Building Resilience through Infrastructure Planning

NOAA-funded Regional Coastal Resilience Grant

- Toledo, OH metropolitan area
  Lucas County (pop. ~430,000)
  City of Toledo

- Savannah, GA, metropolitan area
  Chatham County (pop. ~290,000)
  Savannah/Chatham County MPO

- **PAS 596: Planning for Infrastructure Resilience**

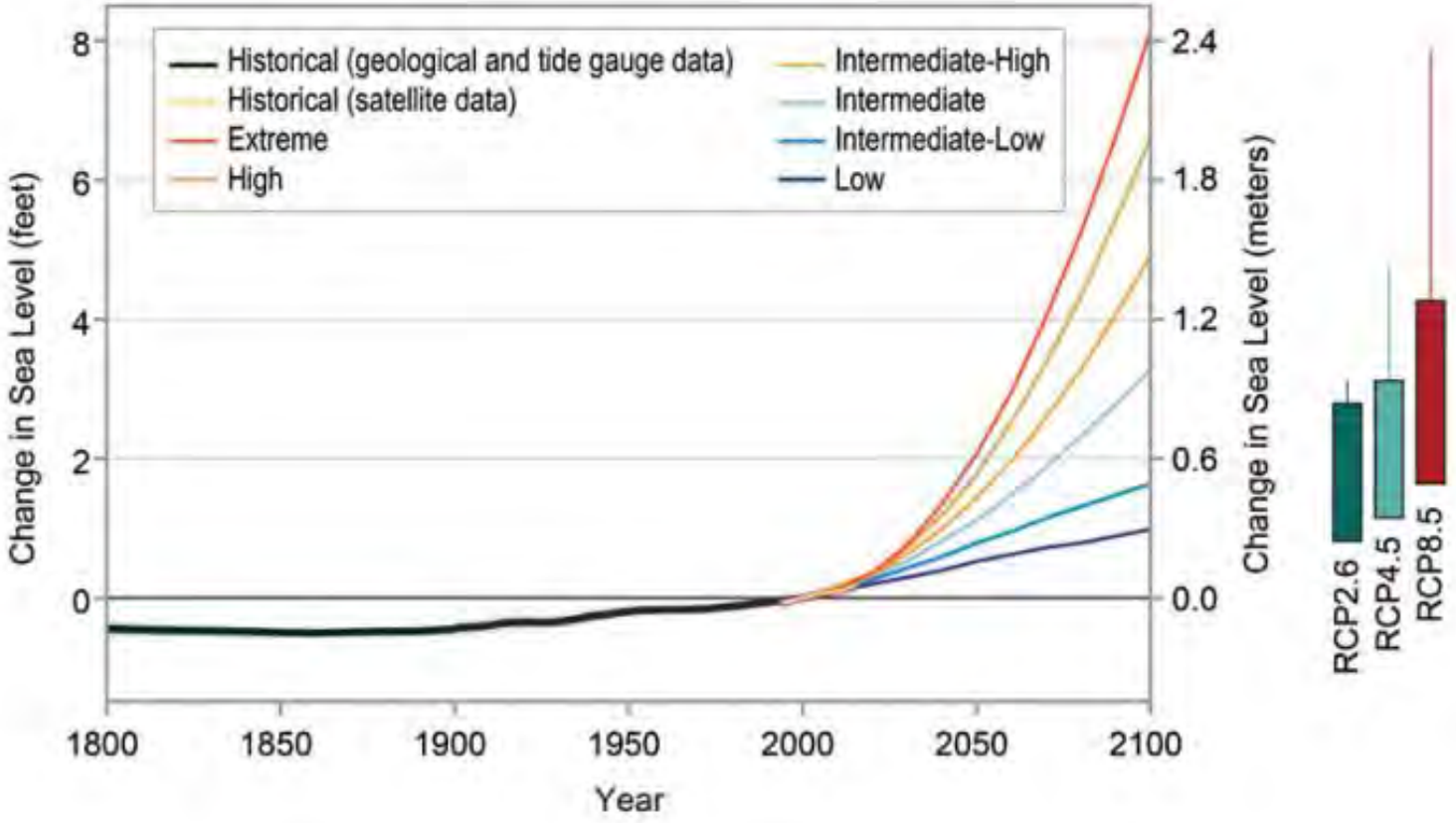
ASSOCIATION OF STATE FLOODPLAIN MANAGERS

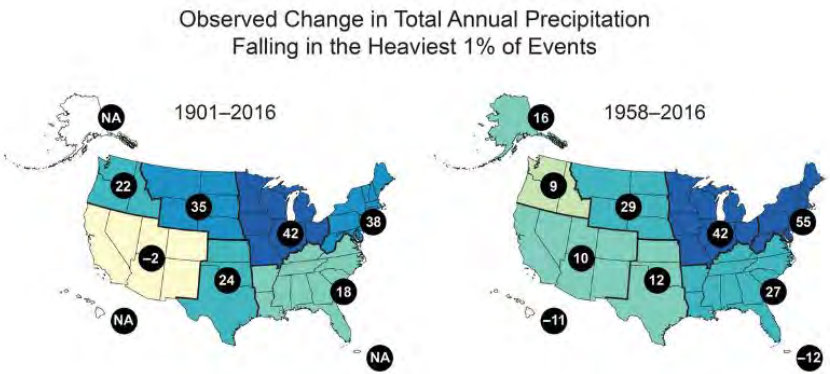
APA

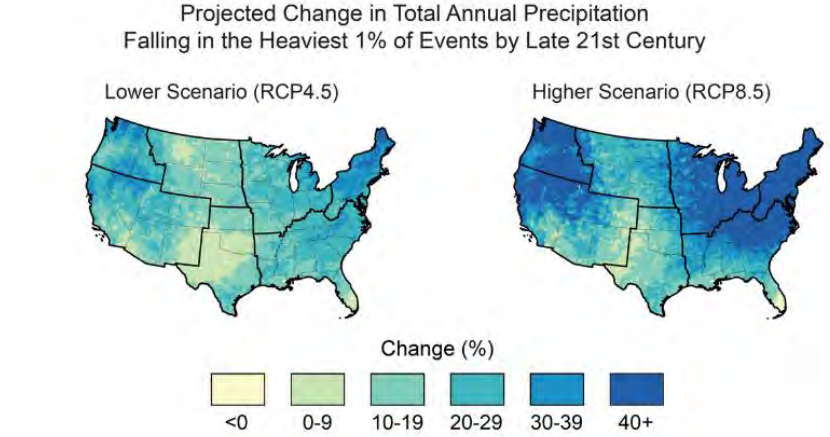
American Planning Association

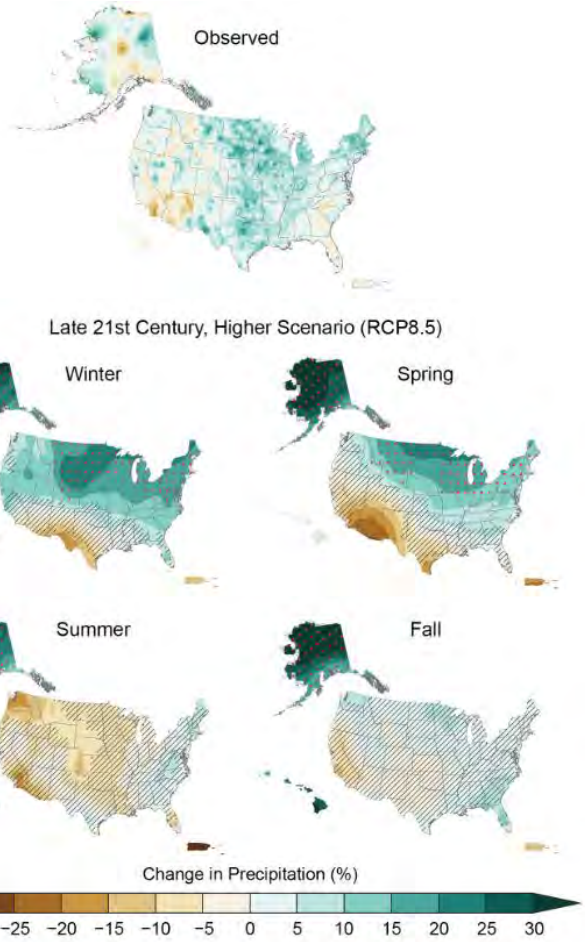
Infrastructure Sector	Infrastructure Type
Water, wastewater, and stormwater	Water and wastewater treatment plants, distribution systems, drainage, retention
Transportation	Roads, bridges, public transit, airports, ports
Public facilities	Community centers, schools
Energy	Electric grid of municipal utility
Parks and open space	Public parks, bike paths
Health and emergency management services	Fire and police stations, emergency operations centers
Coastal protection	Groins, jetties, seawalls, dams

(US Global Change Research Program 2018)


Historical (geological and tide gauge data)
Historical (satellite data)
Extreme
High
Intermediate-High
Intermediate
Intermediate-Low
Low
Change in Sea Level (feet)
Change in Sea Level (meters)
8
6
4
2
0
2.4
1.8
1.2
0.6
0.0
1800
1850
1900
1950
2000
2050
2100
Year
RCP2.6
RCP4.5
RCP8.5


Observed Change in Total Annual Precipitation
Falling in the Heaviest 1% of Events
1901–2016
1958–2016
NA
22
35
42
38
–2
24
18
NA
NA
16
9
29
42
55
10
12
27
–11
–12


Projected Change in Total Annual Precipitation
Falling in the Heaviest 1% of Events by Late 21st Century
Lower Scenario (RCP4.5)
Higher Scenario (RCP8.5)
Change (%)
<0
0-9
10-19
20-29
30-39
40+


Observed
Late 21st Century, Higher Scenario (RCP8.5)
Winter
Spring
Summer
Fall
Change in Precipitation (%)
−30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30

Survey of planners

Climate adaptation practice

Capital improvements and infrastructure planning

Are planners involved?

What did we find?

Are planners involved?

Planners not necessarily empowered in either area

- Often not empowered to seek out and use available sources of climate data and information
- Ability to influence decision-making in CIP and infrastructure planning is limited

What did we find?

Climate adaptation practice

Capital improvements and infrastructure planning

Local approaches vary

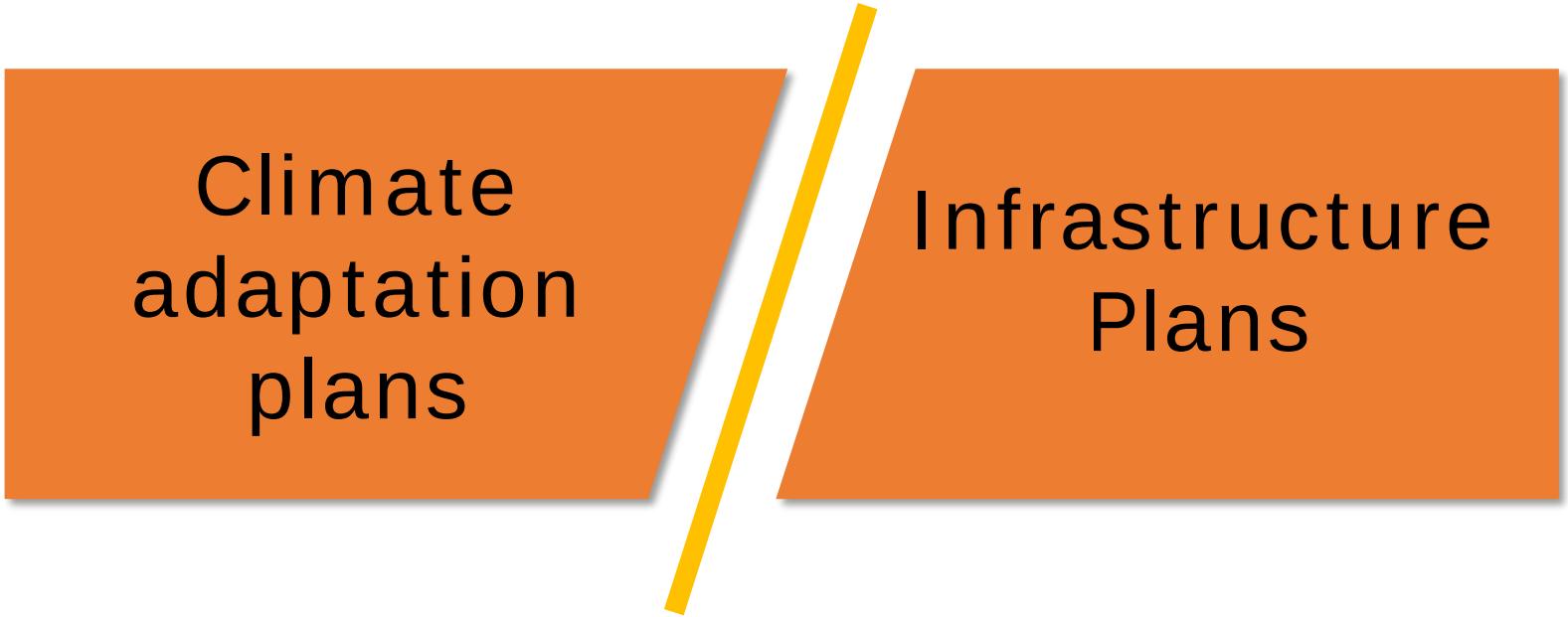
- Ad hoc
- Comprehensive
- And everything in between
- Pros and cons for any approach

Interviews

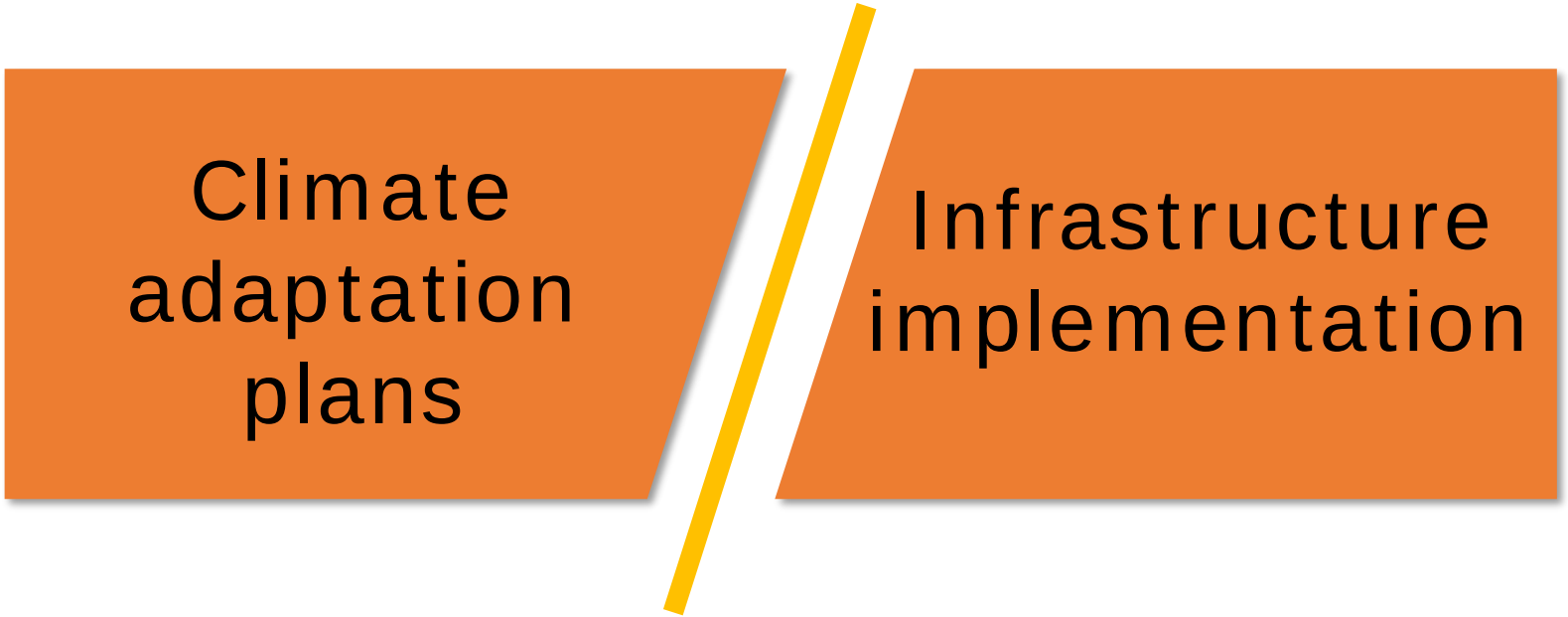
- Many different approaches
- Factors:
  - Community size
  - Local capacity and expertise
  - Funding
  - Support from state and regional organizations
  - Access to data

The challenges of climate, infrastructure, and planning

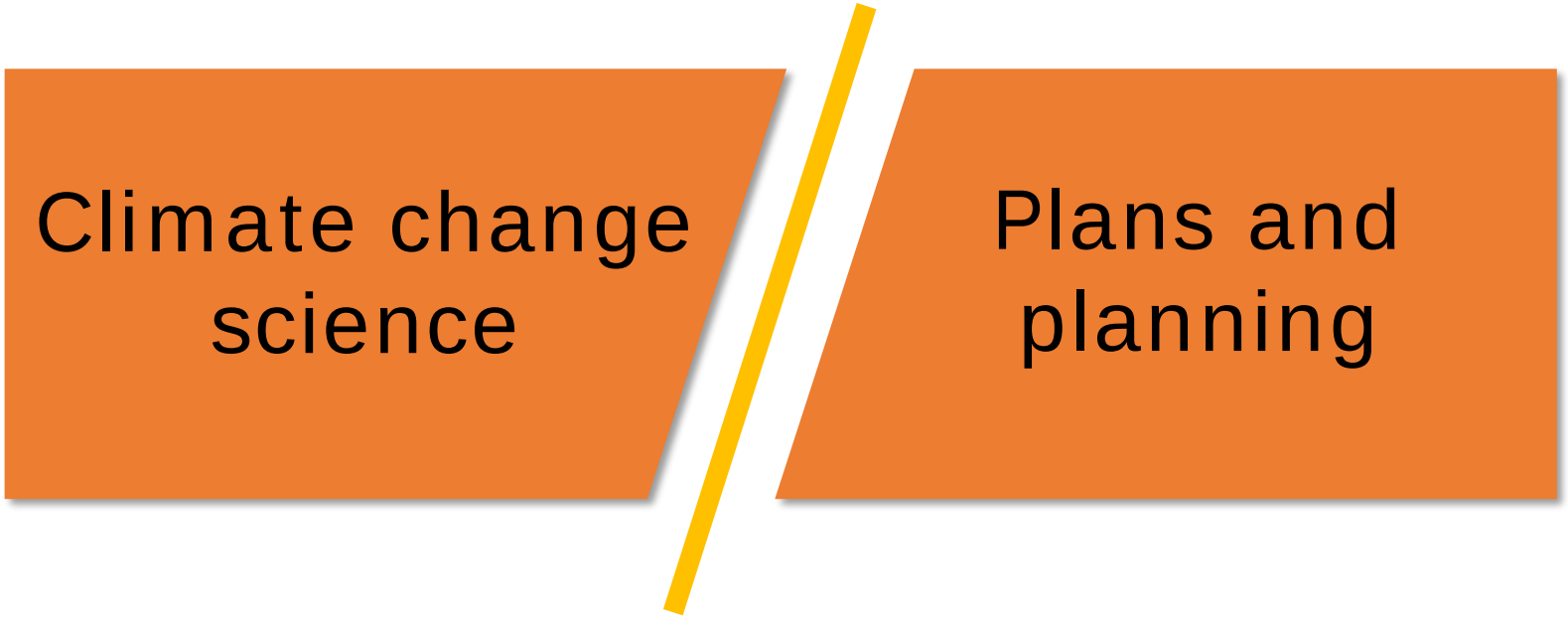
The challenges of climate, infrastructure, and planning



The challenges of climate, infrastructure, and planning



The challenges of climate, infrastructure, and planning



Challenge of uncertainty

- Infrastructure expected to last for decades
- Infrastructure is expensive
- Climate models are imperfect

Long-term decision-making under climate impact uncertainty

What is the role of community planning in infrastructure resilience?

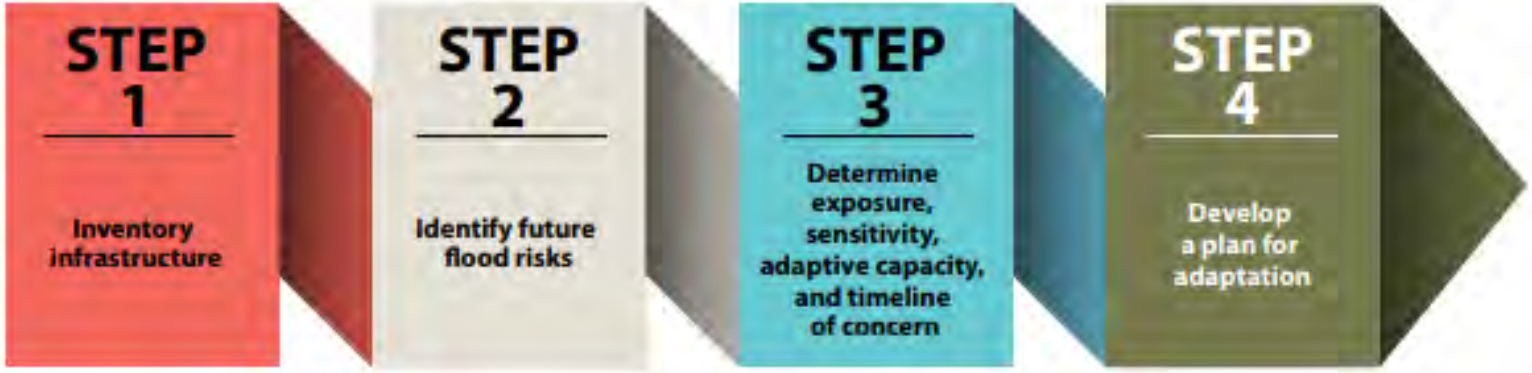
- **Long-range** perspective
- Approach problems **comprehensively**
- Deal with unique **place-based** issues

PAS 596: Planning for Infrastructure Resilience

- Guidance for planners and allied professionals
  - The state of climate science/infrastructure
  - Assessing Vulnerability
  - Creating Plans
  - Implementing Infrastructure

Vulnerability Assessment

- Establish a baseline condition of infrastructure across a community
- Understand community-wide risk and long-term infrastructure needs
- Rely on this assessment in future planning and implementation stages



Creating Plans

- Comprehensive Plans
- Hazard Mitigation Plans
- Climate Adaptation Plans
- Sustainability Plans
- Green Infrastructure Plans
- Open Space and Parks Plans
- Area and Sub-area Plans
- Transportation Plans
- Regional Plans

Stages of the CIP Process	Integrating Future Flood Considerations
Establish scope, process, and participants	Engage a wide variety of potential participants, including departmental representatives from outside the traditional infrastructure agencies in the CIP committee to ensure a wider variety of factors are considered throughout the process
Identify needs	Integrate findings from vulnerability assessments and local plans on the potential impacts of future flooding on infrastructure levels of service and the exposure of neighborhoods and populations into existing processes for analyzing existing conditions and long-term infrastructure needs
Identify projects	Ensure that the projects identified for potential inclusion in the CIP are aligned with long-term infrastructure goals and needs identified in local plans, and that future climate risks to both the infrastructure itself and the communities that infrastructure is intended to serve are identified in a vulnerability assessment
Prioritize and select projects for funding	Assess the long-term value and costs of infrastructure projects in light of the future flood risks posed to those projects, the maintenance and adaptation measures that might be necessary to ensure the continued operation of infrastructure, the overall vulnerability of the areas and populations that infrastructure is intended to serve, and the potential resiliency benefits that the project might bring
Prepare and recommend the CIP	Establish a clear rationale for project selection that is consistent with comprehensive (or functional) plan recommendations, a sound understanding of the flood vulnerability of the selected projects, and clear justifications for how the selected projects advance flood resiliency goals
Adoption and implementation	Review the adopted CIP annually and help to define a regular update process to ensure continued integration of flood resilience goals into the CIP and alignment with existing or ongoing planning processes

Climate Change & Sea Level Rise in the Florida Keys:
Monroe County Begins to Bridge the Gap with Roads Elevation

Sea Level Rise and Infrastructure
Capital Facilities Planning
Friday, April 30, 2021

Presented by Rhonda Haag
Chief Resilience Officer
Monroe County, FL

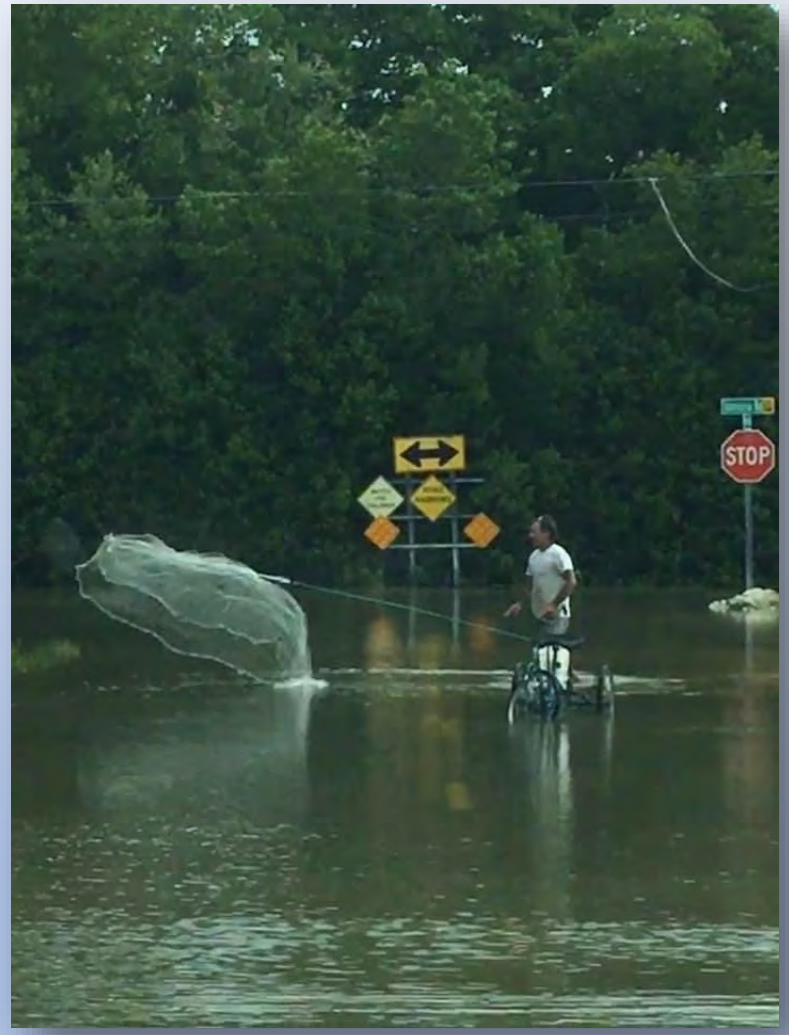
HDR wood.

Erin L. Deady, P.A.

Monroe County Roadway Vulnerability Study and how Planners are Assisting

Agenda

1. Location of Project
2. Background on County's Resiliency and Climate Program and Key Issues related to Sea Level Rise
3. Local Infrastructure Adaptations and How Sea Level Rise is Being Addressed
4. Role of planners in the planning process as it relates to Sea Level Rise adaptation efforts



Kristen Key Szpak, 10/19/20

Location:
Monroe County, Florida
“Florida Keys”

Roadway Vulnerability Study Goals:

- Help make the Florida Keys island chain more resilient to sea level rise.
- Help maintain access to homes.
- Help maintain property values.

Why the Urgency? Key Issues

Key Largo – Stillwright Point (85 days)

Key Largo – Twin Lakes

Big Pine

Monroe County, Florida Among Most Vulnerable Counties in Nation

Rank	County	Population Displaced
1.	Tyrell, NC	45%
2.	Hyde, NC	42%
3.	**Monroe, FL**	**36%**
4.	Dare, NC	21%
5.	Currituck, NC	20%
*	Miami-Dade, FL	3%
*	Broward, FL	1%

Land that's dry now that will go under water by 2060 in relation to the number of people living there

**National-scale analysis of over 300 coastal counties Matthew Hauer, Applied Demography Program, University of Georgia*

King Tides
Fall 2015 and 2016

Fall 2019-2020 King Tides

Sea Level Rise Planning Process to Date

1. County's sea level rise planning launched in 2016: GreenKeys
    - 5-year work plan, 165 recommendations
    - Recommendations included:
        - Amendments to Comprehensive Plan
        - Pilot Roads Projects
        - Improve elevation data
        - Engineering level analysis of transportation impacts countywide
2. Energy and Climate Element of Comprehensive Plan (2016)
3. Pilot Road Elevation Projects (Big Pine and Twin Lakes) initiated in 2016 and design/permits completed 2020
4. New Roads Mobile LiDAR elevation data (2019 completed)
5. Grants for Sea Level Rise planning

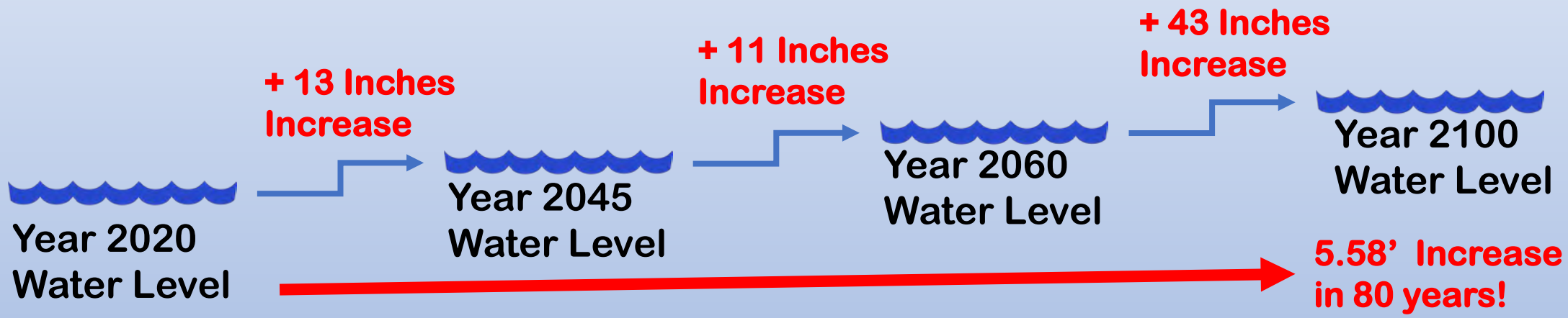
Sea Level Rise Planning In Process

1. Roads Adaptation Plan -launched 2019
   - Identify sea level rise impacts to roads and drainage comprehensively
   - Develop Ranking Criteria –with Planners assistance
   - Identify policy options –with Planners assistance
   - Develop engineering alternatives and Implementation Plan
2. Vulnerability Assessment for other County non-road assets being updated separately
   - For habitat, buildings, and infrastructure
3. Comprehensive Plan - 2021 update
   - Peril of Flood amendments to address State requirements (drafted 2019)
   - Adaptation Action Areas (in process 2020)
   - Other amendments as necessary

Monroe County Roadway Vulnerability Study

Increasing Projected Water Levels Throughout County…

Sea Level Rise Condition: ***NOAA 2017 Intermediate-High***



Monroe County Roadway Vulnerability Study

Increasing Projected Water Levels Throughout County…

Sea Level Rise Condition: NOAA 2017 Intermediate-High + King Tides

2035

2045

2060

Monroe County Roadway Vulnerability Study
How Sea Level Rise is Being Addressed

Increasing Projected Water Levels Throughout County…

Sea Level Rise Condition: NOAA 2017 Intermediate-High + King Tides

$1.8 Billion*

Projected SLR + King Tides will affect the following:	2045	Unincorporated Countywide %	2060	Unincorporated Countywide %	2100	Unincorporated Countywide %
Miles of Vulnerable and Critical County Maintained Roadways	**152 MI**	**49%**	**206 MI**	**66%**	**252 MI**	**81%**
# of Residential Units along County Maintained Roadways	**12,585 Res. Units**	**71%**	**14,501 Res. Units**	**82%**	**16,370 Res. Units**	**92%**

311 Total Road Miles County Wide

* Cost estimate is conceptual and assumes reconstruction of the roadway and use of an injection well system. Cost estimates do not include design, right-of-way acquisition, harmonization/cost to cure, and legal fees. Cost estimates are preliminary and subject to change.

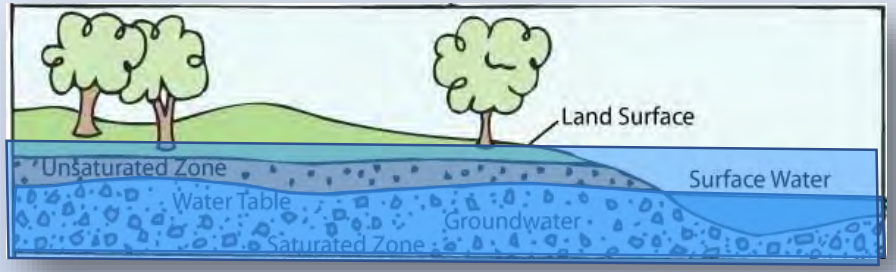
Monroe County Roadway Vulnerability Study

What is vulnerability?

What is criticality?

Monroe County Roadway Vulnerability Study

Step 1: Vulnerability Assessment



1. Groundwater Clearance

2. Surface Inundation Depth (SLR)

3. Storm Surge

4. Surface Wave Impact Potential

5. Roadway Existing Pavement Condition

Monroe County Roadway Vulnerability Study

Step 1: Vulnerability Assessment – What did it reveal?

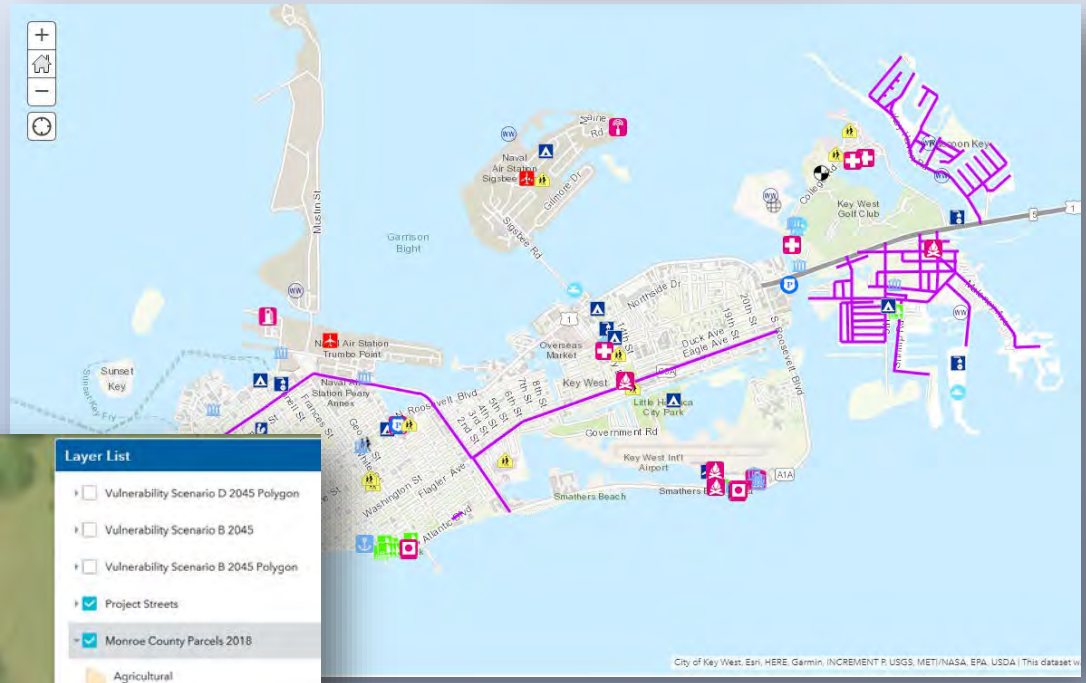
Old State Rd 4A (SLR Projection + King Tide measured from Roadway Surface Elevation)

Monroe County Roadway Vulnerability Study

Step 2: Criticality Assessment

1. Vulnerability Score

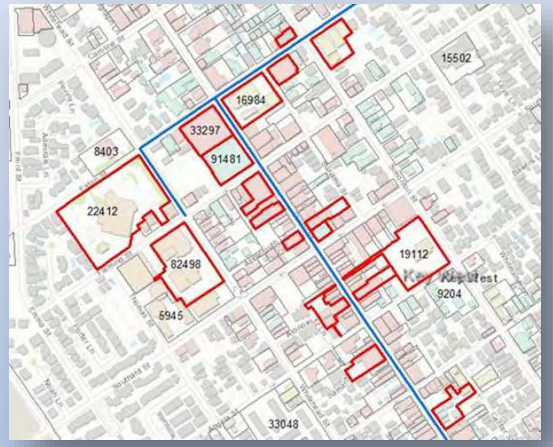
2. Number of Residential Units



3. Roadways Associated with Critical Facilities

Monroe County Roadway Vulnerability Study

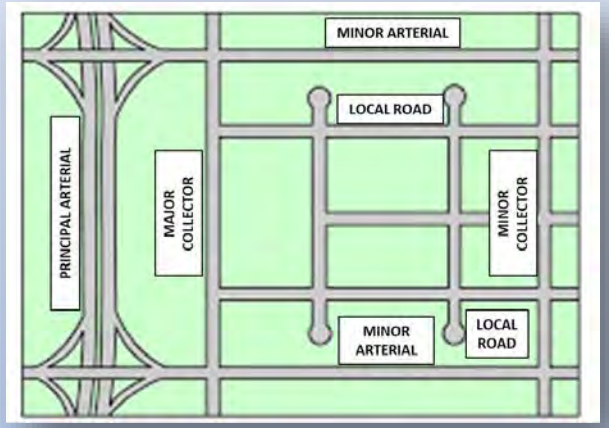
Step 2: Criticality Assessment (Cont.)



4. Commercial Buildings

5. Threatened, Endangered and Focus Species

6. Wetlands/Natural Habitats



7. Roadway Functional Classification and Evacuation Route

Monroe County Roadway Vulnerability Study

Planners Recommended Criteria and Weight Factors to Rank Roads for Vulnerability

STEP 1

Vulnerability Evaluation Factors	Weighting Percentages
Roadway Surface Inundation Depth	60%
Roadway Groundwater Clearance	25%

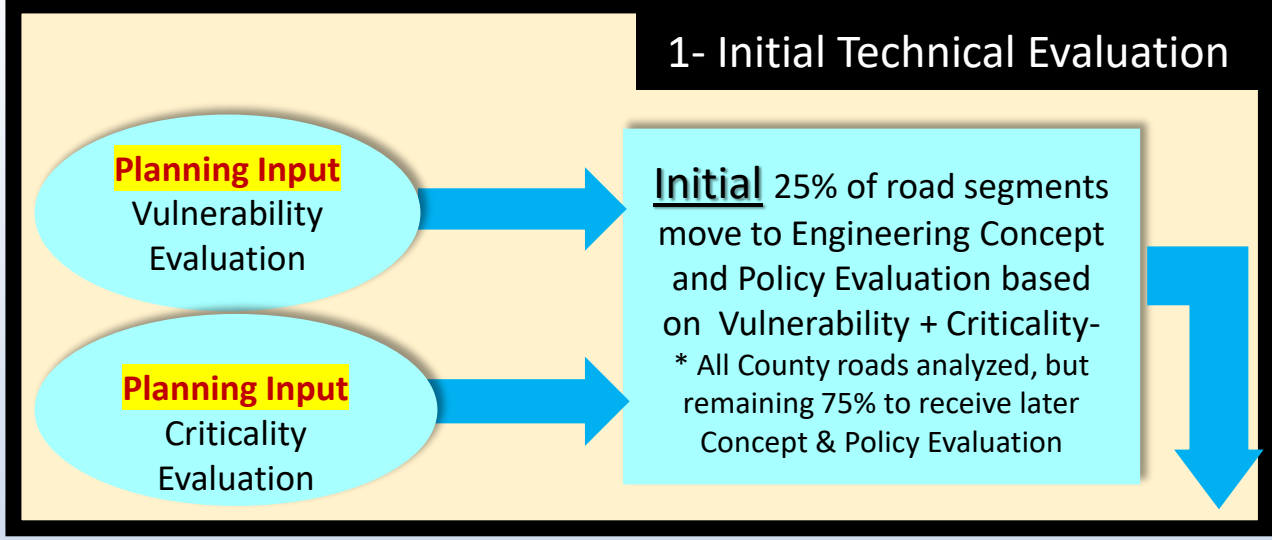
Criteria and Weights will Affect How Roads Are Ranked for Elevation

STEP 2

Criticality Evaluation Factors	Weighting Percentages
Vulnerability Score	50%
Number of Residential Units	25%

Planning Process for Roads Adaptation

Data collection
Review Compact's 25 year SLR (useful life) projections & King Tide predictions for future impacts



Planning Process for Roads Adaptation

Data collection
Review Compact's 25 year SLR (useful life) projections & King Tide predictions for future impacts

1- Initial Technical Evaluation

Planning Input
Vulnerability Evaluation

Planning Input
Criticality Evaluation

Initial 25% of road segments move to Engineering Concept and Policy Evaluation based on Vulnerability + Criticality-
* All County roads analyzed, but remaining 75% to receive later Concept & Policy Evaluation

2- Policy and Economic Evaluation

Board Presentation
November 2020

Engineering Concept
Evaluation = Preliminary Design & Conceptual $$$

Further Evaluation with Planning Input Considerations *could* include: Level of Service, cost effectiveness, affordable housing issues, access, staging efficiency + other factors depending on road project

Planning Process for Roads Adaptation

Data collection
Review Compact's 25 year SLR (useful life) projections & King Tide predictions for future impacts

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Evaluation = Preliminary Design & Conceptual $$$

Further Evaluation with Planning Input Considerations *could* include: Level of Service, cost effectiveness, affordable housing issues, access, staging efficiency + other factors depending on road project

3- Plan & Implementation

Board Review and Public Engagement
Review results of full roads evaluation process and results

Draft Roads Adaptation Plan & Implementation Strategy With Planning Input
* New projects in remaining 75% added as reviews completed

Board Approval (Fall 2021)
Roads Adaptation Plan and Implementation Strategy

After Fall 2021 = Implementation
Detailed design, project permitting/ implementation and funding

Aligning Comprehensive Plan Policy Initiatives: Evaluation & Appraisal Report EAR by 5/1/21

Initiatives	Timeframe
Energy and Climate Element Updating now to incorporate all climate planning initiatives To be finalized *in Evaluation and Appraisal Report* based Comp Plan amendments	2013 Completed In process (RPG) 2020-2021
Peril of Flood Amendments To be finalized in *Evaluation and Appraisal Report* based Comp Plan amendments	Drafted (RPG) 2020-2021
Overall **Integration of Sea Level Rise into other Comp Plan Elements** To be finalized in *Evaluation and Appraisal Report* based Comp Plan amendments	Drafted (RPG) 2020-2021
Stormwater Policy Implementation Policy 1001.1.3 & 1001.1.6: Updating stormwater management regulations & inventory and analysis of existing public drainage facilities	In process (DEO Grant)

Identifying the Issues for Future Comprehensive Plan Updates

1) Integration of Countywide Roads Study into capital improvements planning process
2) Updating other vulnerability work beyond roads/stormwater to form the basis for establishing adaptation action areas
3) Assessment of shorelines and policies (natural and hardening)
4) Remaining growth in the Keys (2026) and vulnerable neighborhoods
5) ROGO and transfer of development rights (evaluation of sea level rise vulnerability)
6) Framing infrastructure commitments (deficiencies, maintenance and growth/expansion)
7) Land acquisition and evaluation of sea level rise
8) Maintaining access for recreation and open space
9) Disaster recovery and rebuilding more resiliently

Planning Decisions to Develop Roads and Flood Mitigation Implementation Strategy

- **Planning Decision** Framework of Adaptation Approaches
  - Analysis of Future Growth
    - Where is the remaining growth (and demand for services) going to go?
  - Level of Service issues
    - Differing levels of service across neighborhoods
    - Case studies related to "natural hazards" and government providing services (ie; flooding, snow plowing, fire management, etc.)
  - "Road Maintenance"
    - County obligations to maintain roads and authority to upgrade
- Implementation strategies:
  - Comprehensive Plan, Ordinances, Code, Special Districts/MSBU, etc.

Twin Lakes

County Adaptation + Parcel Adaptation

Countywide Adaptation

- Roads
- Habitat/Resources
- Elevate or mitigate County buildings
- Infrastructure

+

Private Property Response

- Elevate or mitigate private structures
- Lot fill and driveways
- Shorelines
- **Comp Plan Amendments Required**

=

Achieving Resilience

- County
- People
- Habitat
- Economy

How Communities Are Implementing Resilience for Infrastructure or Allowing Private Property Adaptation

Sample Adaptation Implementation Strategies for Communities	Comprehensive Plan	LDRs & Other Code provisions	Local Govt. Capital Improvement Funding	Private Property Owner Funding (assessments or other sources)
1. Public- Road elevation & flood mitigation	X	X (Design standards)	X	X

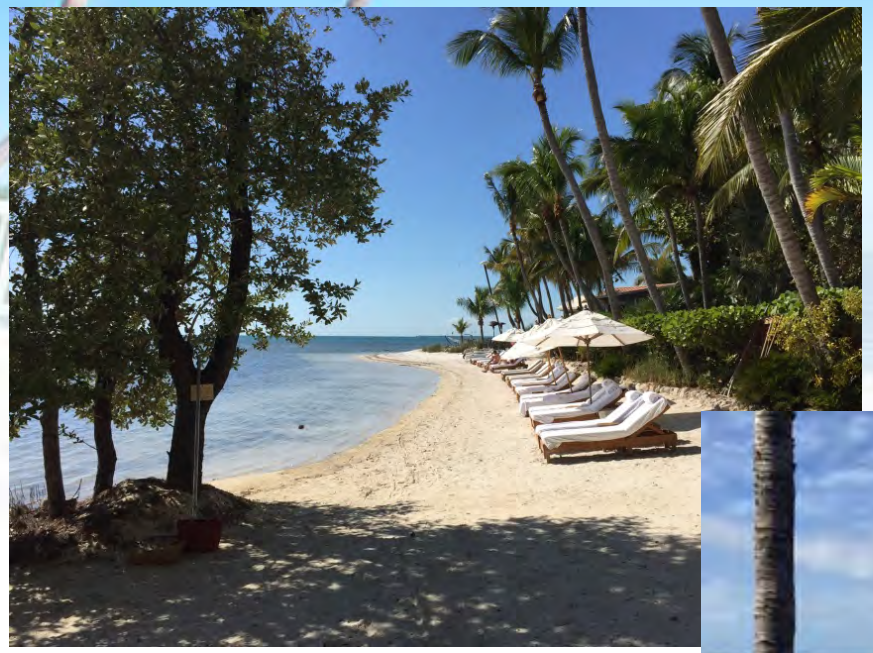
How Are Other Communities Implementing Resilience for Infrastructure or Allowing Private Property Adaptation?

Sample Adaptation Implementation Strategies for Communities	Comprehensive Plan	LDRs & Other Code provisions	Local Govt. Capital Improvement Funding	Private Property Owner Funding (assessments or other sources)
1. Public- Road elevation & flood mitigation	X	X (Design standards)	X	X
2. Private property- Shoreline, fill & driveways, etc.	X	X (Site development)		X

How Communities Are Implementing Resilience for Infrastructure or Allowing Private Property Adaptation

Sample **Adaptation Implementation Strategies for Communities**	**Comprehensive Plan**	**LDRs & Other Code provisions**	**Local Govt. Capital Improvement Funding**	**Private Property Owner Funding (assessments or other sources)1.**
1. Public- Road elevation & flood mitigation	X	X (Design standards)	X	X
2. Private property- Shoreline, fill & driveways, etc.	X	X (Site development)		X
3. Public or private property- Available lands for road adaptation, management of acquired lands and vacant parcels where flooding crosses onto roads	X	X (Uses/Mgmt. of lands)	X	X

Thank You



Haag-Rhonda
@MonroeCounty-Fl.gov

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Characterizing the Expressions of Aging Urban Infrastructure for Resilience

Presented to:

APA HMDR Webinar

April 30th, 2021

WISRD WHOLE INFRASTRUCTURE SYSTEMS FOR RESILIENT DEVELOPMENT

a Jacobs platform

By: Mark Reiner, PhD, PE - Director of Resilient Infrastructure

*The Infrastructure bill has a **heavy and appropriate emphasis on aging infrastructure**, which is part of the long-term resilience stresses…*

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Characterizing Urban Infrastructure for Resilience

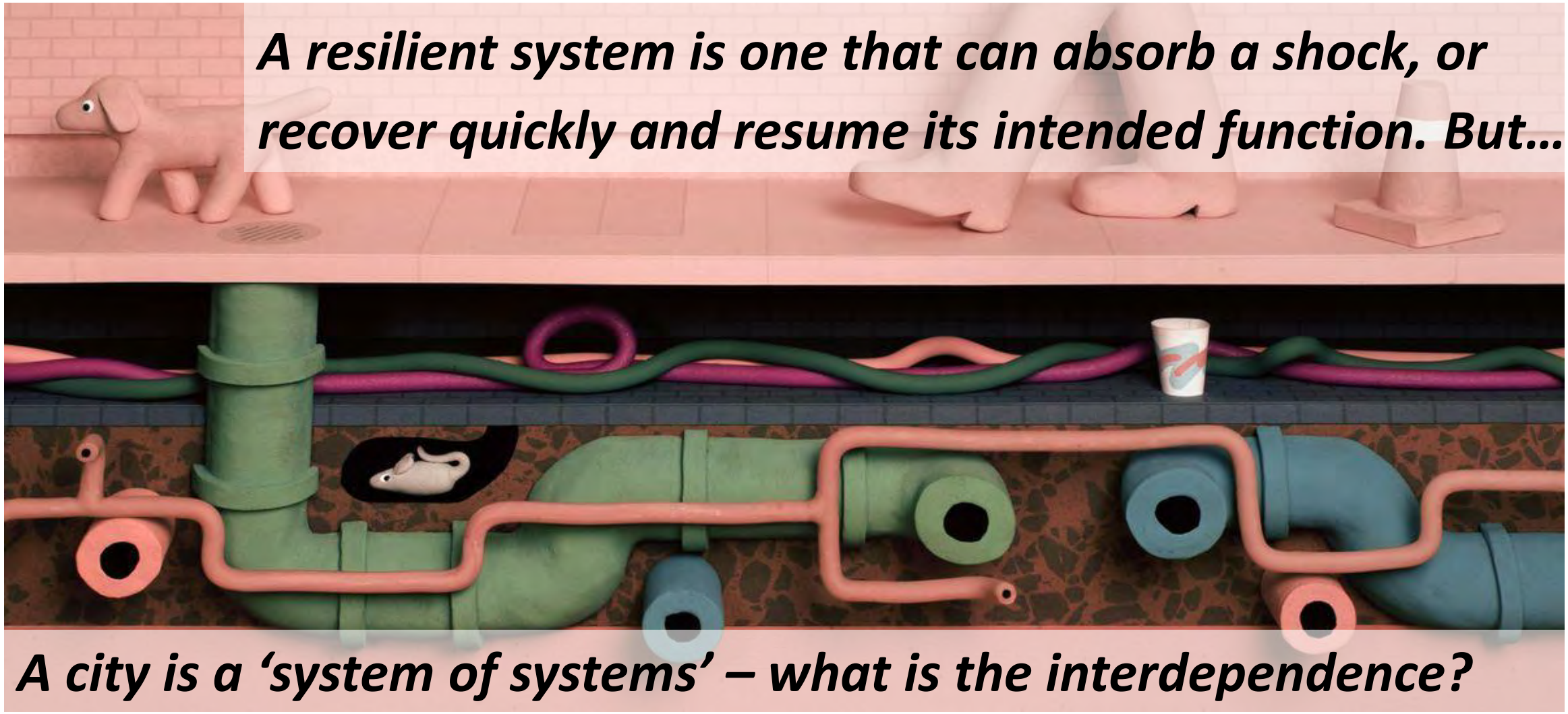

ILLUSTRATION: HUDSON CHRISTIE

Obtained from: https://www.bloomberg.com/news/features/2017-08-10/nobody-knows-what-lies-beneath-new-york-city

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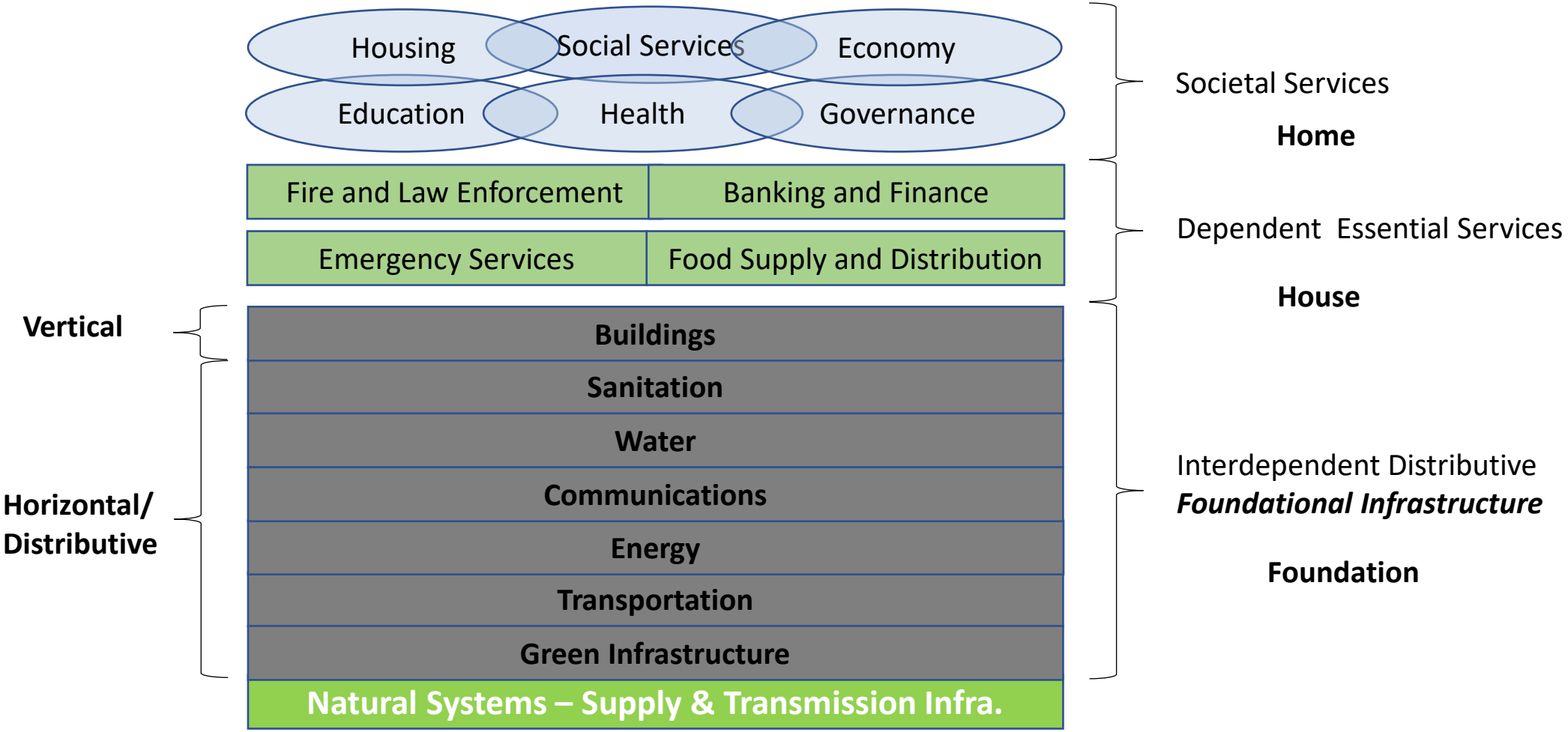
Foundational Infrastructure Framework



Reiner, M., & McElvaney, L. (2017). Foundational infrastructure framework for city resilience. Sustainable And Resilient Infrastructure, 2(1), 1-7. doi: 10.1080/23789689.2017.1278994

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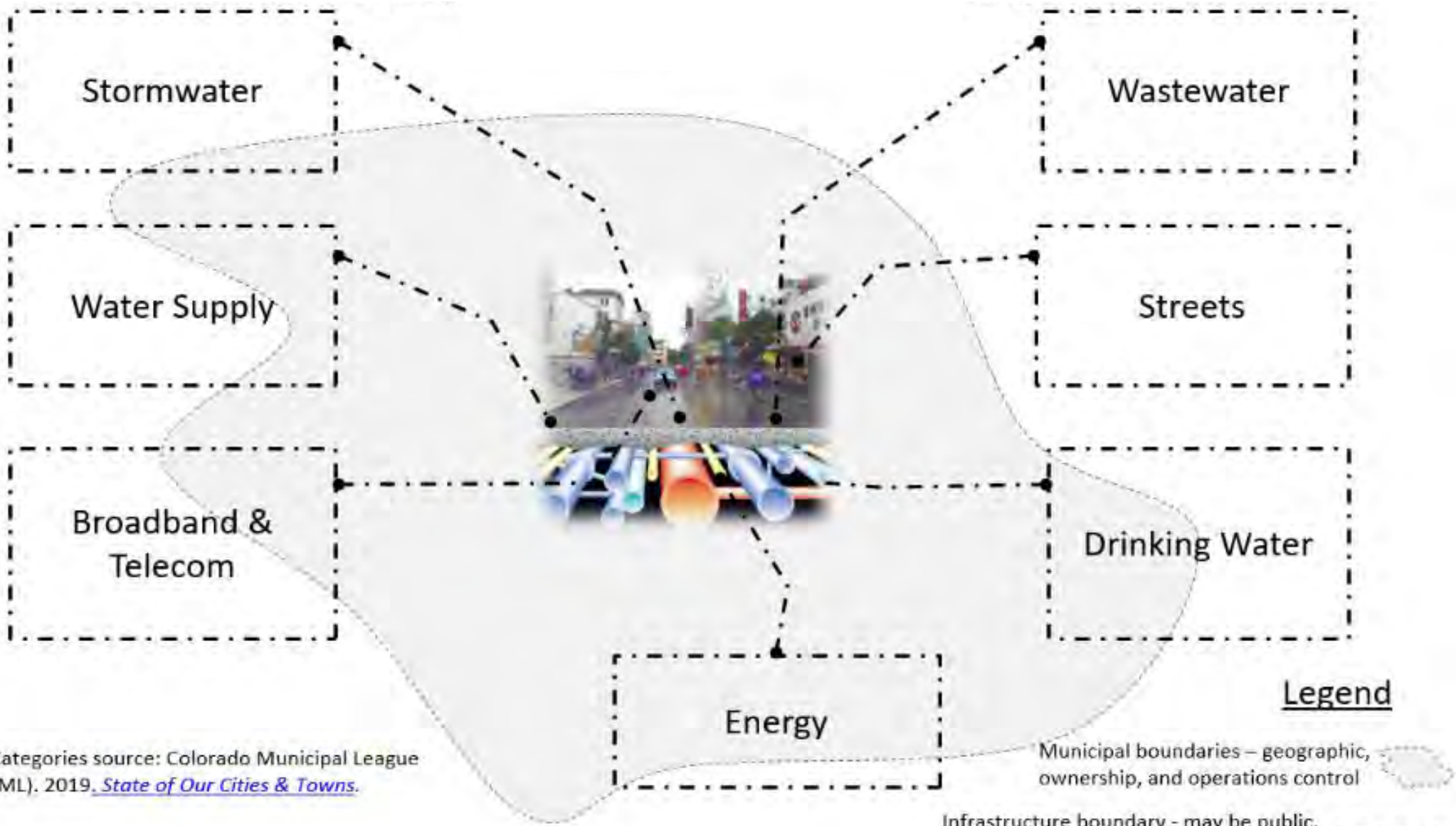
Key: A single view of distributive infrastructure



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Threats: Inaccessibility & deferred maintenance

The U.S. devotes an estimated $10 billion annually to simply locate existing underground infrastructure

ASCE 38-02 standard for the quality of location information of subsurface utilities.

Physicists and civil engineers are developing new quantum technology (QT) instruments.

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Image obtained from https://www.nytimes.com/2019/07/16/opinion/smart-cities.html

Characterization requires communication

'Infrastructure **Disruption**' has been defined solely by the loss of service to **End-users**
(World Bank, Lifelines, 2019)

We need to quantify the related physical disruptions of distributive infrastructure.

- In NYC, roads are cut open 550 times ***per day*** – could be related to any sector of paradigm
- Toronto patches an average of 20,300 potholes during the ***month of January*** (2017-2021)
- Crash rates are likely to increase by ***20 to 70 percent*** when there is a work zone in place (Ullman et al, 2008)

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The indirect costs of failed/damaged infrastructure

True Costs = Direct Costs (<u>utility</u>) + Indirect Costs (<u>public & individuals</u>)

Indirect costs include; property damage, traffic delays, environmental impacts, lawsuits, injuries, fatalities, …etc.

Damage to buried infrastructure

- Research (University of Birmingham, UK) estimated that indirect are ***29 times*** direct costs.
- In 2019 alone, the indirect costs of damaged buried utilities in the U.S. was $30 billion, and to NYC alone is $300 million ***per year*** – *multiple sectors*.

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Indirect costs: If not planners, then who?

Despite being a straightforward methodology, indirect costs are rarely used for three reasons:

1. ***Responsibility:*** *Indemnity and No Notice allow utilities to avoid paying*

2. ***Perspective:*** *Single sector (e.g. Grand Central model) vs. the whole*

3. ***Location:*** *Need to characterize where disruptions are actually hazards*

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Urban planners already deal with the legacy of aging infrastructure, but need the language and methodology to characterize when disruptions become hazards that impact urban resilience.

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Friends,

There are few things that make me more proud than being mayor of this great city. With that pride comes a deep sense of history, responsibility, and awareness that we must work collectively to ensure that our future is a resilient one. Our task is to confront our deepest challenges, find opportunity in them, and strengthen Boston for all Bostonians.

With Resilient Boston, we have an opportunity to do just that. Through the dedicated work of Chief Resilience Officer Dr. Atyia Martin and the rest of our team, we have already begun to make great strides in making Boston stronger. We are addressing our most serious shocks, such as extreme weather events, and our chronic stresses, such as economic inequality and aging infrastructure.

However, what sets our strategy apart is our commitment to view urban resilience through the lens of racial equity. Our engagement with race can no

We are addressing our most serious shocks, such as extreme weather events, and our chronic stresses, such as economic inequality and aging infrastructure.

R

BO

AN EQUITABLE AND

PRIORITIZING INFRASTRUCTURE MAINTENANCE THROUGH AN EQUITY LENS

Our efforts to improve data transparency and collection can also be used as a means of addressing aging infrastructure. Strengthening our 311 data can help the City prioritize investments where they're most needed.

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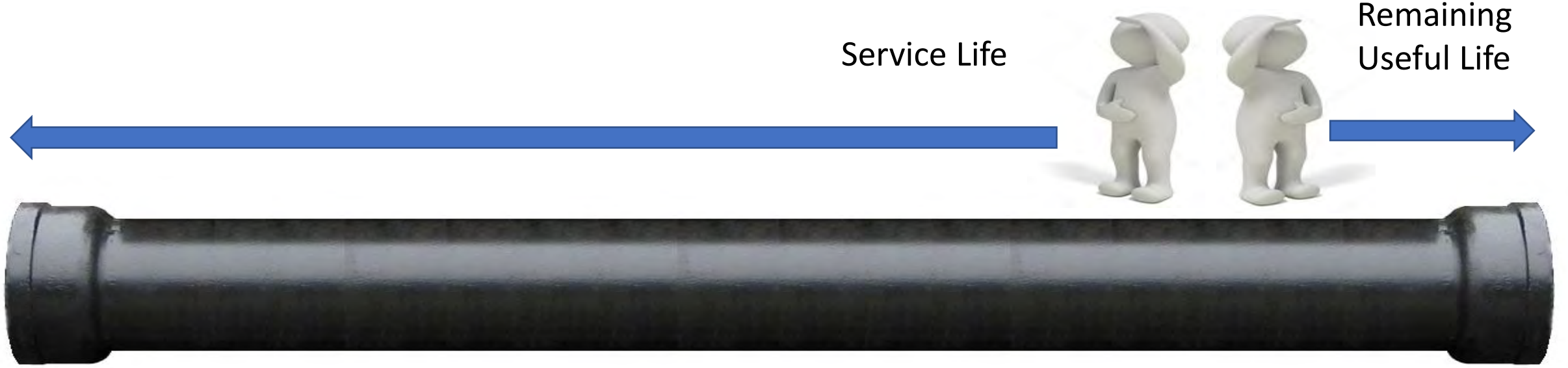
Empowering the city stakeholder - language

City's Perspective – Vulnerabilities and indirect costs

Asset Management – direct costs

Service Life

Remaining Useful Life



Date of Installation

Date of Repair/Replace

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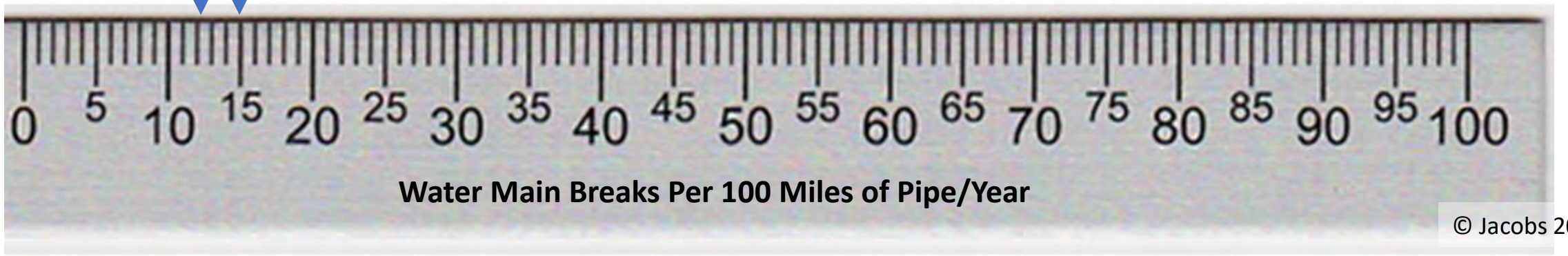
Miscommunication translates to unclear KPIs

"Our nation's drinking water infrastructure system is made up of 2.2 million miles of underground pipes that deliver safe, reliable water to millions of people. Unfortunately, the system is aging and underfunded. There is a water main break every two minutes."

ASCE 2021 Report Card

*Water utilities utilize a KPI of 15 breaks or fewer, per 100 miles of pipe (T&D) per year – as **Best Practice**.*

Great! ⟷ **Crisis!**



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Is a break a disruption or a hazard?

Should scale, season, frequency, and location determine if a hazard?

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The data exists to characterize <u>where</u> and <u>why</u> in a city chronic disruptions are hazards – we just need a methodology

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Does infrastructure grading at the city-level work?

ASCE's Infrastructure Report Card

Provides a single letter grade across 17 infrastructure categories across the USA, but……

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What about grading an important urban intersection?

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A GPA does not account for collocation hazards

Grading requires the concepts of collocation and ‘weak-link’ scoring

C?

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WISRD: Cross-sector vulnerability analyses

Characterization begins with a base map of vulnerabilities

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'Disruption-free' zones: Removing the chronic threat

High accident intersections

demographic characteristics

historical and tourism districts

primary employer use tax (PEUT)

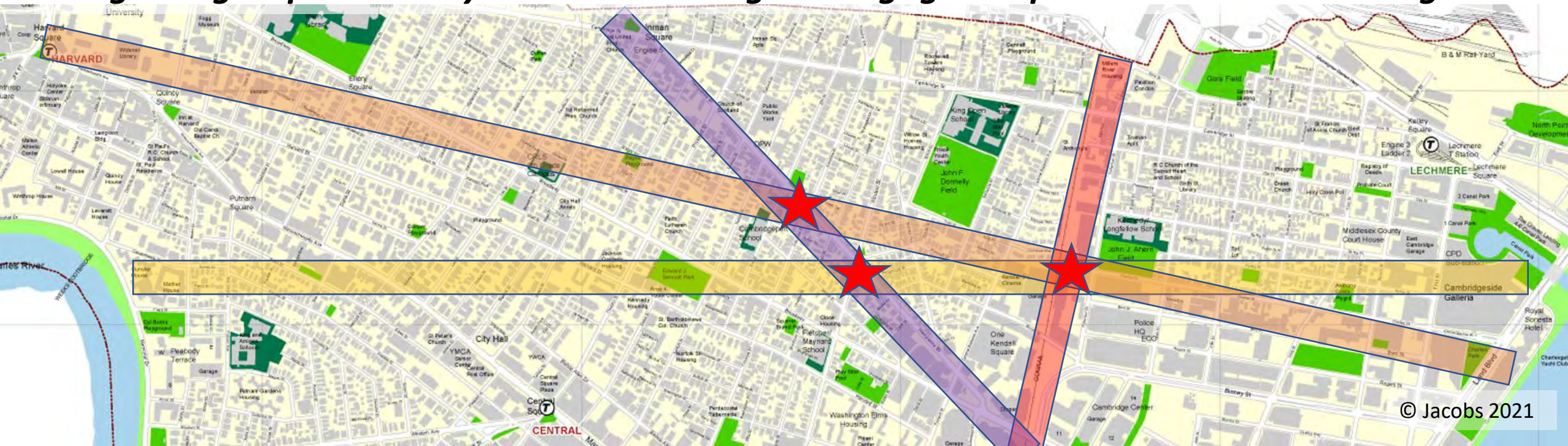
sales tax (commercial) as a portion of the city's GDP

residential, commercial, and industrial density areas

vehicle miles traveled (VMT) as % of transportation model

key public transit infrastructure

Weighted geospatial analyses and GeoDesign to engage the public in decision-making



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Conclusion, what should we consider…

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A complementary view of aging infrastructure risk

infrastructure Risk = Asset + Threat + Vulnerability
(ISO 27001/ISO 27005)

Indirect costs of failure/damage and ***location***

Determined with ***existing*** data and geospatial analyses

chronic threat of ***inaccessibility***

Engineered solutions: utilidors, forever pavements, trenchless

Asset's ***service life*** and ***collocation***

WISRD's MVCs

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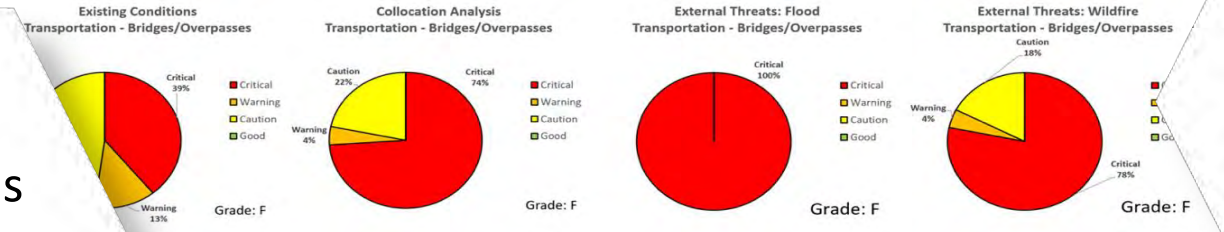


Urban Planners

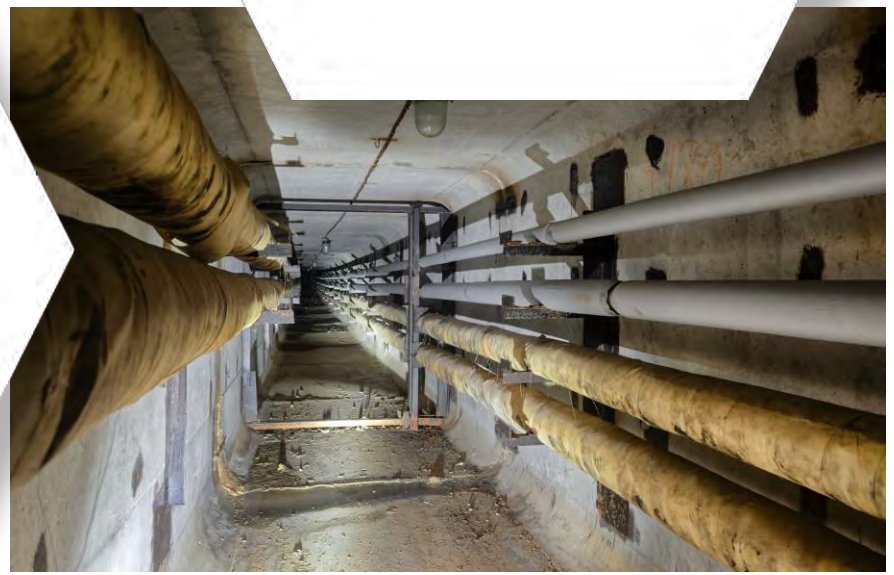
- KPIs for chronic hazards
- Indirect costs
- Identify intersections & segments to integrate into resilience planning

- Service life exceedance
- Collocation
- External threats
- City-wide vulnerabilities

WISRD Analyses

Engineered Solutions

- Disruption free zones
- Utilidors, tunnels
- Trenchless technology
- ‘forever pavements’



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Thank you!

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Reinventing tomorrow.

Characterizing the Hazard of Aging Infrastructure

Hazard: *A condition with the potential for harm to the community or environment.* **Risk:** The actual exposure of something of human value to a hazard and is often regarded as the combination of probability and loss. *(FEMA training doc, 2006)*

- Characterizing the "…harm to the community…" through indirect costs and disruptions
- Who is determining "risk" (CoF and PoF) for urban aging infrastructure?
- Characterizing "…human value…" is not money, i.e., – "'My kingdom for a horse!"

All value is, in the end, subjective.

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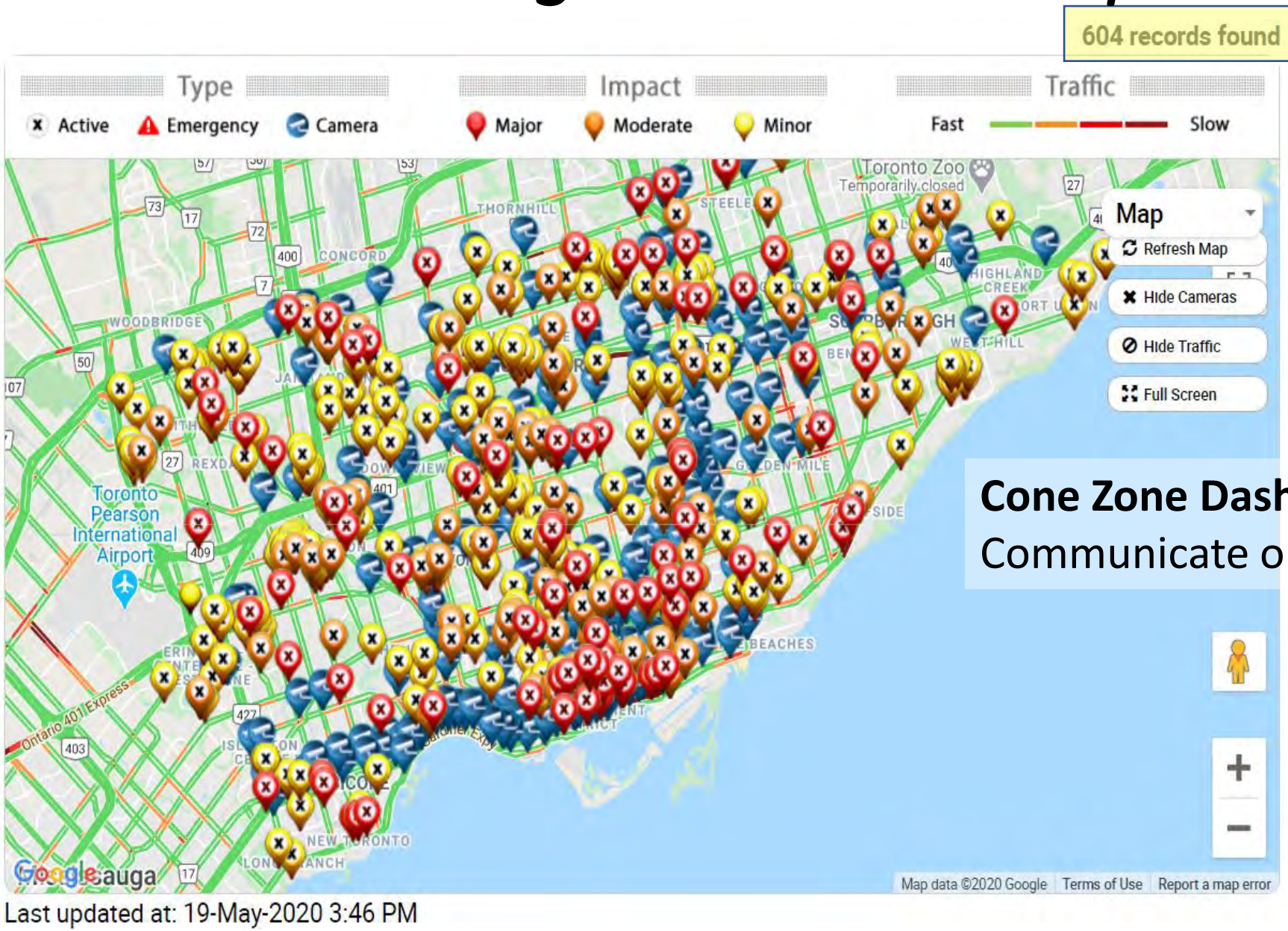
Do cities recognize when disruptions are hazards?



Cone Zone Dashboards

Communicate only location of disruptions.

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Frog in boiling water parable? New metrics

- 90 percent of LAWP's 7,600 miles of water main (6,800 miles) equal or exceed AWWA's recommended service life.

- Quick repairs to failures leaves a network of patches – geospatial clues.

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