Integrating Asset Management Principals to Emergency Preparedness: A Risk and Resilience-Based Management Approach to Infrastructure Assets

Presenter:

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ARCADIS

Agenda

- What is **Resilience**?
- Why a Resilience Strategy Based Approach to Risk Management?
- How to Merge Vulnerability Assessment and Asset Management Disciplines?
- What is the Financial ROI and How to Fund These Measures?
- Questions

Resilience: One Definition

Resilience is the capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience *(Rockefeller Foundation)*

Need for Resilience Strategy Based Approach

ENVIRONMENTAL BUSINESS JOURNAL®

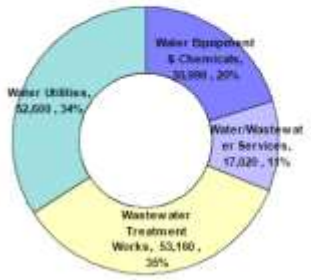
Strategic Information for a Changing Industry

Volume XXVI, Number 12, 2013 | *The U.S. Water Industry 2013* | Environmental Business International Inc.

U.S. WATER INDUSTRY CONTINUES TO STRUGGLE WITH INFRASTRUCTURE FUNDING GAP

Water: Can't live without it. Can't pay for it. An exaggeration, of course, but if there is any one trend in the water industry that stands out, at least in the United States, it's the ongoing gap between the maintenance and rehabilitation needs of drinking-water and wastewater infrastructure and the abil-

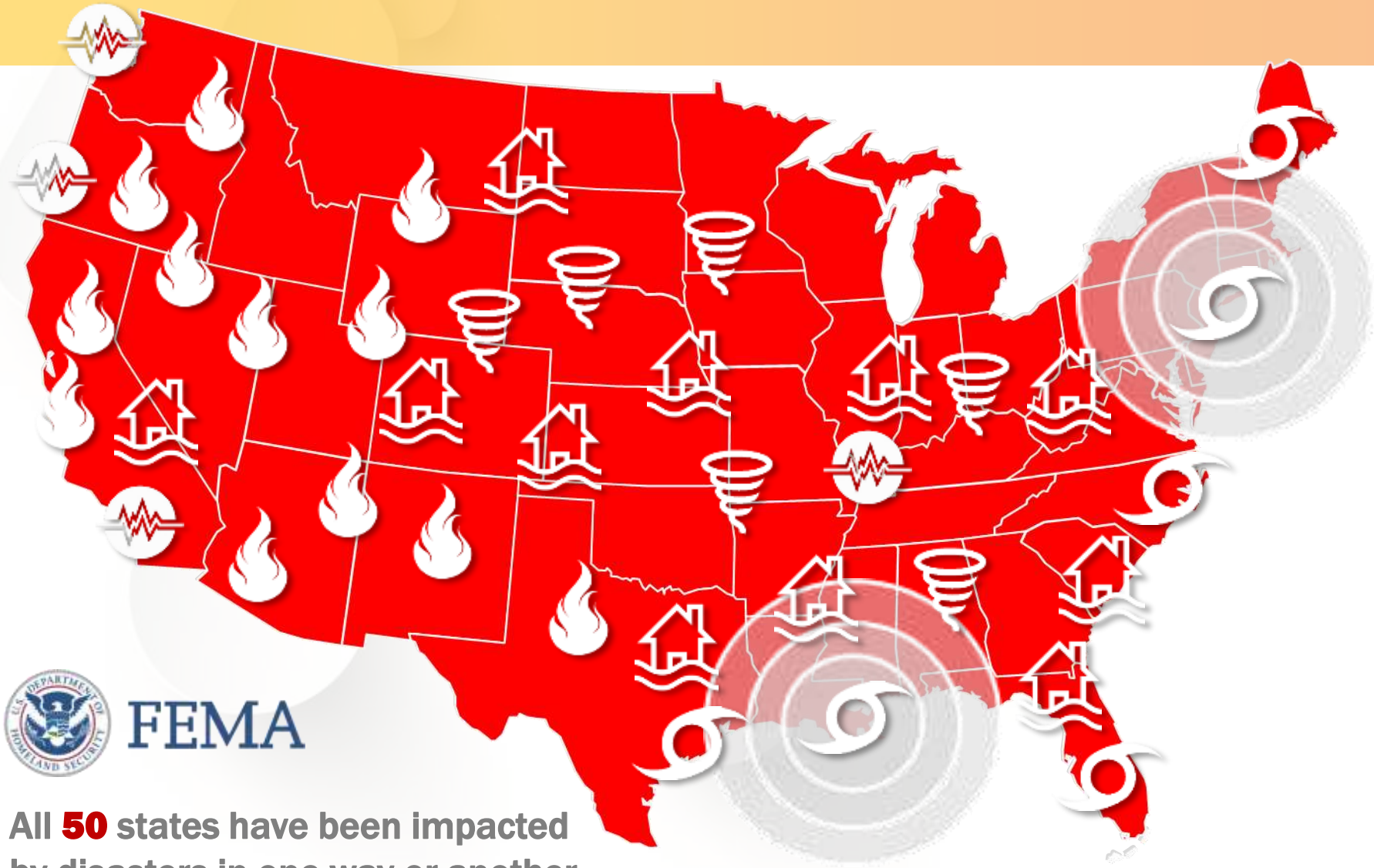
The U.S. Water Industry in 2013 ($mil)



Source: Environmental Business International, Inc.

Natural Hazards

Declared U.S. Disasters Since 2011



FEMA

All 50 states have been impacted by disasters in one way or another

Resilience Strategy Based Risk Management – VA + RBAM

1) Asset Characterization

2) Threat Characterization

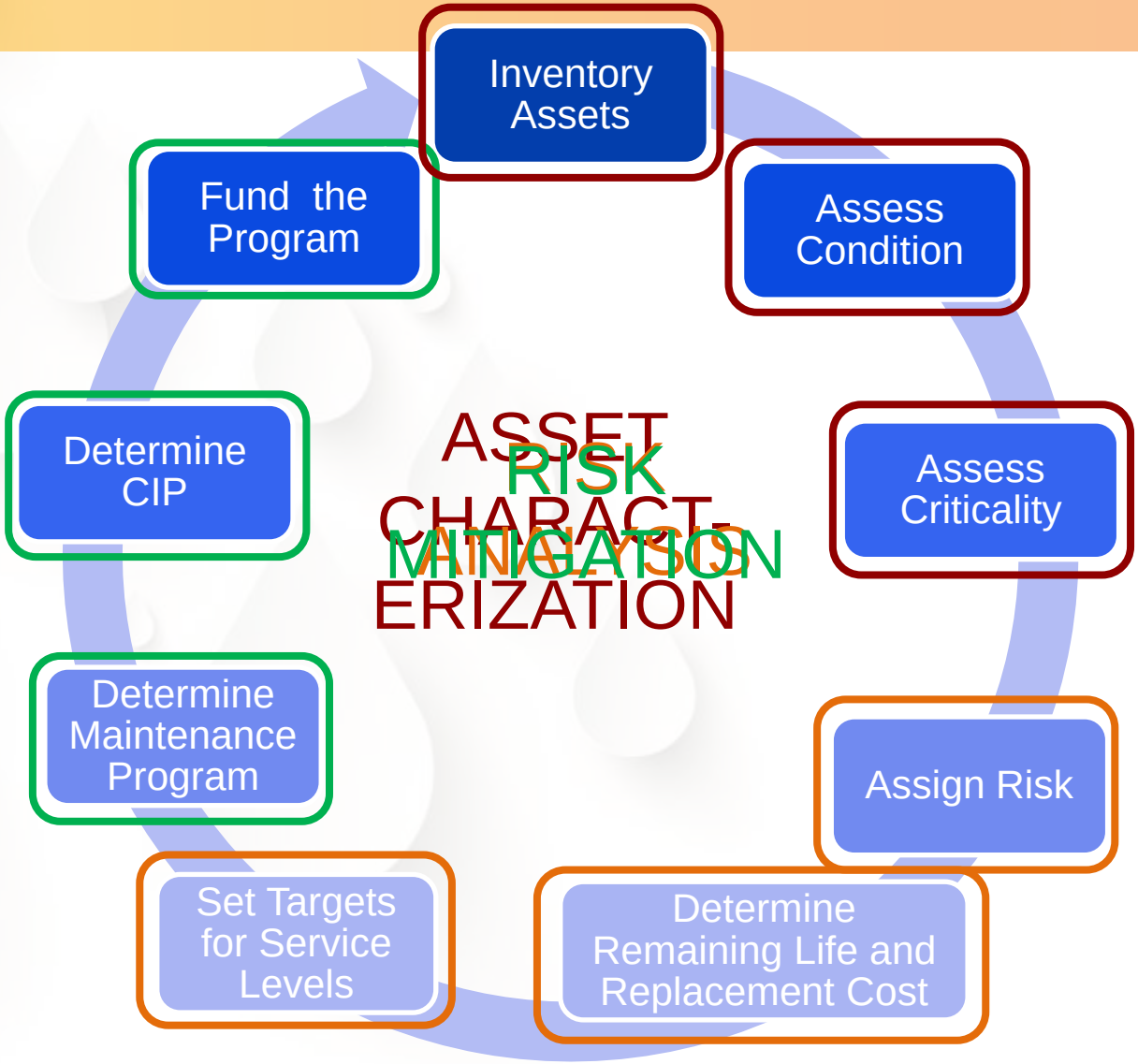
3) Consequence Analysis

4) Vulnerability Analysis

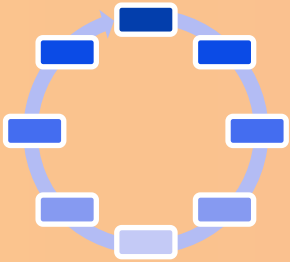
5) Threat Likelihood Analysis

6) Risk/Resilience Analysis

7) Risk/Resilience Management (to inform the CIP)



Asset Characterization: Asset Attribute Data Categories



Physical Attributes:

- Facility ID
- Asset ID
- Asset Name
- Asset Type
- Capacity/Size
- Etc.

Financial Attributes:

- Install Date
- Install Cost
- Replace Cost
- Estimated Useful Life

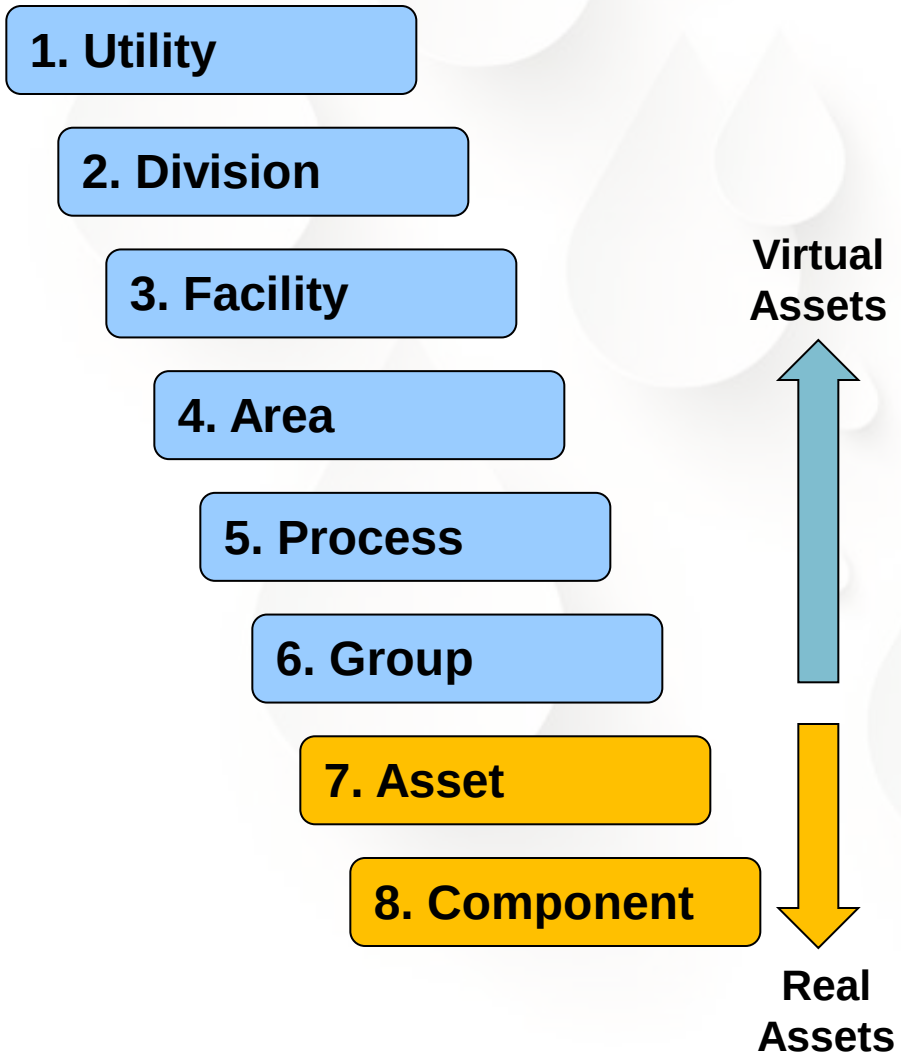
Location Attributes:

- Asset Location
- Community
- Watershed

Asset Management Attributes:

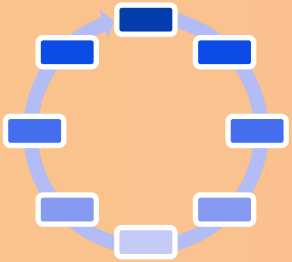
- Physical Condition
- Performance Condition
- Consequence of Failure
- Risk

Typical “Parent-Child” Asset Hierarchy



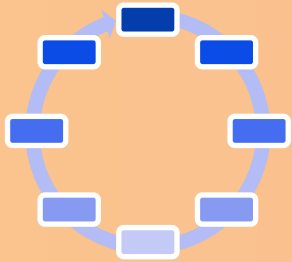
- Levels: varies with utility size and complexity.
- Virtual Assets: performance and cost centers for reporting.
- Real Assets: maintenance work orders are written here.
- Components: optional - depends on CMMS capabilities.

Condition Based Probability of Failure & Vulnerability



Condition Type	Failure Mode	Description	Assessment Method
Performance	Capacity	Does not meet demand (flow, loading, storage volume, etc.)	Test or Desktop
	Level of Service	Does not meet functional needs (regulatory permits, customer commitments)	Desktop
	Efficiency	Not lowest cost alternative (labor, maintenance, obsolescence)	Desktop
Physical	Mortality	Current state of repair and operation as influenced by age, historical maintenance and operating environment	Test, Visual, Desktop, Modeling

Condition Assessment Methods:



- **Desktop Assessment:** Considers operating data, maintenance history, staff knowledge, current needs, future needs and industry standards.

Site Assessment

- **Visual Assessment:** Uses a set of standard criteria specific to the type of asset. Results in a comparative ranking of assets on a standard scale (e.g. 1-best to 5-worst). Most effective when applied against a broad asset base with a large quantity of assets.

- **Testing:** Uses industry accepted methods. Examples include: capacity test and advanced condition testing. Performed on individual assets. Provides an absolute ranking for asset condition. Results can be expressed on a standard scale. Some tests are “failure finding” – not condition assessment.

Condition Assessment by Asset Type: Stormwater, Wastewater, Vertical, Horizontal

- Define Condition Scoring Criteria for Physical and Performance
  - Pipe/Culvert/Outfall
    - Structural, Erosion, Trash, Sedimentation, Odor, Algae, Etc…

Pipes / Culverts / Outfalls	**1**	**2**	**3**	**4**	**5**
Structural (PACP)	None *(no/minor defects, failure is unlikely)*	Slight *(minor defects, pipe is unlikely to fail for 20+ years)*	Moderate *(has moderate defects and will likely fail in the next 10 - 20 years)*	Severe *(has severe defects and will likely fail in the next 5 - 10 years)*	Failure *(has failed or will likely fail in the next few years)*
Erosion	None *(No erosion near barrel observed)*	Slight *(Slight erosion near barrel, no imminent concern on condition of barrel)*	Moderate *(noticeable erosion near barrel that could lead to future collapse or pipe failure)*	Severe *(severe erosion/undercutting around barrel, collapse or failure could oocur)*	Failure
Trash	None *(No trash or debris present)*	Slight *(Limited trash and/or debris present)*	Moderate *(Trash and/or debris present, but will not cause flooding or inhibit O&M or emergency operations)*	Severe *(Trash and/or debris present that will likely cause flooding or inhibit O&M or emergency operations)*	Failure
	None *(No sedimentation*	Slight *(Limited*	Moderate *(Sedimentation present, but will not cause flooding or inhibit O&M or emergency*	Severe *(Sedimentatoin present that will likely cause flooding or inhibit O&M or emergency*	

Field Data Collection

Visual Condition – Score 1

- Equipment & Ancillary Items
  - Like new with tag

Equipment

- Equipment appears new with factory applied painting/coating, which is not corroded or degraded by UV exposure.
- Equipment is not leaking nor showing any evidence of historic leaks.
- Equipment does not exhibit any vibration or noise outside of normal operating levels.
- Equipment pedestals and mounting equipment are not damaged in any way.
- Equipment appears to be well maintained with no evidence of rehabilitation/overhaul. Note whether grease fittings appear used, filters are replaced regularly, etc.
- Equipment is in the beginning part of its estimated useful life and no rehabilitation or renewal actions are required.

Visual Physical Condition – Score 2

- Equipment & Ancillary Items
  - Older equipment
  - Little to no signs of wear and/or degradation

Equipment

- Equipment looks relatively new, may have been repainted since installation.
- Equipment may have some minor surface corrosion or UV degradation (<10% of surfaces).
- Equipment is not leaking but may have evidence of historic leaks.
- Equipment may exhibit very little vibration or noise outside of normal operating levels.
- Equipment pedestals and supports are not damaged and have little to no surface corrosion (<10% or surface).
- Equipment appears to be well maintained. Equipment may have recently undergone rehabilitation/overhaul. Note whether grease fittings appear used, filters are replaced regularly, etc.

Visual Physical Condition – Score 3

- Equipment & Ancillary Items
  - Older equipment
  - Visible signs of wear and/or degradation

Equipment:

- Equipment may have surface corrosion or UV degradation (<50% of surface) and is in need of painting/coating.
- Equipment may have minor leaks (visible slow drip at connections only – not from holes or other damage) or evidence of historic similar leaks.
- Equipment may exhibit moderate vibration or noise outside of normal operating levels (equipment feels and sounds rough – need to discuss with O&M staff).
- Equipment pedestals and supports may have surface cracking, grout loosening, etc (no through cracks) and/or surface corrosion (<50% of surface).
- Equipment appears to require routine or preventative maintenance of normal wear items (e.g. lubrication, belts, gaskets, seals, etc).
- Equipment is approaching the end of its estimated useful life and will need moderate renewal or rehabilitation in near term.

Visual Physical Condition – Score 4

Equipment & Ancillary Items

- Older equipment
- Excessive wear and/or degradation
- Near end of “useful” life

Equipment

- Equipment has extensive surface corrosion or UV degradation (>50% of surface area) and/or evidence of structural corrosion (1 location).
- Equipment has heavy leakage at gaskets/connections (steady stream) and/or there is evidence of current or previous leakage from holes or other failure (1 location).
- Equipment exhibits excessive vibration or noise outside of normal operating levels with evidence of nonstructural damage resulting from excessive vibration (loose guards, connections, etc) - need to discuss with O&M staff.
- Equipment concrete pedestals have 50%-75% surface cracking and/or are cracked through (<25% of pedestal) and/or steel supports are damaged (<25% of steel supports with structural corrosion, missing/broken anchors or other similar damage).

Visual Physical Condition – Score 5

- Equipment & Ancillary Items
  - Older equipment
  - Excessive wear and/or degradation
  - At end of “useful” life

Equipment

- Equipment has extensive and heavy surface corrosion or UV degradation (>75% of surface area) and/or evidence of structural corrosion (2 or more locations).
- Equipment has heavy leakage at gaskets/connections (steady stream) and/or there is evidence of current or previous leakage from holes or other failure (2 or more locations).
- Equipment exhibits excessive vibration or noise outside of normal operating levels (evidence of structural damage resulting from excessive vibration – need to discuss with O&M staff).
- Equipment pedestals and/or supports are heavily damaged (>25% of concrete pedestal cracked through with loose or missing pieces), (>25% of steel supports with structural corrosion, missing/broken anchors or other similar damage).
- Equipment appears inoperable in current state – need to discuss with O&M staff.
- Equipment has exceeded its estimated useful life.

Likelihood of Failure (LOF)

- **Approaches**
  1. **Weighted scores:**
  - Define failure criteria (based on generic break stats), weights; calculate score
  2. **Multivariable Regression Model:**
  - Run descriptive statistics, calibrate and validate regression model that takes all failure factors into account at once.

- **Data Requirements/Tools**

  For both approaches: pipe level

  1. **Weighted scores:**
  - Some knowledge of failure factors
  - Weights from general break statistics
  - GIS or Excel
  2. **Multivariable regression:**
  - Pipe and environmental data

  Active (ACT) and Abandoned (ABN)
  - Breaks assigned to (ACT and ABN) pipes
  - Statistical model

Example of Weighted Scores at Cohort Level for Pipe Breaks

Criteria	Weight	Score 1	Score 3	Score 5
Pipe Age (install date)	60%	> 2000	1970 to 1999	<1969
Break Rate by Cohort brks/100 mi/yr	30%	< 10	10 to 20	>20
Soils (Agressiveness)	10%	No	N/A	Yes

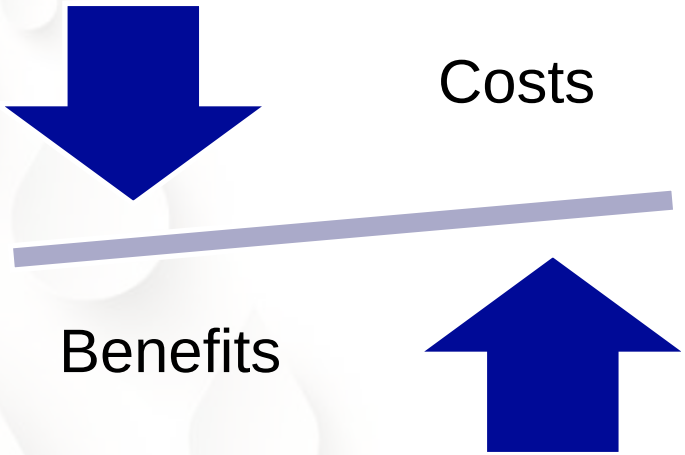
Example of Regression Model Output Results

FeatID	NB BRKS	YOI	DIAM	SOIL	L	COMMENTS	LOF	LOF
439406	0	1960	12	BAD	0.001	SAME CO-VARIATES	0.00012	SAME LOF
5020359	0	1960	12	BAD	0.0011	SAME CO-VARIATES	0.00012	SAME LOF
414765	1	1960	12	BAD	0.0314	MORE BREAKS	0.01604	HIGHER LOF
423809	0	1960	12	BAD	0.0319		0.00135	
396706	2	1948	6	BAD	0.0612	OLDER	0.08651	HIGHER LOF
379035	2	1967	6	BAD	0.0643		0.04741	
438274	1	1953	4	BAD	0.0048	SMALLER DIAM	0.00544	HIGHER LOF
448483	1	1954	8	BAD	0.0044		0.00384	
389358	1	1972	12	BAD	0.1847	WORSE SOIL	0.05209	HIGHER LOF
433341	1	1973	12	GOOD	0.1924		0.01721	
379182	0	1960	12	4	0.27	LONGER	0.00757	HIGHER LOF
447565	0	1960	12	4	0.0137		0.00071	

Likelihood of Failure (LOF)

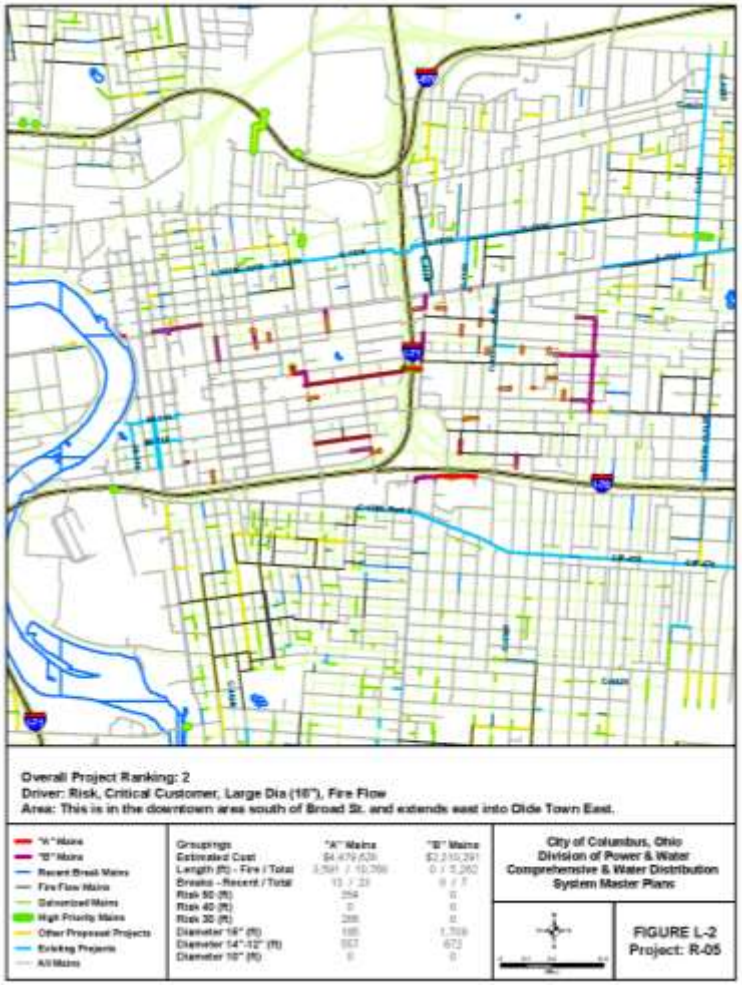
- **Plus**
  1. **Weighted scores:**
  - Breaks do not need to be assigned to pipes; take break info from break reports
  2. **Multivariable regression:**
  - No guessing (the model decides how much of as role a factor plays), more differentiation, more precise and reliable, no counting factors twice

- **Minus**
  1. **Weighted scores:**
  - Failure factors, weights assumed; could be questionable
  - Risk of redundancy
  - Little differentiation
  2. **Multivariable regression:**
  - Data available and thoroughly cleaned up
  - Preliminary statistics and expertise to calibrate model
  - Data collection and structure may need to change (also a plus!)



Visualization

All results at the pipe level (LOF, COF, STP) can be visualized on a map or GIS if utility has GIS and pipes are identified in a GIS layer



What data could be used to define Likelihood of Failure (LOF) score?

- **Operations/hydraulic**
  - hydraulic capacity
  - I/I
  - pressure
  - service points
  - consumption
  - Leaks
- **Service**
  - customers criticality
  - complaints (backups, frequency of construction projects)
  - planned work for water lines or pavement
- **Cost**
  - repair (from basic to very advanced if indirect and social costs included)
  - rehabilitation
  - replacement
- **Environmental/location**
  - soil
  - traffic
  - population density/construction
  - sensitive targets (rail track, subway entrance, tunnel)
- **Pipes**
  - material
  - diameter
  - year of Installation
  - year of Abandonment
  - Length
- **Collapses**
  - type
  - date
  - pipe

Consequences:
Triple Bottom Line & VA Analyses

- Revenue Loss
- Repair/Replacement Cost
- Work-around Cost

- Injuries
- Deaths
- Regional economic loss

- Non-compliance
- Cleanup

Consequence of Failure (COF)

- **Approaches**
  1. **Weighted scores:**
     - Define COF criteria
     - Assign weight (wi) to each criterion
     - Calculate COF score = Sum (wi x COFi)
  2. **Monetized:**
     - Same but criteria are monetized

- **Data Requirements/Tools**

  Pipe level

  1. **Weighted scores and Decision Tree**:
     - Impact criteria data
     - Excel/GIS
  2. **Monetized**:
     - Same
     - Cost history

Triple Bottom Line Approach for Criteria Selection

Example Monetized Criteria

Magnitude Ranges for Triple Bottom Line Analysis					
Criteria Category	Criteria	Low	Moderate	High	Very High
Economic	Asset Repair Costs	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Emergency Repair Costs	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Asset Replacement Costs	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Property Damage	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Operational Losses (lost revenue, exporting to other facilities)	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Administrative and Legal Costs of Damage Settlements	<$20K	$20K - <$100K	$100K - <$500K	>$500K
	Consultant/Engineering Services	<$20K	$20K - <$100K	$100K - <$500K	>$500K
Environmental	Permit Violation	do not apply to permit violations			yes
	Environmental Regulatory Fine for Spills or Releases	<$20K	$20K - <$100K	$100K - <$500K	>$500K
Social	Disruption of Service	do not apply to safety			yes
	Safety- Public and CWW staff	do not apply to safety			yes

Consequence of Failure (COF)

- **Plus**

  Both:
  - Can be computed in excel or GIS
  - Incremental: start with simple data and scores and build from there over time

  1. **Weighted scores:**
  - Easy to start

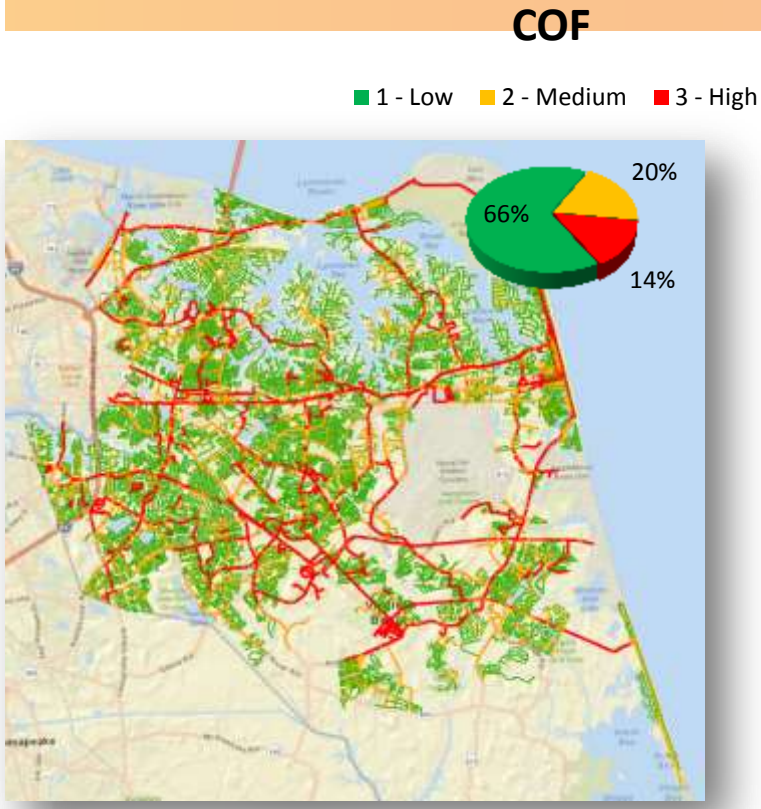
  2. **Monetized:**
  - Better differentiation
  - Real cost of collapse

- **Minus**

  Both: Difficult to evaluate social and indirect impact

  1. **Weighted scores:**
  - Poor differentiation
  - 1 x 100 = 10 x 10

  2. **Monetized**:
  - Can be difficult to put price tag even on direct cost



What data could be used to define Consequence of Failure (COF) score?

- **Operations/hydraulic**
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  - I/I
  - pressure
  - service points
  - consumption
  - leaks
- **Service**
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  - planned work for water lines or pavement
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  - sensitive targets (rail track, subway entrance, tunnel)
- **Pipes**
  - material
  - diameter
  - year of Installation
  - year of Abandonment
  - Length
- **Collapses**
  - type
  - date
  - pipe

Risk Analysis – Threat Likelihood

Risk (R) Analysis – Different Definitions

*R = Probability * Consequence*

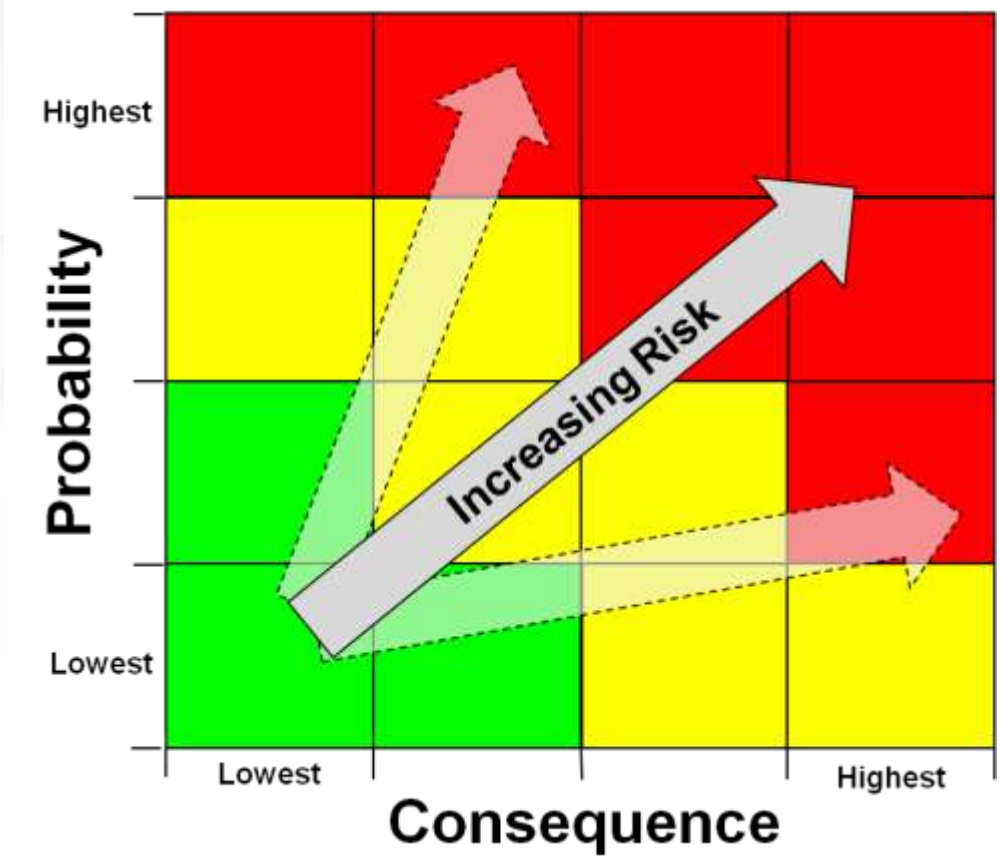
$$R = C \times V \times T$$

Where:

C = Consequences

V = Vulnerability

T = Threat likelihood



Assign Risk: Risk Supports Optimization of Capital Improvement Programs

Probability of Failure x **Consequence of Failure** x **Redundancy Factor** = **Risk Score**

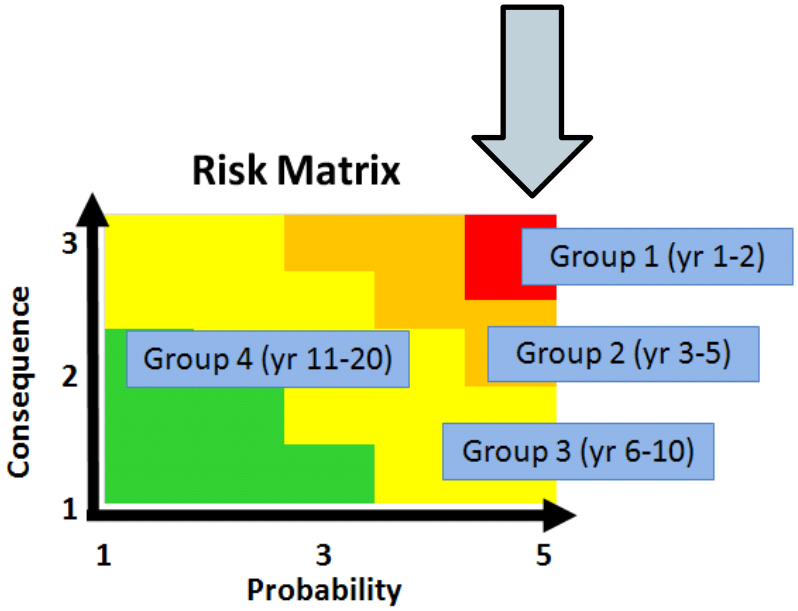
Failure Mode

- Mortality
- Level of Service
- Capacity
- Efficiency

Consequence

- Economic
- Social / Safety
- Environmental

TBL:Triple Bottom Line

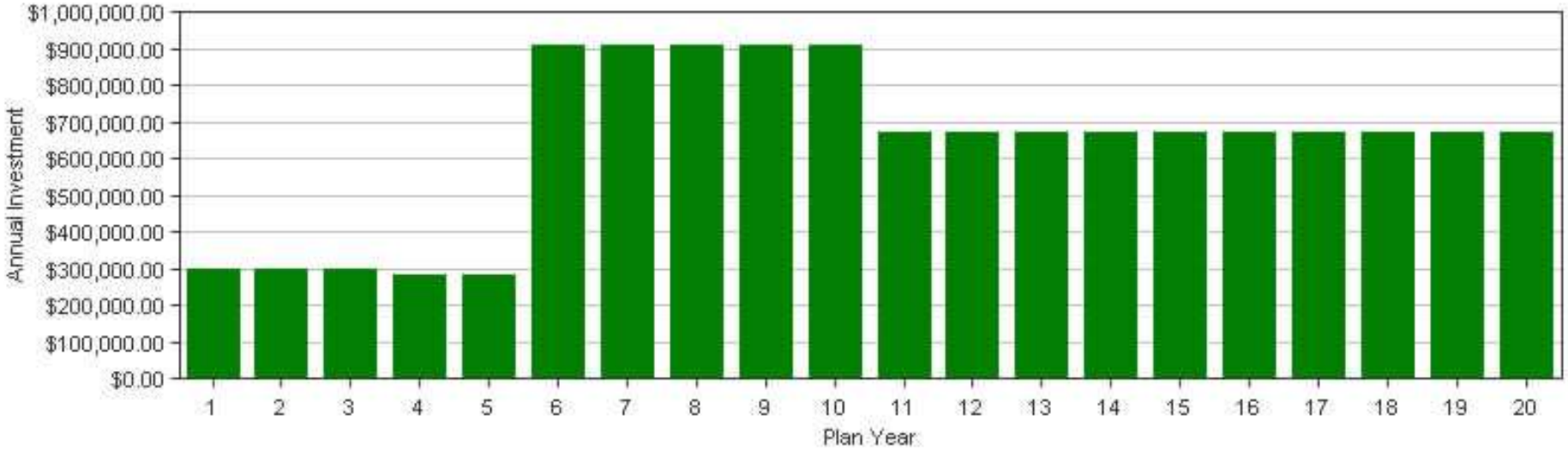


"Right projects at the right time"

Remaining Life and Replacement Cost

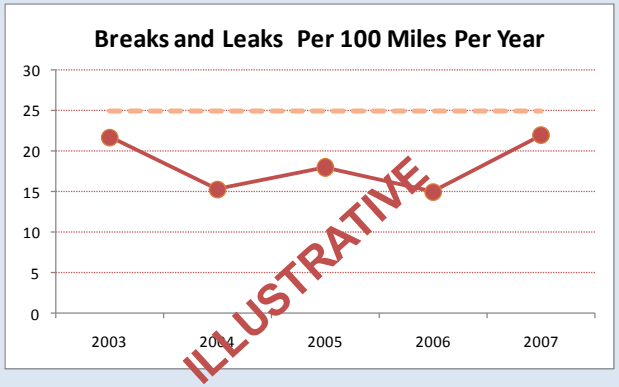
- **Remaining Life**

- **Cost (Replacement, Rehabilitation, and Maintenance)**



Set Targets for Service Levels:
Build Transparency and Stakeholder Relationships

SL Category	Water	Wastewater
Reliability	•water main breaks •unaccounted for water •worst served customers	•sewer blockages / collapses •SSOs / CSOs •spills / backups
Quality	• customer complaints (pressure, taste/odor, color)	•odor complaints from plants pump stations, and WWTPs
Customer Service	•outage response •call enter performance	•event response •call enter performance
Regulatory	•water quality compliance	•discharge permit compliance



Current Performance Trends and Issues

- Stable performance driven by rehabilitation and renewal program of 100 miles per year.
- Continued focus on oldest cast iron pipe and worst served areas.
- 2007 performance impacted by spike of 75 third party damage incidents during downtown light rail construction .

What Are Service Levels?

- **A commitment** to deliver a specified level of service, and quality to customers and stakeholders
- **A mechanism** to communicate and report performance results, focus organizational efforts, and prioritize investments
- **The linkage** between your strategic objectives and operational or tactical objectives

Service Levels & Performance Measures

Service Levels

- Externally-driven
- Strategic level
- Contracts/agreements with customers/stakeholders
- Focused on highly visible areas (quality, response, etc.)
- Link the municipality and asset management “charters”

Performance Measures

- Internally-driven
- Operational and field level
- Translate strategic goals into tactical plans
- Comprehensive tracking of cost, productivity, and performance
- Drive tactical plan implementation

Both are Required for
Successful Asset Management

Sample Service Level and Supporting Maintenance Performance Measures

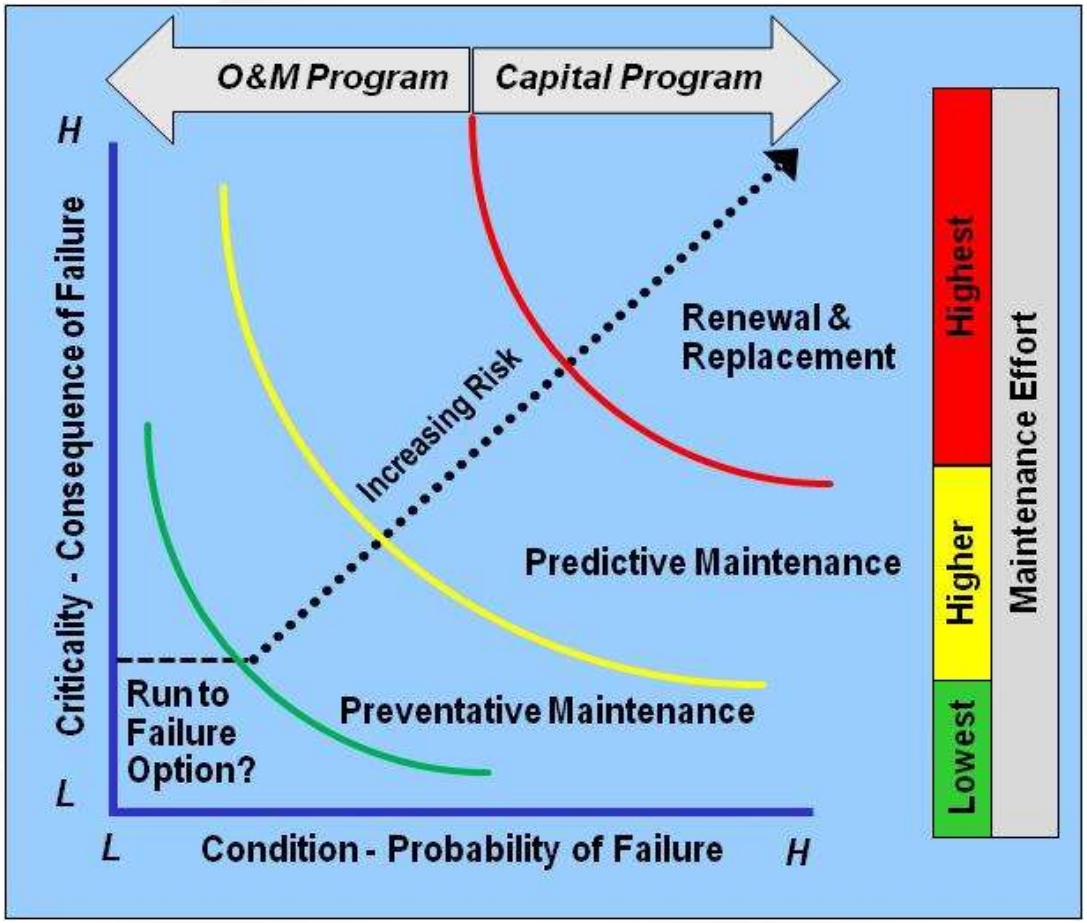
Strategic Plan Elements		LOS Category and Measures
1	Ensure system and asset reliability and minimize interruptions	**Wastewater/Stormwater Collection** • LOS X1 Collapses / Blockages Per 100 Miles • LOS X2 Property Flooding • LOS X3 Discharge Compliance • LOS X4 Event Response Time
2	Provide high quality service and effective response	

Key Performance Indicators

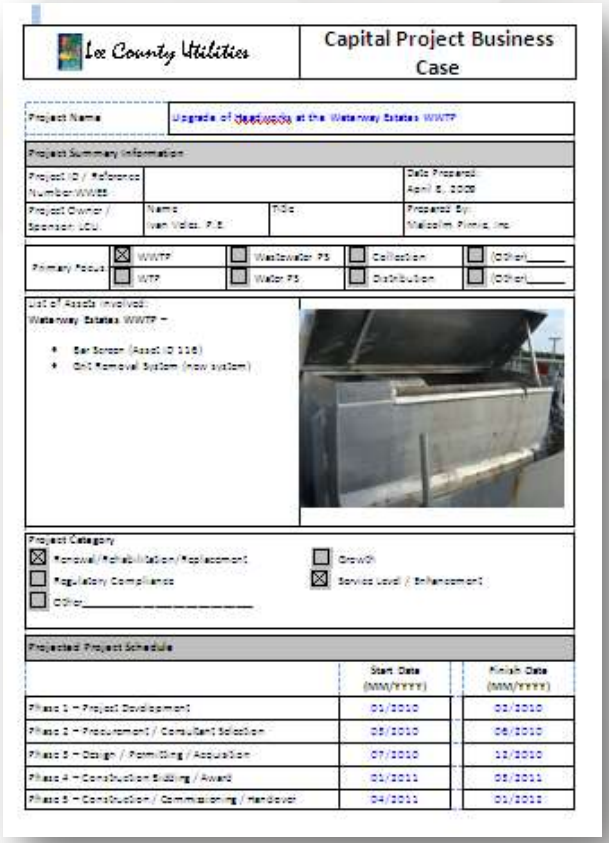
Operations and Maintenance

- Number of feet of sewer line cleaned
- Number of times assets were inspected
- Ratio of PM/CM work orders
- Work order completion ratio

Determine CIP and Maintenance Program Risk Assessment Balances Capital with Maintenance



Fund the Program:
Business Cases and TBL / Cost Benefit Analysis Support Funding



Lee County Utilities — Capital Project Business Case

Project Name: Upgrade of [illegible] at the Waterway Estates WWTP

Project Summary Information

Project ID / Reference Number WWES			Date Prepared: April 8, 2008
Project Owner / Sponsor: LCU	Name: Ivan Velez, P.E.	Title	Prepared By: Malcolm Pirnie, Inc.

Primary Focus: ☒ WWTP ☐ Wastewater PS ☐ Collection ☐ (Other)____ ☐ WTP ☐ Water PS ☐ Distribution ☐ (Other)____

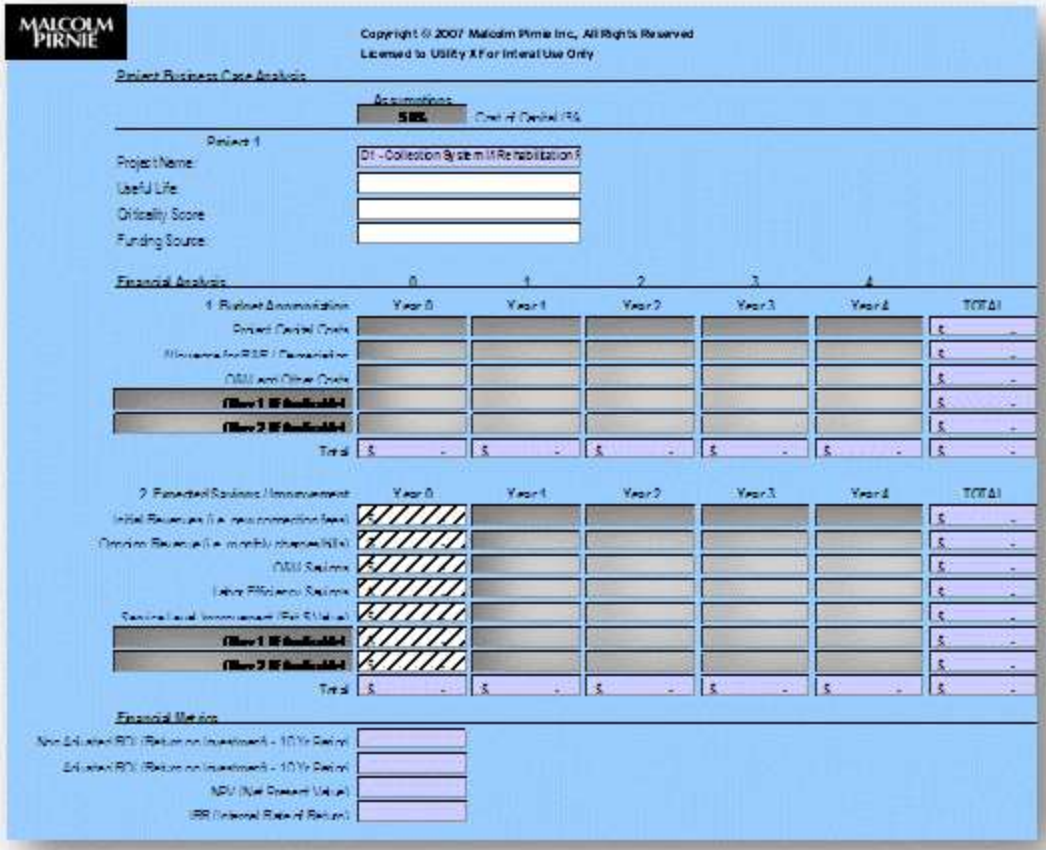
List of Assets Involved:
Waterway Estates WWTP –

- Bar Screen (Asset ID 116)
- Grit Removal System (new system)

Project Category
☒ Renewal/Rehabilitation/Replacement ☐ Growth
☐ Regulatory Compliance ☒ Service Level / Enhancement
☐ Other:_____

Projected Project Schedule

	Start Date (MM/YYYY)	Finish Date (MM/YYYY)
Phase 1 – Project Development	01/2010	03/2010
Phase 2 – Procurement / Consultant Selection	05/2010	06/2010
Phase 3 – Design / Permitting / Acquisition	07/2010	12/2010
Phase 4 – Construction Bidding / Award	01/2011	03/2011
Phase 5 – Construction / Commissioning / Handover	04/2011	01/2013



MALCOLM PIRNIE

Project Business Case Analysis

Assumptions
5.0% Cost of Capital (%)

Project 1
Project Name: D1 - Collection System I/I Rehabilitation P
Useful Life:
Criticality Score:
Funding Source:

Financial Analysis

1 Project Annualization	0 Year 0	1 Year 1	2 Year 2	3 Year 3	4 Year 4	TOTAL
Project Capital Costs						$ -
Allowance for R&R / Depreciation						$ -
O&M and Other Costs						$ -
Flow 1 If Included						$ -
Flow 2 If Included						$ -
Total	$ -	$ -	$ -	$ -	$ -	$ -

2 Financial Savings / Improvement	Year 0	Year 1	Year 2	Year 3	Year 4	TOTAL
Initial Revenues (i.e. new connection fees)						$ -
Ongoing Revenue (i.e. monthly charges/bills)						$ -
O&M Savings						$ -
Labor Efficiency Savings						$ -
Service Level Improvement (Put $ Value)						$ -
Flow 1 If Included						$ -
Flow 2 If Included						$ -
Total	$ -	$ -	$ -	$ -	$ -	$ -

Financial Metrics

Non-Discounted ROI (Return on Investment - 10 Yr Basis)	
Discounted ROI (Return on Investment - 10 Yr Basis)	
NPV (Net Present Value)	
IRR (Internal Rate of Return)	

Next Steps Upon Program Completion

- Sustainable Financial Projections
  - Capital Prioritization
  - Affordability Analysis
  - Funding Options

Helps Balance Capital Funding and Rate Impacts

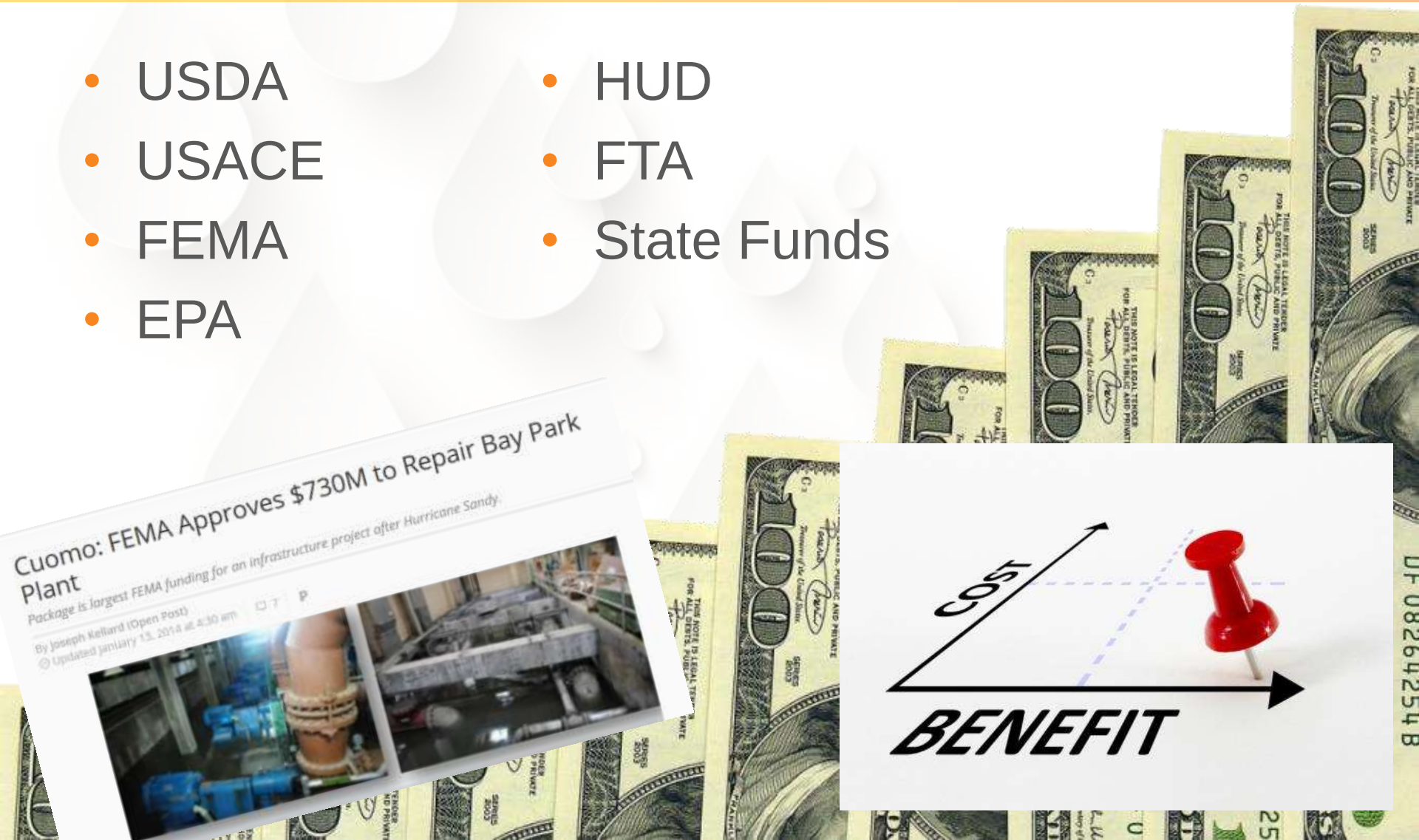
ROI – Asset Management Program Implementation Outcomes

- Quantitative
- Qualitative

ROI – Vulnerability Assessment Outcomes

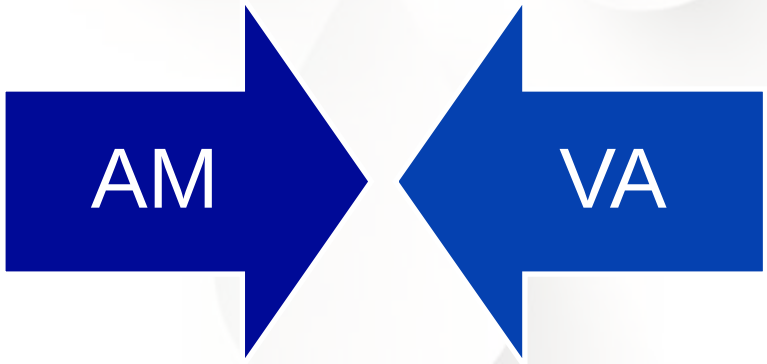
Numerous Funding Sources

- USDA
- USACE
- FEMA
- EPA
- HUD
- FTA
- State Funds



A More Holistic Resilience Management Approach

- Understand Internal Risks (Asset Management)
- Understand External Risks (Vulnerability Assessment)
- Holistic Perspective



The Resiliency Cycle

THANK YOU

Together we can do a world of good.

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