than discrete events
  - Rain on snow
  - High snowfall followed by rapid thaw
  - Extreme high temperatures followed wildfires
- Meteorological data used in design is often dated
  - Engineering curves are often based on historic, and now outdated, data

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LESSONS LEARNED FROM INFRASTRUCTURE CLIMATE RISK ASSESSMENTS

- Multidisciplinary teams are very important
  - Fundamental understanding of risk and risk assessment processes
  - Directly relevant engineering knowledge of the infrastructure
    - Climatic and meteorological expertise relevant to the region
    - Hands-on operation experience with the infrastructure
    - Hands-on management knowledge with infrastructure
    - Local knowledge and history

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LESSONS OF INFRASTRUCTURE CRVA

- Climate change projections should be based on ensembles of model outputs
  - There is always a temptation to use only one set of data
- Understanding your baseline climate is critical
  - How infrastructure has responded to historical weather events informs judgment on how it will likely respond to future, more extreme, events
- It is important to monitor and maintain
  - Good records of weather events
  - The impact they had on your infrastructure
  - How you responded

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BENEFITS OF INFRASTRUCTURE CRVA

- Identify nature and severity of risks to system components
- Optimize more detailed engineering analysis
- Quick identification of most obvious vulnerabilities
- Structured, documented approach ensures consistency and accountability – due diligence
- Adjustments to design, operations and maintenance
- Application to new designs, retrofitting, rehabilitation and operations and maintenance
- Reviews and adjustments of codes, standards and engineering practices

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0	5	5
0	5	5
–	3	5
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INTERDEPENDENCIES

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THE NEED TO THINK IN NATIONAL AND LOCAL SYSTEMS SIMULTANEOUSLY

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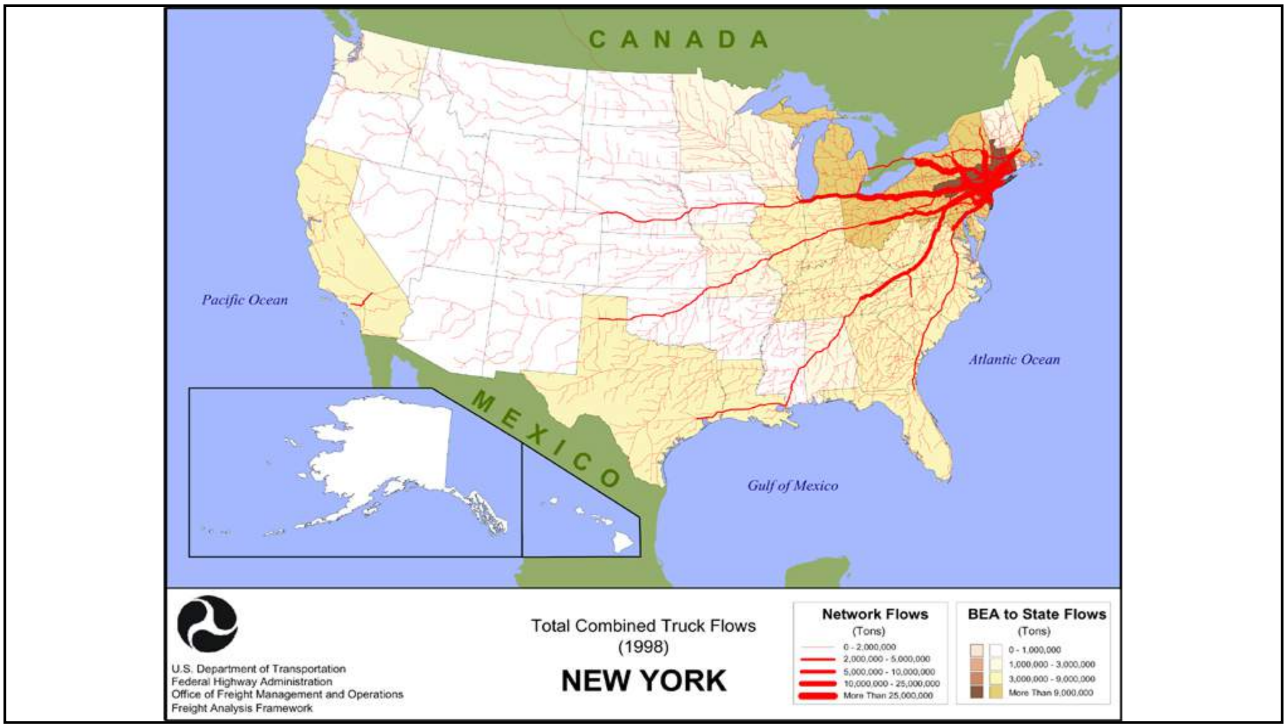
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
U.S. Department of Transportation
Federal Highway Administration
Office of Freight Management and Operations
Freight Analysis Framework
Total Combined Truck Flows
(1998)
NEW YORK
Network Flows
(Tons)
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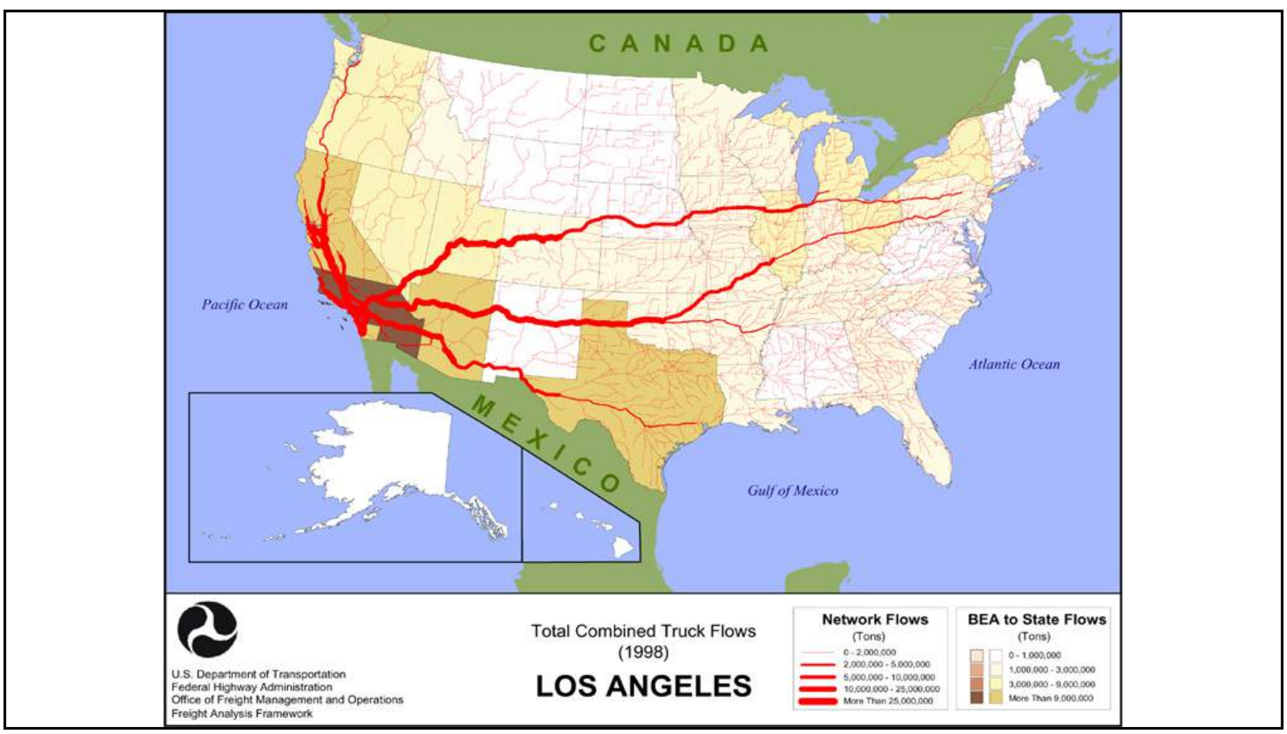
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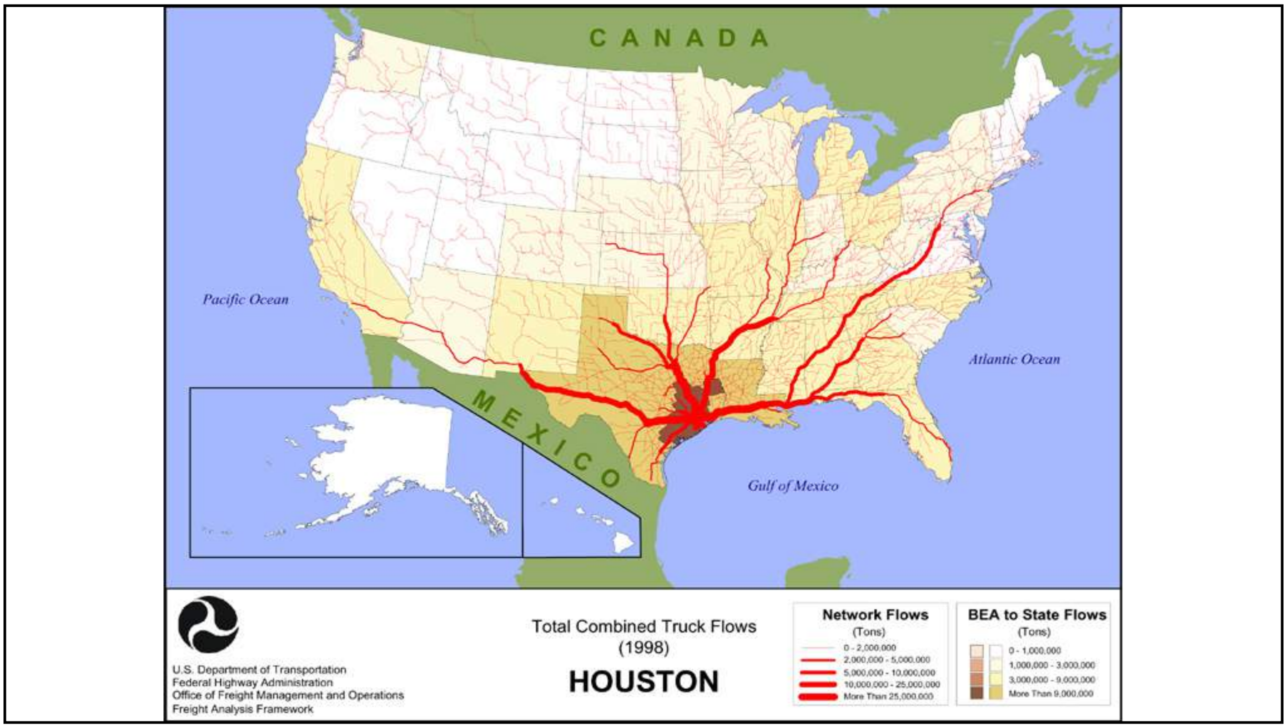

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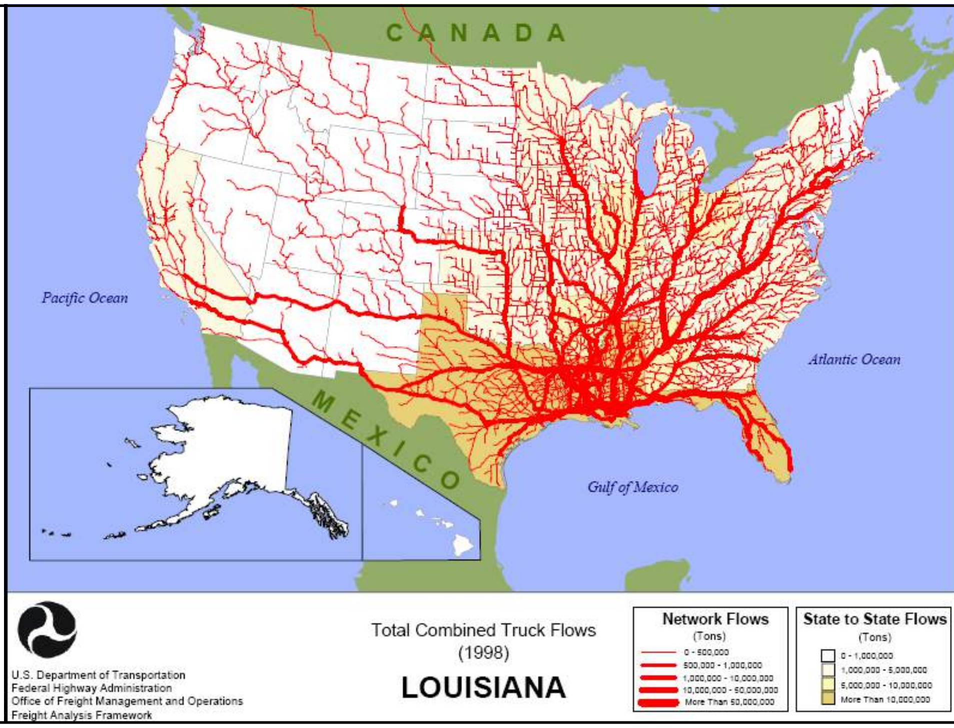

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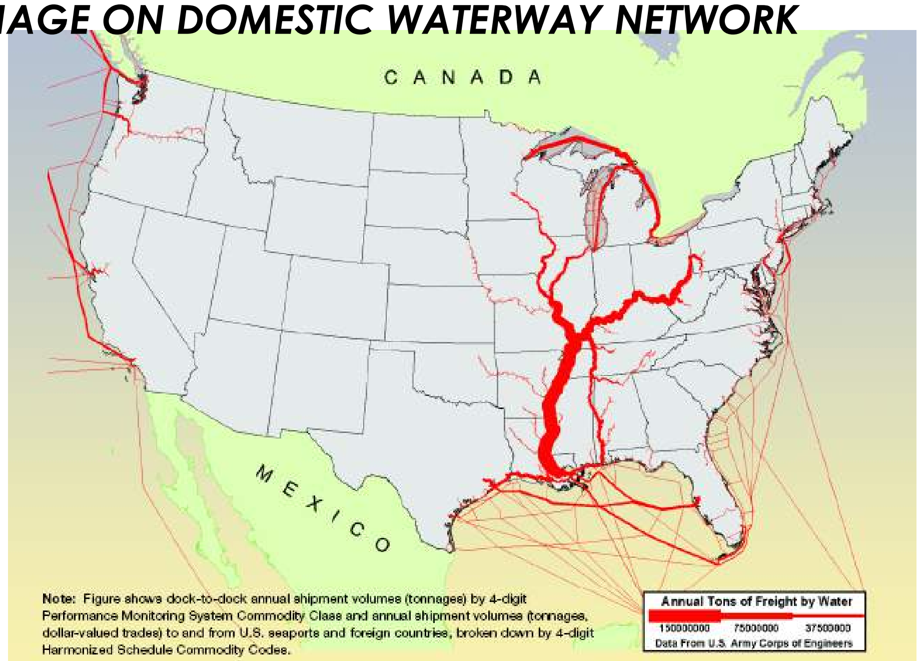
TONNAGE ON DOMESTIC WATERWAY NETWORK



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CASE STUDIES

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VULNERABILITY OF STORMWATER & DRAINGE INFRASTRUCTURE IN MINNESOTA, USA

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CONTEXT: SEVERE FLOODING EVENTS

Minneapolis, MN – July 1987

Rainfall: ~10" (25.4 cm) over 8 hrs
Damage Total: 30 million USD

Hokah, MN - August 2007

Rainfall: 15.10" (38.3 cm) over 24 hrs (state record)
Damage Total: $27 million USD

Duluth, MN – June 2012

Rainfall: ~9-14"(22.8-35.5) over 24 hrs
Damage Total: 108 million USD






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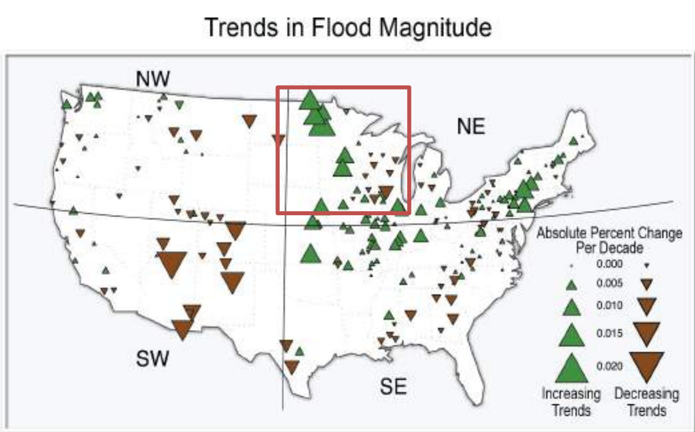
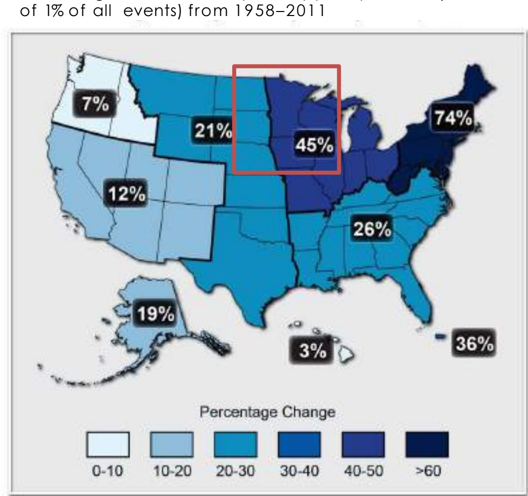
HEAVY PRECIPITATION & FLOODING TRENDS



National Climate Assessment Report 2013

Percentage increase in very heavy precipitation (heaviest of 1% of all events) from 1958–2011



Karl et al. 2011

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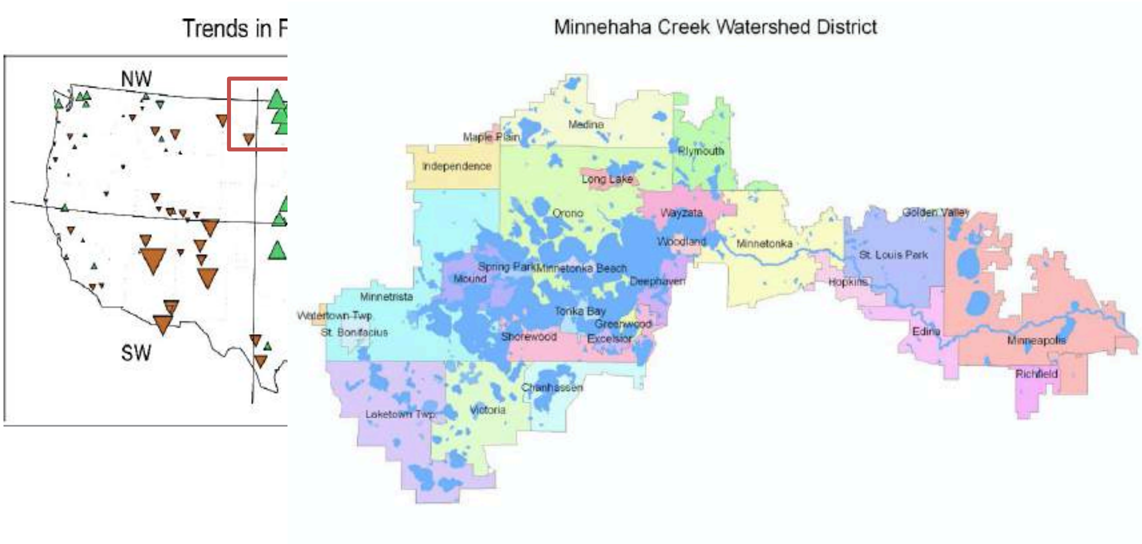
MINNEHAHA CREEK WATERSHED



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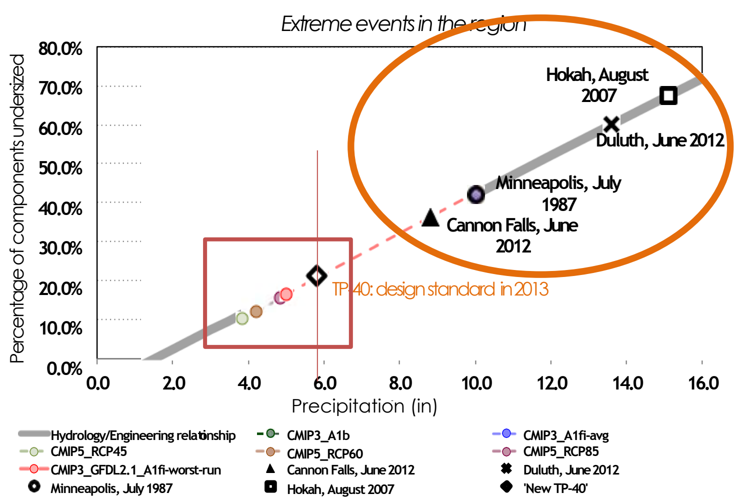
STORMWATER INFRASTRUCTURE

Historical engineering design standard: design storm is 10 year – 24-hour precipitation event



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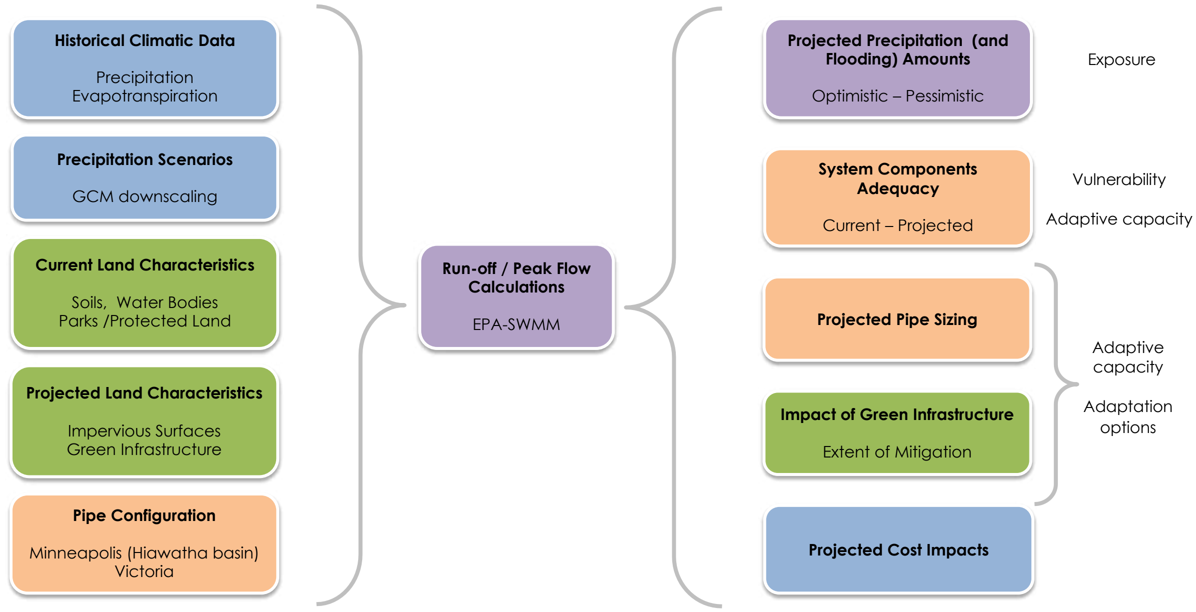
APPLIED RESEARCH APPROACH



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PROJECTED PRECIPITATION AMOUNTS AND FREQUENCY: CURRENT AND FUTURE

	Return period (years)	Recent climate	mid-21st cent. Optimistic	mid-21st cent. Moderate	mid-21st cent. Pessimistic
	2.5	2.5	2.84	3.3	6.86
	5	3.17	3.47	4.11	8.4
	7.5	3.57	3.88	4.66	9.39
"Design Storm"	10	3.86	4.19 +9%	6.56 +70%	10.13 +157%
	25	4.84	5.28	6.74	12.75
	50	5.67	6.22	8.31	15.03
	75	6.2	6.82	9.39	16.5
	100	6.59	7.27	10.23	17.59

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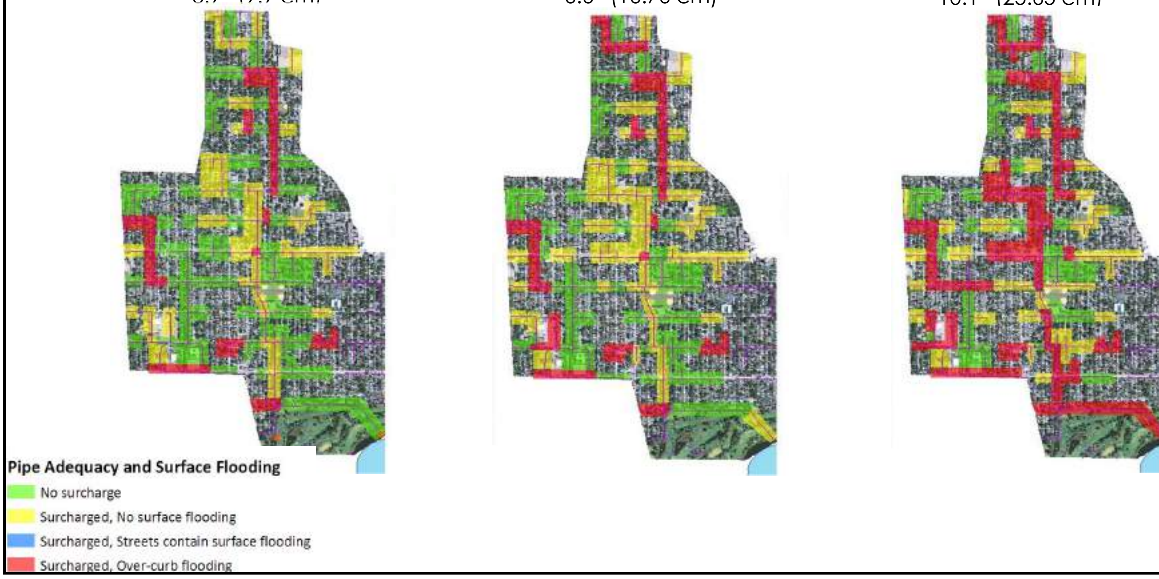
HIAWATHA CATCHMENT, MINNEAPOLIS

Recent storms
3.9" (9.9 cm)

Moderate projection
6.6" (16.76 cm)

Pessimistic projection
10.1" (25.65 cm)



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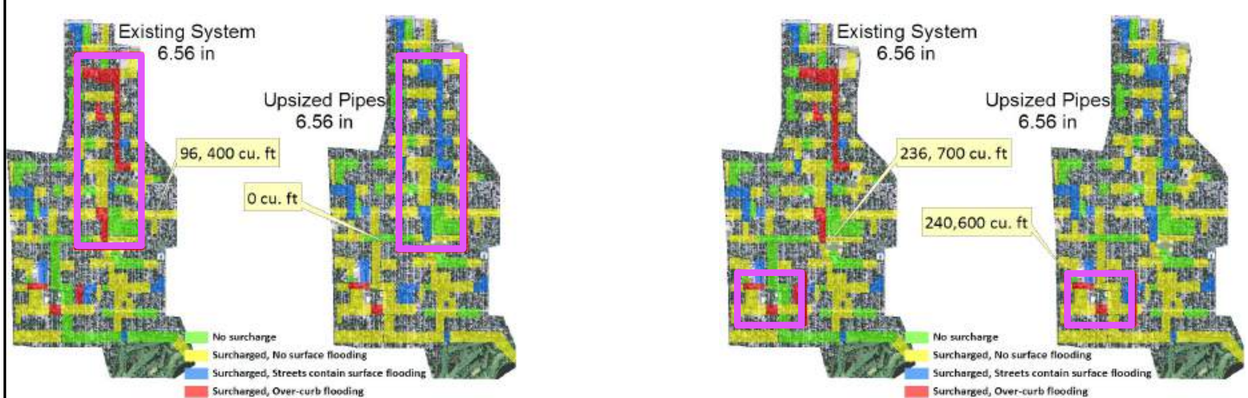
COST OF PIPE UPSIZING



10-yr Event	Flood volume (over curb)	Increase undersized pipes to eliminate over-curb flooding	
	Million gallons	Length of pipe	Cost
3.9" (9.9 cm)	2.92	3,439 ft	6.5 million
6.6"(16.76 cm)	6.34	20,405 ft	38.8 million
10.1" (25.65 cm)	34.11	—	—

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ADAPTATION COSTS IN CONTEXT

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COST OPTIONS IN $/MG

Dry detention basin	Upsizing pipes	Underground storage	Cost of damages (per flood)
0.11 $/gal	1.72 $/gal	2.4 $/gal	41,000 – 157,000 $/gal

Cost of damages to property (low end) 1.197 billion

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KEY POINTS

- Need for new and updated codes and standards that reflect climate projections
- Increasing importance of forensic analysis of engineering design
- Increasing importance of improved asset management
- Importance of updated maintenance schedules and budgets
- Increased understanding of interdependencies and their integration into calculations

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