A Framework For Assessing the Scale of Potential Benefits from Subterranean Information Management (SIM)

Customizable for Any Jurisdiction or Nation

Underground Infrastructure Data Modeling Categories

One Model Builds upon the Other: Benefits Are Shared Between Them

Single Utility Model

- Underground Utility Information generally evolves within single utility silos with minimal interoperability
- While some underground environment (soils) information may be available, it is of limited extent and quality
- Many utilities do not take advantage of government Enterprise GIS data
- Single utility data drives many beneficial but monolithic management applications
- Increases in utility data completeness and accuracy adds to value

MUDDI Model for Interoperable Utility Data

- Built upon a foundation of increasingly high quality single utility data
- Model includes Environmental Data and Contextual Enterprise GIS data
- Significantly increases benefits being realized within the single utility model
- Drives work processes that require interoperable data

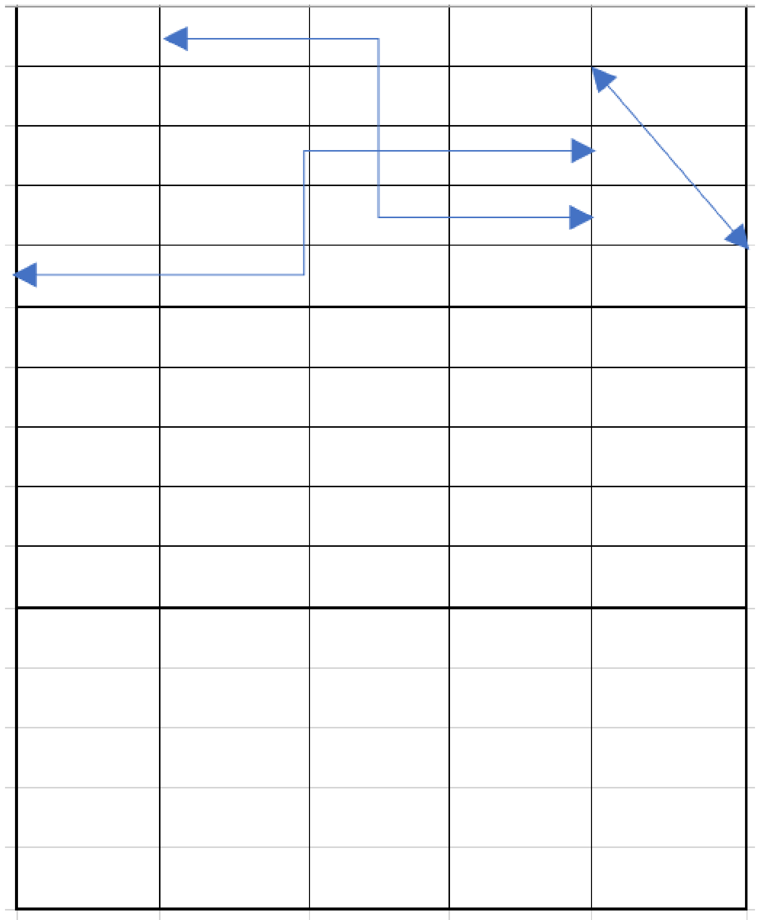
- **Interdependency Model: A MUDDI Extension**
  - Adds important detail to other models by depicting inter-utility dependences that allow identification of single points of failure and triggers for cascading effects

Model Use Cases

- **Single Utility Model (Silo)**
  - Drives Work Processes in Individual Utilities or Utility Divisions
  - Asset Management Systems
  - Operations and Maintenance Operations
  - Customer Relationship Management (CRM) and Revenue Collection Systems
  - Feeds standardized data into MUDDI Model
- **MUDDI Model (Interoperable)**
  - Excavations: Routine, Extended Trenching, Foundations
  - Emergency Response: Distribution System, Transmission System
  - Disaster Preparedness and Response: Transmission System and Large Facilities
  - Large scale construction projects: site planning, excavation, foundation, basements, mechanical rooms, utility connections
- **Interdependency Model**
  - Identify, Map and Model Interdependencies
  - Determine Triggers and Consequences for Cascading Effects
  - Guide Mitigation Projects

Three Tier Model

Vertical lines represent single utilities, horizontal lines represent interoperability between utilities, arrows represent interdependencies between utilities



Functional Interdependency Model

Data Interoperability Model: MUDDI

Single Utility Model

Benefits Calculation Approach

- Addresses the universe of benefits coming from all three UGI models which build upon each other
- The foundation for all benefits lies in the quality, completeness and standardization of data at the single utility level
- But only a fraction of benefits can be realized without interoperability and interdependency models
- To support specific MUDDI use cases an attempt can be made to identify specific benefits provided by the interoperability model
  - Excavations
  - Emergency Response
  - Large Scale Construction

Steam Pipe Explosion Flatiron District, NYC

What Happened: 20” asbestos clad steam pipe explodes at 6:40am Thursday, July 20, at 21st Street and 5th Avenue.

Response: 49 Buildings evacuated, 500 people displaced, luckily only a few injuries

MUDDI Relevance

- **Identify characteristics of steam pipe**: age, material, maintenance history + forensics on failed pipe
- **Identify nearby/overlapping infrastructure** including water, electric, gas and underground transit. History of leaks?
- **Identify underground characteristics**: soil composition, settlement, underground streams, vibration
- **Determine factors** causing explosion **and apply** across the 100 mile steam system to identify other sites that might be similarly vulnerable. Then mitigate.

Underground Infrastructure Domains Where Benefits Can Be Quantified

- **Maintenance and Operations of <u>All</u> Infrastructure Networks and Utility Capital Facilities**
  - Excavations
  - Complaint and Outage Response
  - Asset Maintenance and Management
- **Planning and Construction of <u>New</u> Utility Related Facilities**
  - New and replacement utility infrastructure (extended trenching)
  - Facilities for generation, supply, storage, control, monitoring
- **Planning and Construction of Conventional <u>New</u> Building** Foundations, Basements, Basement Mechanical Systems and Utility Connections
  - Where Subterranean Information Management (SIM) Connects to BIM
- **Maintenance and Operations related to <u>All</u> Conventional Building** Foundations, Basements, Basement Mechanical Systems and Utility Connections

Utility Maintenance and Operations

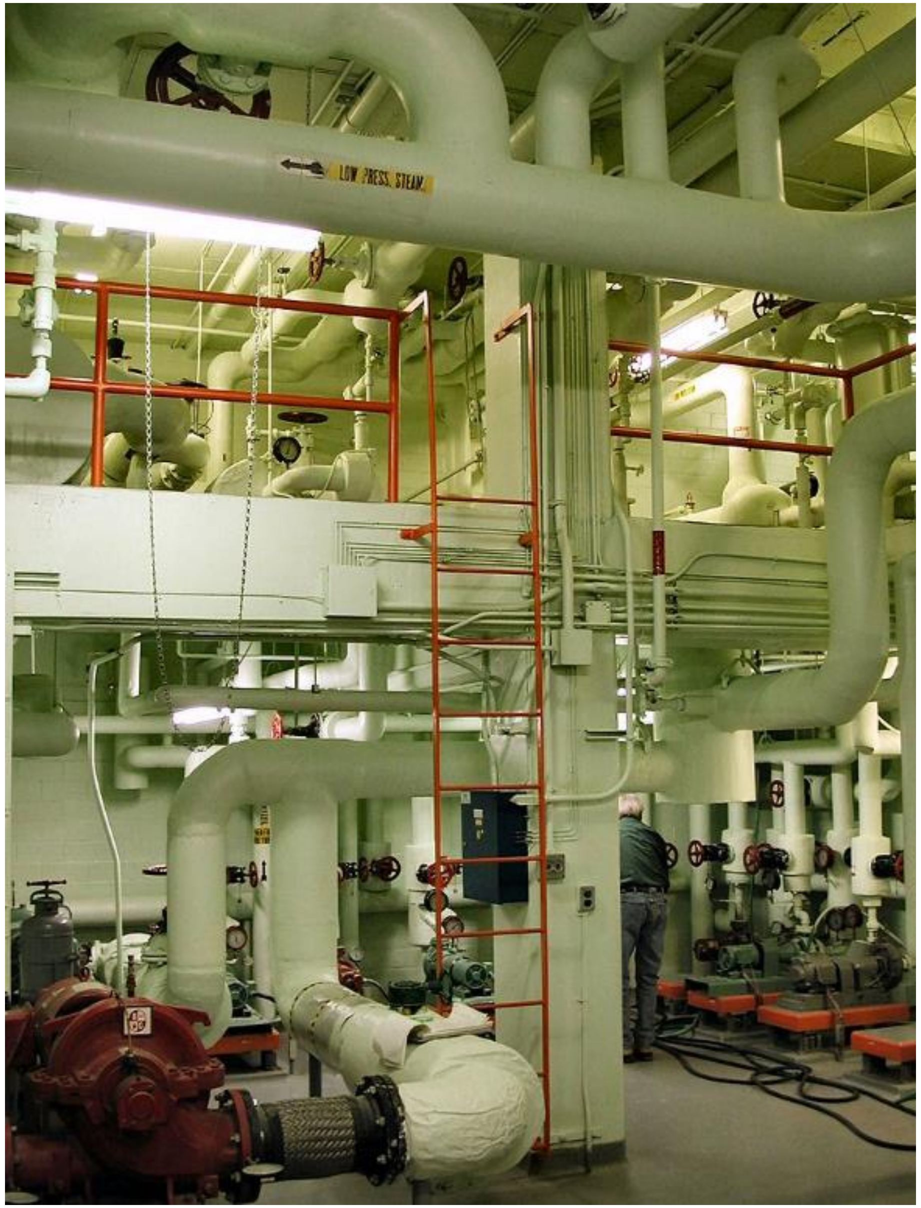
Street Excavations/Asset Management

Utility Capital Construction
Van Cortland Park Valve Chamber

Private Building Construction (Res, Com, Ind)

Basements, Foundations, Mechanical Rooms and Utility Connections

Building O & M Related To Basement Utilities



Scaling Annual UGI Related Spending For NYC

- NY Metro Area GDP: $1.7 Trillion (www.bea.gov: GDP of US Metro Areas)
- NYC GDP: $1 Trillion (est.)
- NYC Population 8.56 Million People
- Average Annual Capital Construction in NYC: $50 Billion: "Building Congress Construction Outlook" https://www.buildingcongress.com/ ***Private utilities not included**
  - **Estimated Annual UGI Related Spending by Construction By Type**
    - Non Residential Construction: **<u>$5 Billion</u>**
    - Residential Construction: **<u>$3 Billion</u>**

      } **Private Bldg UGI Const. Spending (25% spending)**
    - Private Utility Capital Spending for UGI: **<u>$4 Billion</u>**
    - NYC Governmental Spending on UGI Related Public Works: **<u>$12 Billion</u>**

      } **Gov't/Utility UGI Capital Spending (70% spending)**
      - NYC DEP Annual Capital Spending: $3.0 Billion
      - MTA Spending on Infrastructure: $6.5 Billion
      - Port Authority Spending on Infrastructure: $1.5 Billion
      - State and Federal Spending on NYC Infrastructure: $1.0 Billion
  - Other Spending Figures
    - Con Edison Spending on Infrastructure: $3.0 Billion ($1.9B Electric; $1.0B Gas; $0.1B Steam)
    - **NYC DEP Annual <u>Capital</u> Spending on Infrastructure: $3.0 Billion**
    - **NYC DEP Annual <u>Expense</u> Budget Spending: $1.5 Billion**

      } **From NYC Capital and Expense Budget**
- <u>Total Annual UGI Related Construction</u>: **<u>$24 Billion</u>**
- <u>Estimated Amount Spend for UGI related Maintenance:</u> **<u>$12.0 Billion</u>**
- <u>Total Spend Annually on UGI Related Expenditures</u>: **<u>$36.0 Billion</u>**

Benefit Generating Modalities
Improve existing applications; enable new ones

Quantitative

- **Improved Data Interoperability**
  - Enable sharing between Planning and Design, Construction and Operations phases
  - Digital data standardized across utilities to enable interoperability
- **Improved Data Accuracy and Completeness**
  - From “SUE” Accuracy Levels C and D to A and B
  - Capture of All Key Network Features and Characteristics
  - Implement Construction and Maintenance Efficiencies
  - Use in Asset Management/O&M Processes including Billing
- **Infrastructure Extended Life**
  - Analytics to Design best lifecycle approaches
  - Smart Features and Remote Sensing

Evolving Quantitative

- **Improved Disaster Preparedness, Response and Recovery**
  - Identify Major Vulnerabilities and Mitigate
- **Implementation of Innovative, “Smart” Services and Technologies**
  - “Smart Cities”; Sustainable Cities
  - Customizing efficient services to individuals and buildings
  - Implement new/best technologies

Using A Hypothetical Spending Pattern, Benefits by Categories of Infrastructure Expenditures and Benefit Generating Modalities

	Underground Infrastructure Maintenance and Construction Categories By Annual Funding				
		$1 Billion Increments (NYC $36 Billion Total)			
Categories of Underground Infrastructure Related Spending	All Underground Utility Asset Management including Excavation	New Underground Utility Related Capital Construction	All New Construction of Building Foundations, Basements, Mechanicals and Utility Connections	All Building Underground Utility Related Operations and Maintenance/Asset Management	Total
Hypothetical Annual Expenditures	**$224M**	**$448M**	**$224M**	**$112M**	**$1B**
Benefit Generating Modalities	**Percent Expectable Annual Savings**				
Interoperability					
Data Accuracy and Completeness					
Extended Life (Analytics/Sensors)					
Total Savings Percent					
Total Estimated Benefits/Savings					

Quantitative Benefits
Improved Data Interoperability and Accessibility

Guiding Study:

"Cost Analysis of Inadequate Data Interoperability in the U.S. Capital Facilities Industry" by Michael P. Gallaher, et al, National Institute of Standards and Technology (NIST), August, 2004

Method: 105 structured interviews from 70 companies, with measures of inefficiencies by task

Key Metric: Inefficient data interoperability accounts for **1.8%** of total lifecycle construction and operations costs. (1.05% Design and Construction; 2.84% O&M)

Assumption: We assume that the NIST study which addresses commercial, industrial and institutional buildings also applies to infrastructure/utility related construction and maintenance operations and includes basement and foundation components of all structures that are in direct contact with utilities and soils.

Overview of Study

Construction Life Cycle

- Design phase
- Construction phase
- Maintenance phase

Types of Inefficiencies

- Collecting dispersed data
- Recreating lost data
- Re-entering data
- Converting data
- Error identification and correction
- Integrating data
- Duplicate/Redundant systems

Efficiency Gains By Improved Interoperability

- All data available for rapid access
- All data from different contractors can be integrated
- Standardized as-built data capture in the field

Quantitative Benefits
Improved Data Completeness and Accuracy

Guiding Study:

"Cost Savings On Highway Projects Utilizing Subsurface Utility Engineering (SUE)"
Purdue University/U.S. Federal Highway Administration

Method: Analysis of 71 roadway construction projects, valued at more than $1B, relating costs and data quality levels

Key Metric: Raising SUE data quality from Levels C and D to Levels A and B results in an average savings of <u>1.9%</u> of total construction costs.

- Raising SUE to Levels A and B cost, on average, about **<u>0.5%</u>** of overall construction costs

Assumption: We assume that raising data quality levels for highway projects – which involves underground infrastructure and soil conditions – extends to all underground related infrastructure maintenance/operations and construction activities.

Improved Data Completeness and Accuracy

Factors that inflate the cost of construction

- Inaccurate location (x,y,z)
- Missing, deteriorated and incomplete records
- Unknown subsurface environmental conditions
- Accidental strikes and surprise interferences
- Inability to use automated tools to lay pipes and conduit

Methods of raising data accuracy and completeness

- Collect all data records and standardize on a common data platform
- Fill in missing data with field surveys
- Require precise data capture at routine street openings
- Use underground video techniques to capture data

Efficiency Gains

- Fewer strikes and surprise interferences
- Use of automated construction methods with greater confidence
- Fewer delays, change orders, accidents and lawsuits
- More efficient and effective maintenance operations
- Reduced insurance rates and contract contingency costs
- Identification of unmetered and unbilled accounts

Quantitative Benefits

Longer Utility Life based on Remote Sensing, Data Analytics, and Asset Management Systems

Guiding Studies:

"Imaging Construction's Digital Future" Rajat Agarwal, Shankar Chandrasekaran and Mukund Sridhar, McKinsey and Company.

Utility Mapping Service (UMS) and Berenice International Group response to the OGC RFI and presentation at the April 24-25th OGC Workshop in NYC

"Can the Internet of Things Extend Infrastructure Shelf Life" Create Digital, October 22, 2017 http://www.createdigital.org.au/internet-of-things-infrastructure/

Key Metric: Improved underground infrastructure sensing and analytics can extend the life of infrastructure networks from 75 years to 76 years leading to a **1.3%** annual savings.

Assumption: We assume an average utility lifespan before replacement of 75 years and hypothesize that improved analytics and AM/FM applications can lead to strategies that extend the life of utility networks by an average of 1 year.

Methods to Extend Utility Life

- **Geology:** A thorough understanding of underground geological composition, conditions, and features allows better selection of durable construction materials and life extending methods
- **Reduced Wear and Tear**: Analytics of street, pipe and conduit longevity, breakage and leaks, allows improved material use and strategic retrofits
- **Smart Maintenance Strategies**: Customized for specific networks, network features, and environmental conditions to extend life and minimize disruptions
- **Robotics**: Use video and sensors, and robots inserted into conduit and pipes to directly check utility features for leaks and to make repairs
- **Remote Sensing**: Use airborne, underground and street level sensors to detect utility conditions, threats and vulnerabilities for mitigation
- **Smart utility features (IoT):** Communicate physical condition and alert maintenance workers when preventive actions are necessary
- **Analytics**: Improved information and analytics enables strategic replacement strategies and allows multiple utilities to participate in street openings

Quick Calculation of Quantifiable Benefits

For each $1B spent

Assume: Expenditure units of $1B that include 4 categories of Infrastructure work: maintenance and construction for both utilities and the foundations and basements of conventional buildings.

Benefits from Improved Interoperability and Accessibility:	**1.8%**
Benefits from Improved Quality and Completeness:	**1.9%**
Benefits from Extended Life (Focus on Sensors and Analytics):	**1.3%**
Quantifiable Benefit Potential For Improved UGI Data:	**5.0%**

$1B X 5% = ***$50,000,000 annually per billion$ expended***

$50M/$1B X $36B = $1.8B potential annual benefit for NYC

Benefits by Categories of Infrastructure Spending and Benefits

	Underground Infrastructure Maintenance and Construction Categories By Annual Funding				
		$1 Billion Increments			
Categories of Underground Infrastructure Related Spending	Annual Underground Utility Asset Management including Excavation	Annual Utility Capital Construction	Annual New Construction of Foundations, Basements, Mechanicals and Utility Connections	Annual Building Underground Utility Related Operations and Maintenance/Asset Management	Total
Hypothetical Annual Expenditures	**$224M**	**$448M**	**$224M**	**$112M**	**$1B**
Benefit Generating Modalities		**Percent Expectable Annual Savings**			
Interoperability	2.84%	1.05%	1.05%	2.84%	
Data Accuracy and Completeness	1.90%	1.90%	1.90%	1.90%	
Extended Life (Analytics/Sensors)	1.30%	1.30%	1.30%	1.30%	
Total Benefits/Savings Percent	**6.04%**	**4.25%**	**4.25%**	**6.04%**	
Total Estimated Benefits/Savings	**$13.5M**	**$19.0M**	**$9.5M**	**$6.8M**	**$48.8M**

Evolving Benefit: Support for Emergency and Disaster Management

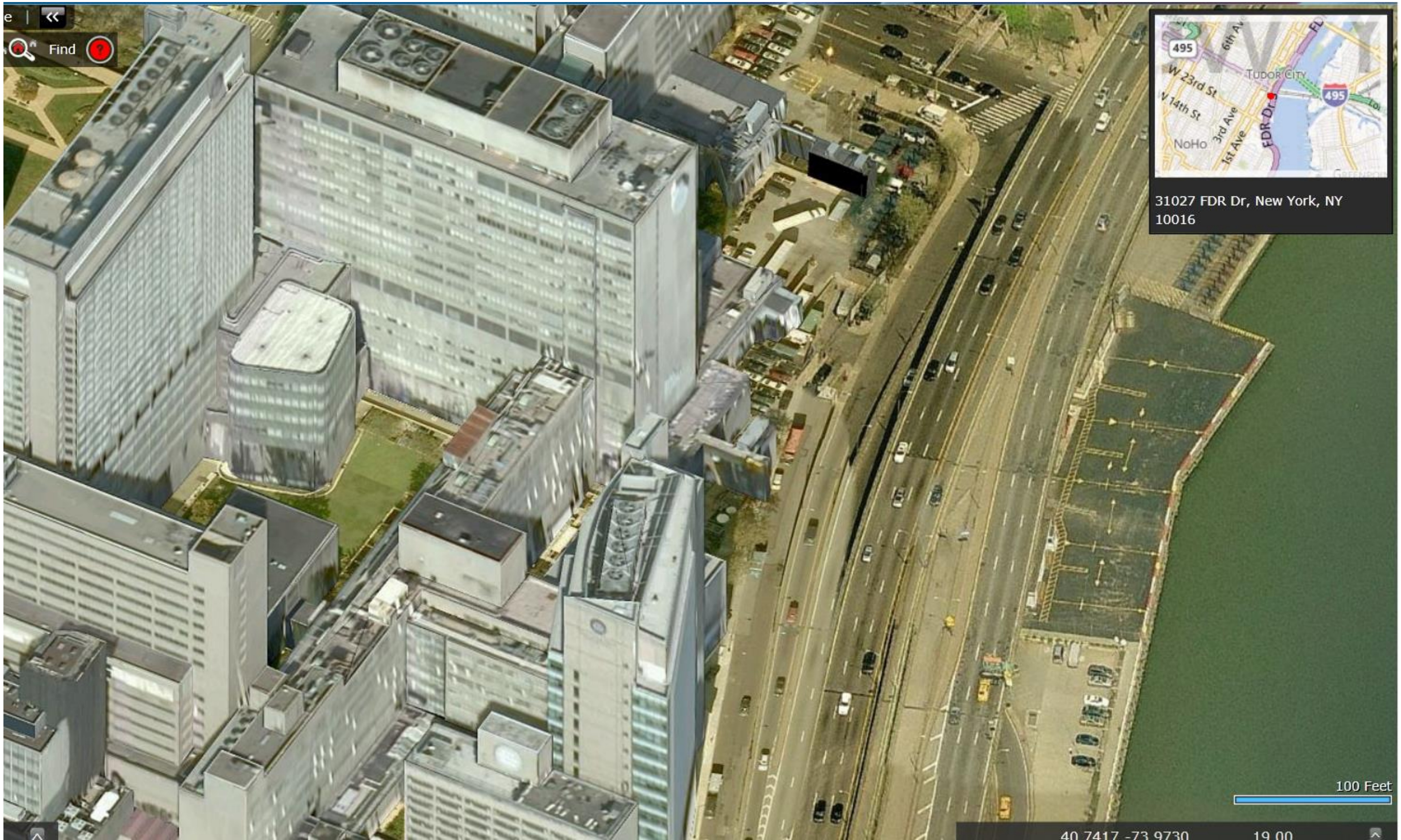
- Enterprise GIS Systems are essential to the management of emergencies and disasters
- **Underground infrastructure is a central focus of disaster planning, prevention, response and recovery efforts**
- Analysis using UGI Data can enable jurisdictions to save lives and reduce the costs of a disaster (harden infrastructure, engineer redundancy)
  - Billions in damage in NYC due to Hurricane Sandy could have been prevented by pre-incident vulnerability analysis and reasonable investment in prevention strategies
  - Comprehensive utility mapping could have prevented the Flanders gas pipeline explosion that killed 24 people
  - Many “routine” emergency situations can be handled more effectively with prompt access to comprehensive UGI.
    - Watermain breaks, gas leaks, street collapses, electric outages, sewer backups
- Newly Identified Guiding Study: *“Natural Hazard Mitigation Saves; 2017 Interim Report”* National Institute of Building Sciences
- <u>Assume</u> that spending on improved infrastructure information is a mitigation activity
- **<u>Assume</u> spending on capturing, improving, extending and maintaining infrastructure information costs 0.5% of total infrastructure related spending or <u>$5M/$1B</u>.**

E 14th Street Power Plant & Substation

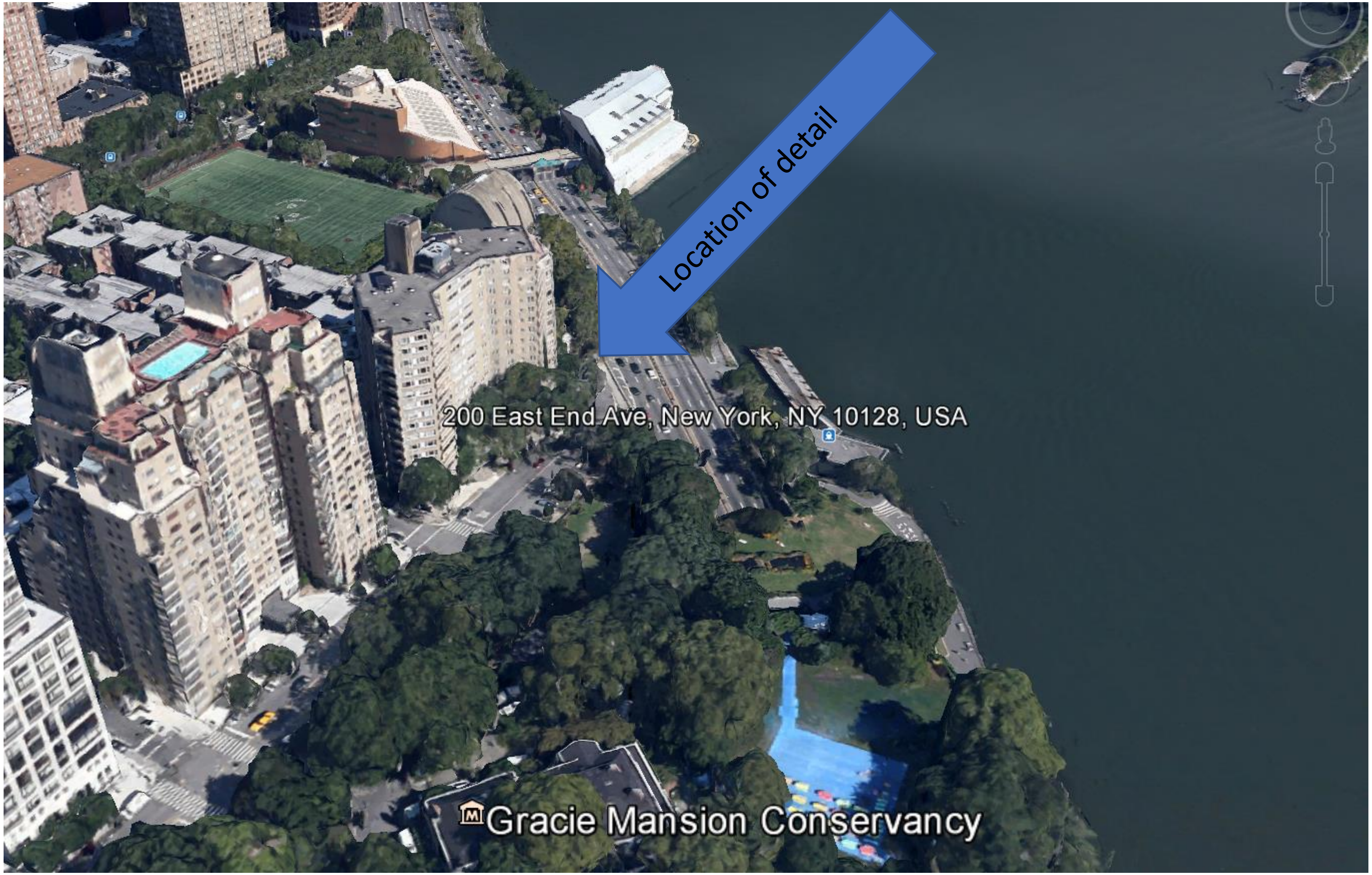
Midtown to Downtown Manhattan Blackout: Oct 29th 8:50PM

NYU Medical Center at E. 32nd Street

A Cascading Effect of the E14th Street Substation Outage



200 East End Avenue nr. Gracie Mansion



Upper East Side near Gracie Mansion FEMA Panel 3604970089F

N.E. Corner: Driveway and Vent

Consequences: Flooded basement, utility outages, fire in boiler room, evacuation of all residents

DAILY NEWS

Hurricane Sandy’s 21 most serious fires caused by sea water hitting electrical systems: FDNY

Breezy Point’s blaze consumed 122 homes when rising sea water set a single house ablaze, says the New York City Fire Department.

BY BARRY PADDOCK / NEW YORK DAILY NEWS

MONDAY, DECEMBER 24, 2012, 6:25 PM

"Natural Hazard Mitigation Saves; 2017 Interim Report" National Institute of Building Sciences

Page 1: Summary of Findings

- Federal mitigation grants <u>save $6 per $1 spent</u>
- Exceeding building codes saves $4 per $1 spent
- 'In the long term, just implementing these two sets of mitigation strategies prevents…600 deaths, 1 million non-fatal injuries, 4,000 cases of post traumatic stress disorder (PTSD)

National Benefit-Cost Ratio Per Peril *BCR numbers in this study have been rounded	Federally Funded	Beyond Code Requirements
Overall Hazard Benefit-Cost Ratio	6:1	4:1
Riverine Flood	7:1	5:1
Hurricane Surge	Too few grants	7:1
Wind	5:1	5:1
Earthquake	3:1	4:1
Wildland-Urban Interface Fire	3:1	4:1

Table 1. Benefit-Cost Ratio by Hazard and Mitigation Measure.

- **Assume:** Building Comprehensive/Strategic Underground Infrastructure Data is a legitimate disaster mitigation investment
- **Assume**: 0.5% X $1B = **$5M** Cost per $1B UGI for Data Creation and Maintenance
- **Assume:** $5M X 6 (6:1 ratio) = **$30M Expected Benefit**

Evolving Benefit: Smart Cities/Sustainable Cities

A smart city is an urban area that uses different types of electronic data collection sensors (along with other strategic data) to supply information which is used to manage assets and resources efficiently. Wikipedia

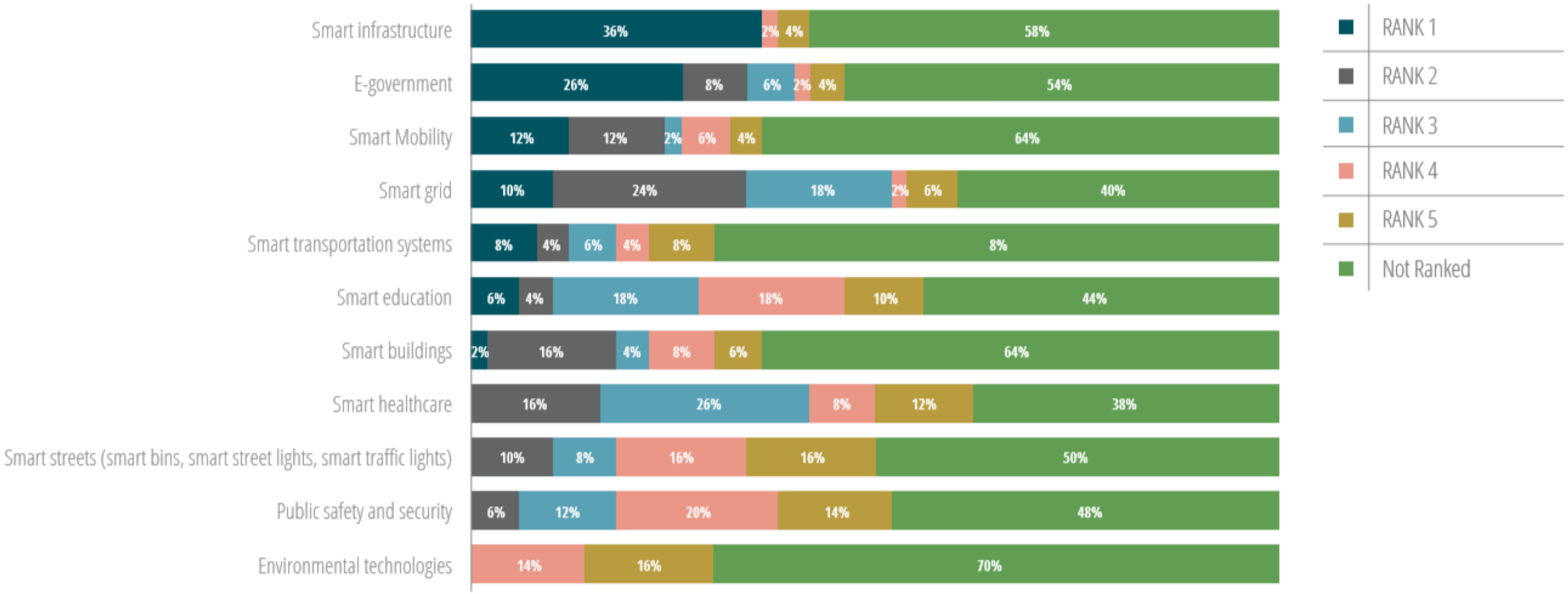
- **Enterprise GIS Systems** are essential to reap the benefits of Smart Cities strategies, technologies and applications
- **UGI Information** is an essential part of Enterprise GIS Systems
- **Smart Cities Strategies** that benefit from UGI data
  - Smart electric grid
  - Autonomous vehicles
  - Telecommunications design and deployment
  - Green roofs and water absorbing landscaping
  - Adjusting utility supply to need patterns to maximize efficiencies
  - Smart customer participation in conservation and generation
  - Customization of services to better meet individual, and organization needs
- **Benefit Types**: Smart Cities strategies can lower costs, increase property values, enhance economic development and vitality, and improve quality of life.

Smart Cities: Guiding Study

"Smart Cities and Cost Savings" ABIresearch, Chordant, ca technologies
Smart Infrastructure Ranked #1
Multi-million annual savings projected – billions for largest cities

2.4.1. EGOVERNMENT AND INFORMATION PORTALS

In a B2B technology survey of 455 United States-based companies across nine vertical markets conducted in March 2017, eGovernment ranked second on the list of top technology priorities for governments, with 26% of respondents ranking it as their first priority.



Smart Cities: The Future

Worldwide Smart Cities Savings (Benefits) Expected to Be <u>>$5 Trillion</u> Annually

- Smart Cities and Cost Savings: Page 6

Yearly Cost Saving ($Trillions)

(Source: WorldAtlas)

Smart City Stake Holder	Per Mega City	All cities > 5 million	All Cities	Savings % (Mega city)
Citizens	0.0267	1.50	3.15	19.0%
Enterprises	0.0141	0.79	1.66	25.3%
City Government	0.0050	0.28	0.58	24.8%
Total	$\boxed{0.0457}$	2.57	5.40	21.1%

- **$45.7 Billion** in Yearly Cost Savings per Mega City (e.g. NYC, London)
- **<u>Assume</u> $20M** annual benefit for each $1B in UGI related expenditures

Quick calculation of Quantifiable Benefits Plus Guesstimates For Smart Cities and Disaster Savings

Assume: <u>Expenditure units of $1B</u>

Benefits from Improved Interoperability and Accessibility:	1.8%
Benefits from Improved Quality and Completeness:	1.9%
<u>Benefits from Longer Life due to RS, Analytics and AM/FM:</u>	<u>1.3%</u>
Quantifiable Benefit Potential For Improved UGI Data:	**5.0%**

$1B X 5% = <u>***$50,000,000 annually***</u>

Disaster: Assume $5M annual cost (0.5% of $1B), for improved data and analysis (Purdue Study). Assume improved data supports mitigation efforts. Benefit is 6X cost = $30M = **+3.0%**

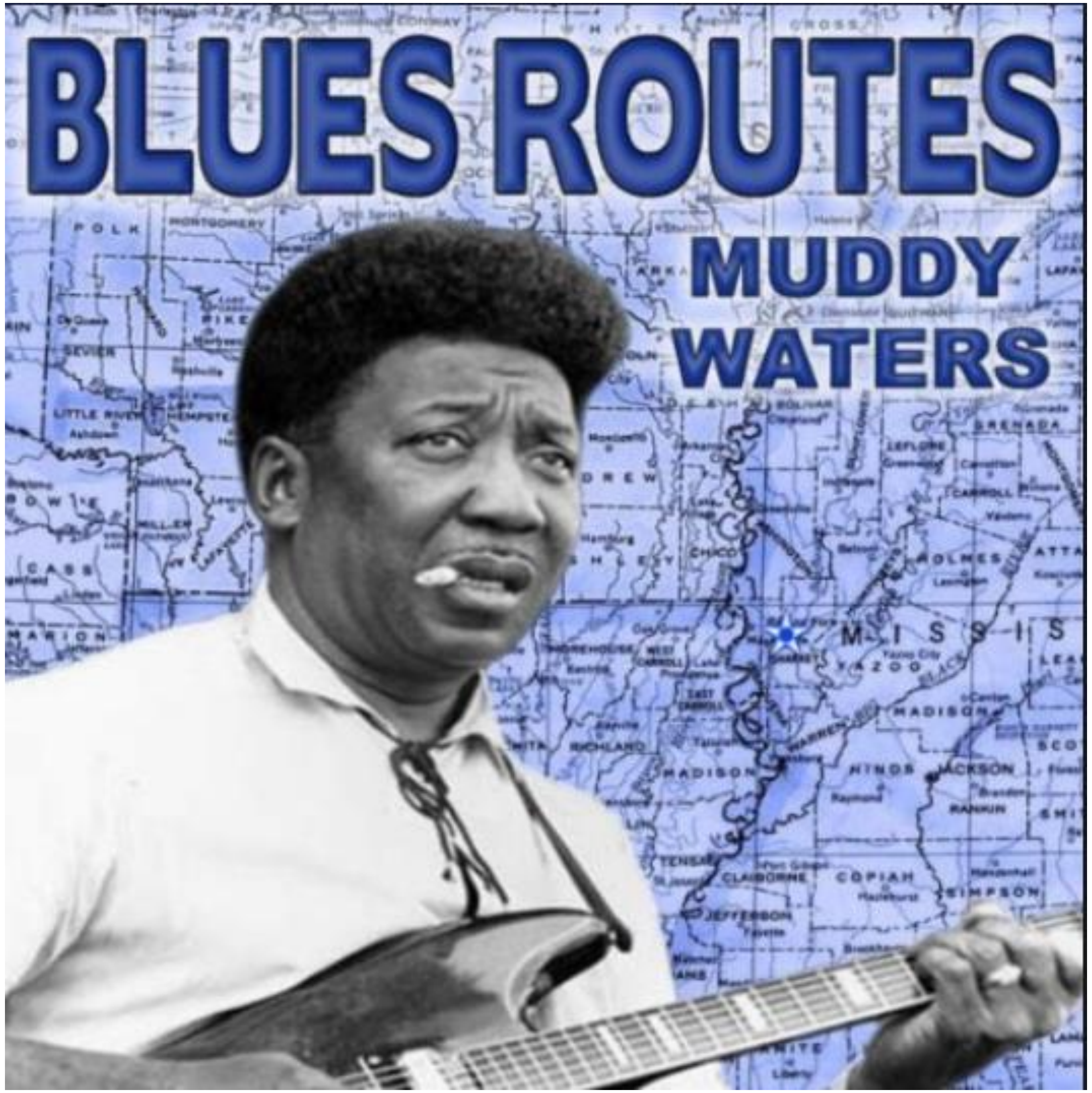
Smart Cities: Anticipate at least 2.0% benefits re: GDP. Conservatively assume **+2.0% X $1B bonus** due to savings/benefits across the regional economy due to smart cities project that utilize UGI data, analysis and sensing.

Total Potential Annual Benefits/Savings Value = 10% or <u>$100M per each $1B</u> expenditure on UGI related projects and operation

Interoperable Use Case: Excavations for Repairs and New Services

- Source: Common Ground Alliance (CGA) Damage Information Reporting Tool (DIRT)
  - Average cost of routine excavation $1,000 ($200M/year Flanders/NYC/London)
  - 1% of excavations result in damages at an average cost of $4,000 per incident
  - 200,000 excavations (30 – 40/mile) yield 2,000 damages cost $8M (Flanders, NYC, London)
- Source: “Deep Dig Summary,” Ordnance Survey GB
  - Improved utility mapping at Heathrow reduced asset strikes by >80%
- Source: Professor Nicole Metje, University of Birmingham
  - Indirect and social costs of utility strikes 29x direct cost of repair
  - Knowledge of underground conditions enables smarter excavation and safety measures
- Source: “KLIP as a Response to the OGC Underground RFI”, Jeff Daems, Informatie Vlaanderen
  - Time for map response went from 15 days to 2 days or less - >85% reduction
  - Reduction in interpretation time >60%
- Source: WaterWorks
  - Average cost of a watermain break: $12,000
  - NYC suffers about 400 watermain breaks annually

The Route To MUDDI



Road to MUDDI: Implementation Steps

- **I.D. Players**: Identify all underground infrastructure related agencies and utilities
- **Form a Underground Infrastructure Coordination Committee**
- **I.D. Data**: Assess status and characteristics of existing utility data and identify useful enterprise GIS data
- **I.D. Utility Operational Deficits** where improved UGI can help
  - Perform SWOT analysis (strengths, weakness, opportunities, threats)
- **Determine utility data specifications** needed to fully support work processes associated with construction and asset management.
- **Identify organizational barriers** to data interoperability and data improvement
  - **Develop security options**: SCIF, Block Chain, Encryption, etc.
- **MUDDI:** Develop data exchange models and methods for utility layers
- Develop a **Strategic Implementation Plan**
  - **Identify Early Action Items and Low Hanging Fruit to build momentum**

Early Action Plan: Low Hanging Fruit

<u>Use the Data You Have for Better Work Processes and Decision Support</u>

- **Share useful infrastructure data already in hand within your own agency and between agencies!**
- **Develop a data repository** containing all available infrastructure data, useful enterprise GIS data including imagery, parcels, building footprints, street beds, curb and building lines, elevation, hydro, geology, etc. Use for work processes and for testing
- **Operational Data**: Add 811, 311 and related data and use for analytic purposes to gain insights into problems and solutions. Improve cooperation and collaboration between utilities.
- **Re-engineer Excavation Approval Processes & Save Time**: Automate 811 notification process
- **Focus Initial Data Gathering** on Strategic Parts of The City under rapid development or at risk
    - **Driven By Local Events**: Steam explosion, Hurricane, Flood, Power Outage, etc.
- **Perform Vulnerability Analysis** on transmission lines and major facilities like treatment plants, generation plants, storage and control facilities to ID single points of failure and triggers for cascading effects (Steam Pipes!!!)
- **Support Utility Revenue Streams** wherever possible (Utility Billing, Fines, Collections)

<u>Build Data Accuracy and Completeness at the Lowest Cost Possible</u>

- **Link CADD data and scans** to surface features to increase accuracy
- **Capture 3D Photos** for each excavation
- **Require Building Plan submissions** to contain key data in appropriate formats
- **Use Remote Sensing arrays** to help find underground obstructions for major construction projects