



Drinking Water Pipeline Condition Assessment



Mark Carlson, PE
Jennifer Henke, PE

Agenda

- Introductions
- Market Drivers and Opportunities
- Approaches to Condition Assessment
 - Prioritization Methods
 - Field Technologies
- Rehabilitation Alternatives
- Additional Resources

1. Introductions



Jennifer Henke



Jerry Duppong



Dan Buonadonna



Mark Carlson

1. Introductions
2. ***What's Driving Condition Assessment?***
3. General Condition Assessment Approach
 - Prioritization Methods
 - Field Technologies
4. Rehabilitation Alternatives
5. Additional Resources

2. What's Driving Condition Assessment

What's the Performance of my system?

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graph TD; A[What's the Performance of my system?] --> B[Where do I focus repairing/replacing my aging infrastructure]; B --> C[Establish strategies to meet these challenges]; C --> D[Understanding the benefits of condition assessment];
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Where do I focus repairing/replacing my aging infrastructure

Establish strategies to meet these challenges

Understanding the benefits of condition assessment

Understanding Historical Performance

- What kinds of failures have occurred, in what kinds of pipe, when, and where

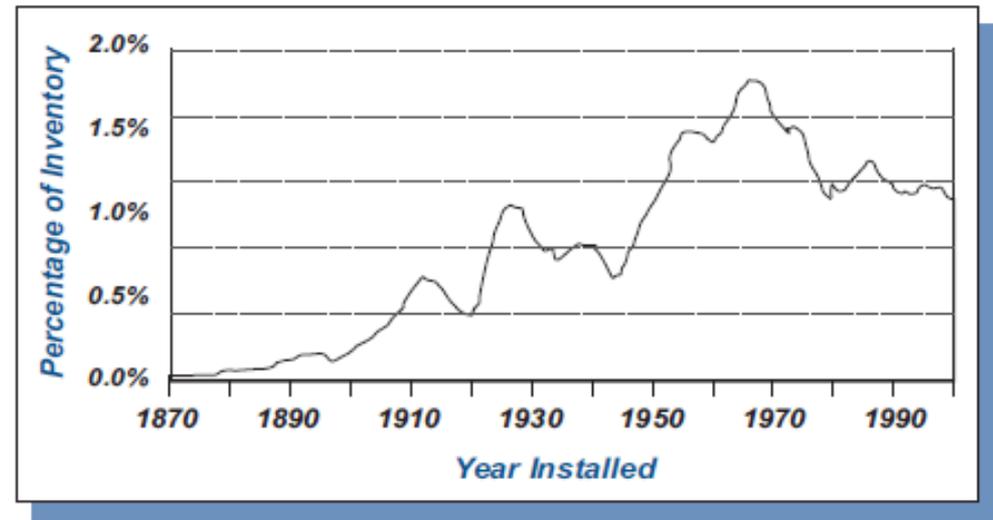
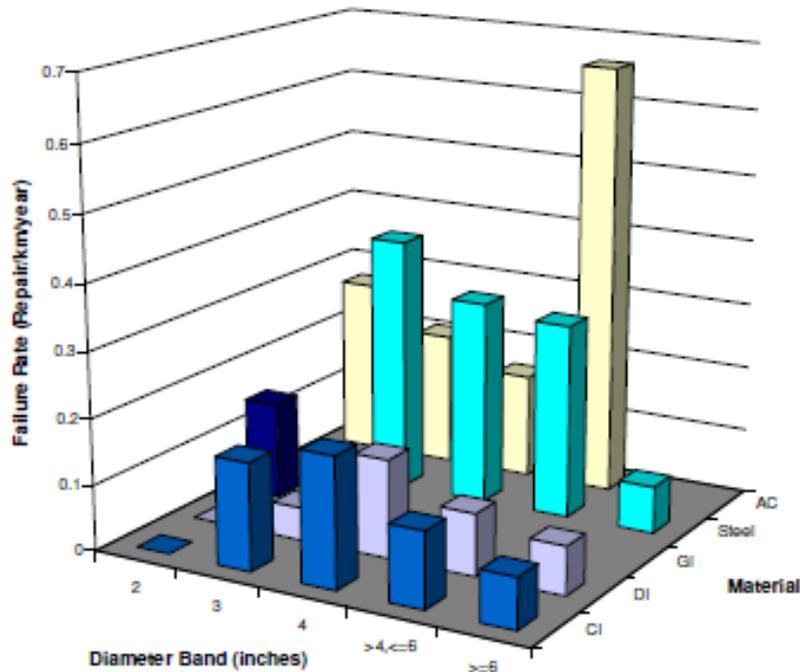
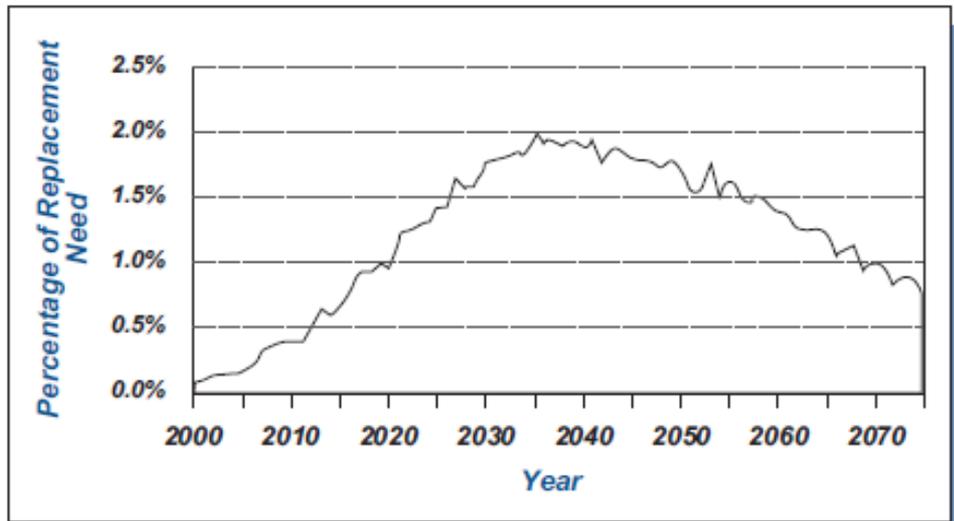


Figure 2-10: Age Distribution of Current Inventory of Pipe for 20 Cities

Predicting the Future

- Infrastructure Funding Gap (IFG) to maintain/replace deteriorating assets
 - ASCE Report Card: D-
 - EPA estimate: \$338 billion over 20 years
 - AWWA estimate: \$1.7 trillion by 2050



*But age isn't
always the best
predictor...*

Figure 2-11: Projected Annual Replacement Needs for Transmission Lines and Distribution Mains, 2000-2075

Determining Specific Drivers and Strategies

- Compare your system against the historical examples and any current issues, what will be your condition assessment drivers?
 - Customers
 - Pressure drops
 - Future capacity
 - Lost revenue
 - Leak detection
 - Asset management
 - Corrosion mitigation
 - Correct improper construction/materials



Quantifying Benefits of Condition Assessment



Cost of Failure

**“Just in Time”
Renewal**

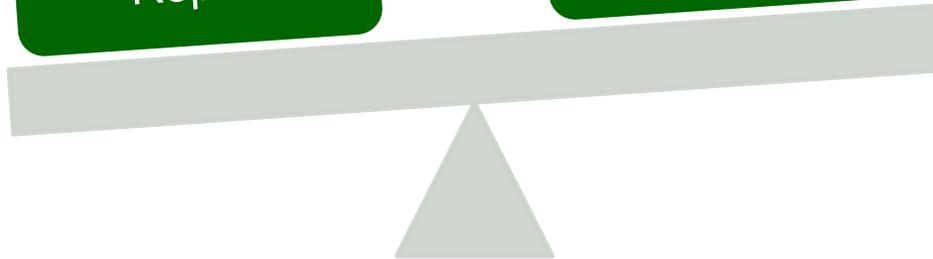
Societal Costs

Damages

Emergency Repair

Planned Rehab Expenditures

Condition Assessment



How did we get here...?

- Gradual infrastructure deterioration
- Customers have become accustomed to low costs for water utility services
- Buried systems have difficulty competing for public funds against “visible” infrastructure

1. Introductions
2. Market Drivers and Opportunities
3. ***Approaches to Condition Assessment***
 - *Prioritization Methods*
 - Field Technologies
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3. Approaches to Condition Assessment

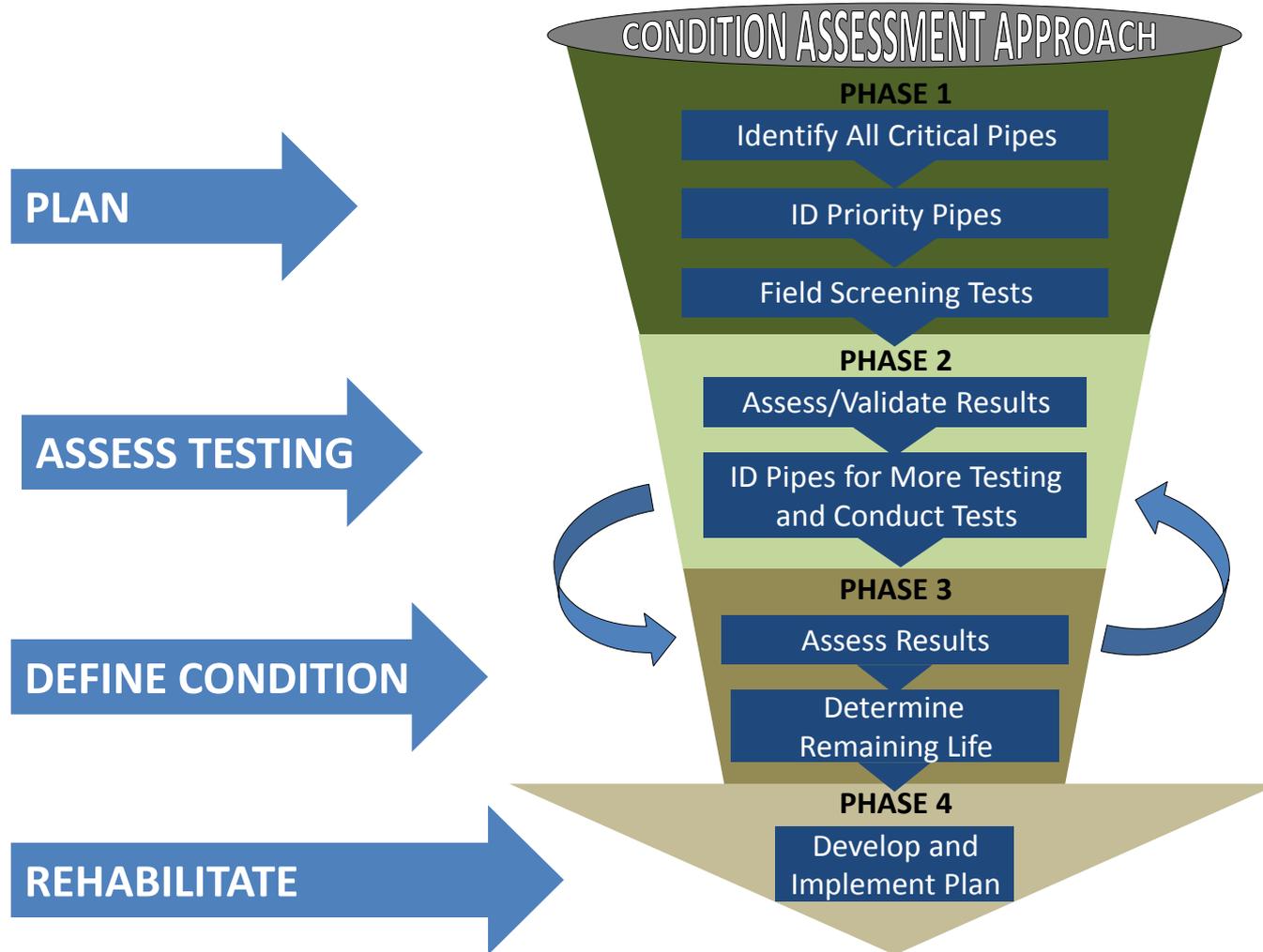
- Goals of this section:
 - Outline of alternative program strategies and prioritization methods

It's a Balancing Act

- Minimize the life-cycle costs of assets
- Continuously deliver established levels of service
-at an acceptable level of risk
- Starting small with a focused goal can help you accomplish your objectives



Condition Assessment Approach



Phase 1: Plan and Conduct Tier 1 Tests

- Identify Priority Pipes for Evaluation
- Phase 1 is analogous to application of “Desktop” and Tier 1 Technologies:

- Pressure/Flow Monitoring
- Soil Survey/Corrosion Study
- “Criticality” Hydraulic Modeling
- Ultrasonic
- Infrared Thermal Imaging
- External acoustic (leak detection/pipe integrity)



Field Screening
Tests

Phase1 – Priority Pipes through Threat Identification (Desktop Study)

- Identify the specific vectors that may compromise the reliability of a specific cast iron pipe asset or a cohort of pipes
- Be creative – study every angle – think bad thoughts
- Use all available resources – as-builts, plat cards, route walks, institutional knowledge, operating records, soil maps, GIS, etc
- Internal, External, and Operational

Example Threats

INTERNAL

- Deteriorated Cement Mortar Lining (CML)
- Corrosion from aggressive pumped media (salinity, pH, dissolved oxygen)
- Deflected joints that leak
- Previous joint seals have failed
- Deflected pipe from external loads



EXTERNAL

- Corrosive soils
- Stray currents
- 3rd Party damage
- Wheel / rail loads resulting in settlement or brittle fracture

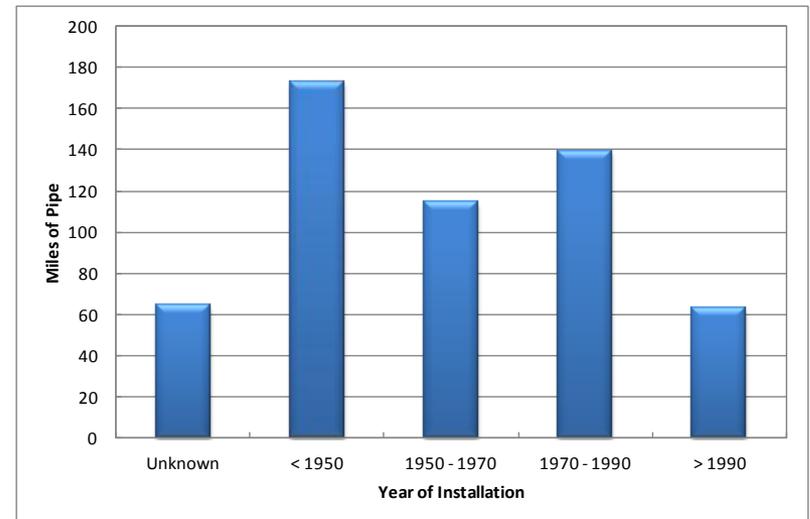
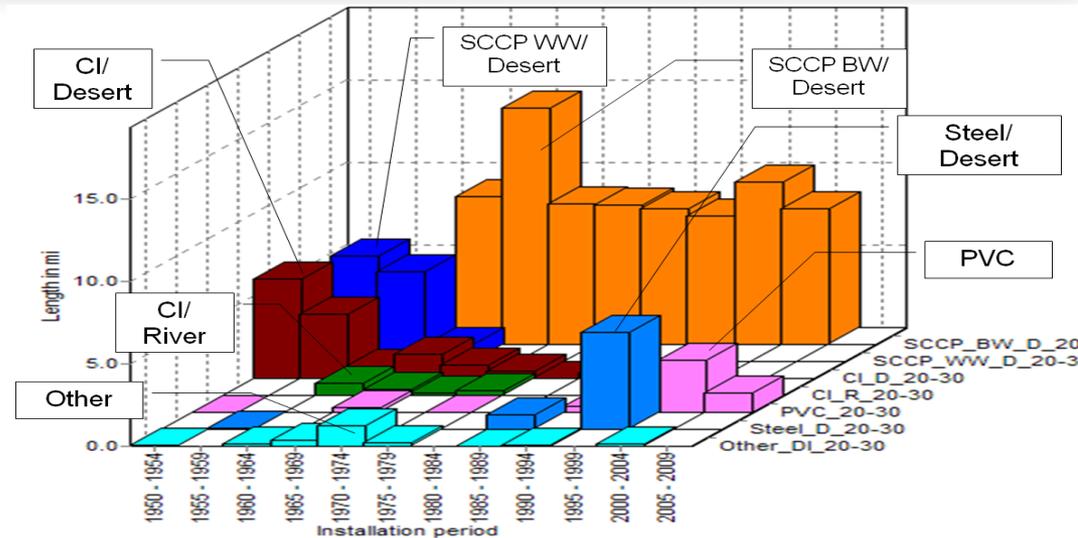


Example Operational Threats

- Waterhammer
- Lost blow-offs
- Failed air release valves
- Frozen valves
- Red water complaints in potable lines

Phase 1: Desktop Study

- Identify facilities/ pipelines at risk from threat analysis
- Summarize historical information and develop pipe groups/cohorts
- Consider
 - System Break History
 - Pipeline Condition Assessments
 - Future Demand
 - Leak Detection
 - Water Loss



Threat identification linked to Risk Assessment and Sample Likelihood and Consequence Criteria

Likelihood Criteria

- Age (e.g. ductile iron pipes are newer with a low likelihood of failure)
- Material Type (e.g. ductile iron pipe)
- **Pressure variation**
- Within liquefaction area
- Within corrosive soil area
- Within historical landfill area
- High historical pipe leak rate
- High pipe pressure
- Prior above-ground or below-ground construction activities near water mains

Consequence Criteria

- High impact water outage
- Near or under a sensitive water body (creek, river, lake, or Puget Sound)
- Within wetland-designated area
- Under a major transportation corridor (freeway, highway, major arterial road)
- Under active and high usage railroad tracks
- Attached to a bridge
- Inside a tunnel or Utilidor
- Within known or potential slide area
- Within Central Business District (CBD)
- Under a high-density residential, industrial, or commercial building

Risk-based approach considers the consequence and likelihood of asset failure to provide focus on specific assets

Consequence Matrix

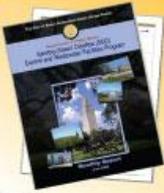
Consequence Levels by Category	Water Treatment								
Level of Service	Asset ID	Question to Ask	Level of Service Affected	Impacts 1	Impacts 2	Impacts 3	Impacts 4	Impacts 5	Risk Score
High & Critical	001	What is the impact on the community if the asset fails to perform?	Highly degraded water quality and odor	No impact	Highly degraded water quality and odor	10.0			
Medium	002	What is the impact on the community if the asset fails to perform?	Highly degraded water quality and odor	No impact	Highly degraded water quality and odor	10.0			
Low	003	What is the impact on the community if the asset fails to perform?	Highly degraded water quality and odor	No impact	Highly degraded water quality and odor	10.0			

Likelihood Matrix

Workshops



Reports



Asset Inventory



GIS



Risk Assessment

ASSET	Consequence	Likelihood	Risk Score
West Reservoir	8.2	4.9	40.2
Water Plan	9.3	3.1	28.7
East chamber to NE	4.3	5.5	23.7
MM to SE	3.8	5.7	21.8
Uplands Reservoir	5.1	4.3	21.7
Chamber to West Leitchbridge	6.6	2.5	16.7
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Chamber to MM Res	4.3	3.4	14.7
MM East Reservoir	4.4	3.2	13.9
MM Reservoir	3.8	3.2	12.0
Plant to East chamber (under slab)	4.1	2.9	11.9
West River chamber to West City	5.0	2.3	11.4
Plant to chamber	3.9	2.5	10.0
East chamber to Uplands	3.0	2.2	6.5
South East Reservoir	3.9	2.1	8.2
East chamber to MM junction	2.6	2.7	7.1
Plant to East chamber	2.6	2.7	7.1
East chamber to MM junction	2.6	2.7	7.1
Plant to chamber	3.0	2.5	7.0

Risk-based approach considers the consequence and likelihood of asset failure to accurately prioritize projects

Consequence Matrix

Level of Service	Norm Wt	Question to ask	Level of Service Attributes
Health & Safety of public and employees	0.23	-What is the impact on the LOS attributes if the <i>system/asset/element</i> fails to perform	<ul style="list-style-type: none"> - Healthy drinking water - Sufficient quantity - Firefighting reserves - Safe work environment
Compliance with regulations, codes, and bylaws	0.23	-What is the impact on the LOS attributes if the <i>system/asset/element</i> fails to perform	<ul style="list-style-type: none"> - Meet OH&S Codes - Meet Environmental regs - Meet Canadian Safe water drinking act

Consequence Levels by category

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Risk Assessment

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Likelihood Matrix

Risk-based approach considers the consequence and likelihood of asset failure to accurately prioritize projects

Microsoft Excel - Water Risk Workbook.xls

File Edit View Insert Format Tools Data Window Help

Type a question for help

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Reply with Changes... End Review...

A25

ASSET	Consequence	Likelihood	Risk Score
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North East Reservoir	4.4	3.2	13.9
MM Reservoir	3.8	3.2	12.0
Plant to East chamber (under slab)	4.1	2.9	11.9
West River chamber to West City	5.0	2.3	11.4
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Water Treatment, Storage and T

Water results V1 | Water Treatment Drill-down | Water Consequence Matrix | Water

start | De... | 3 M... | CH... | DP... | WS... | \O... | Bo... | Wa... | 10:49 AM

Consequence Matrix

Consequence Levels by Category	Category	Level 1	Level 2	Level 3	Level 4	Level 5
Health & Safety	Death or injury to people	Minor	Major	Critical	Catastrophic	Unacceptable
Environment	Water quality	Minor	Major	Critical	Catastrophic	Unacceptable
Asset	Asset failure	Minor	Major	Critical	Catastrophic	Unacceptable
Service	Service interruption	Minor	Major	Critical	Catastrophic	Unacceptable
Cost	Cost of failure	Minor	Major	Critical	Catastrophic	Unacceptable
Reputation	Reputation damage	Minor	Major	Critical	Catastrophic	Unacceptable
Legal	Legal liability	Minor	Major	Critical	Catastrophic	Unacceptable

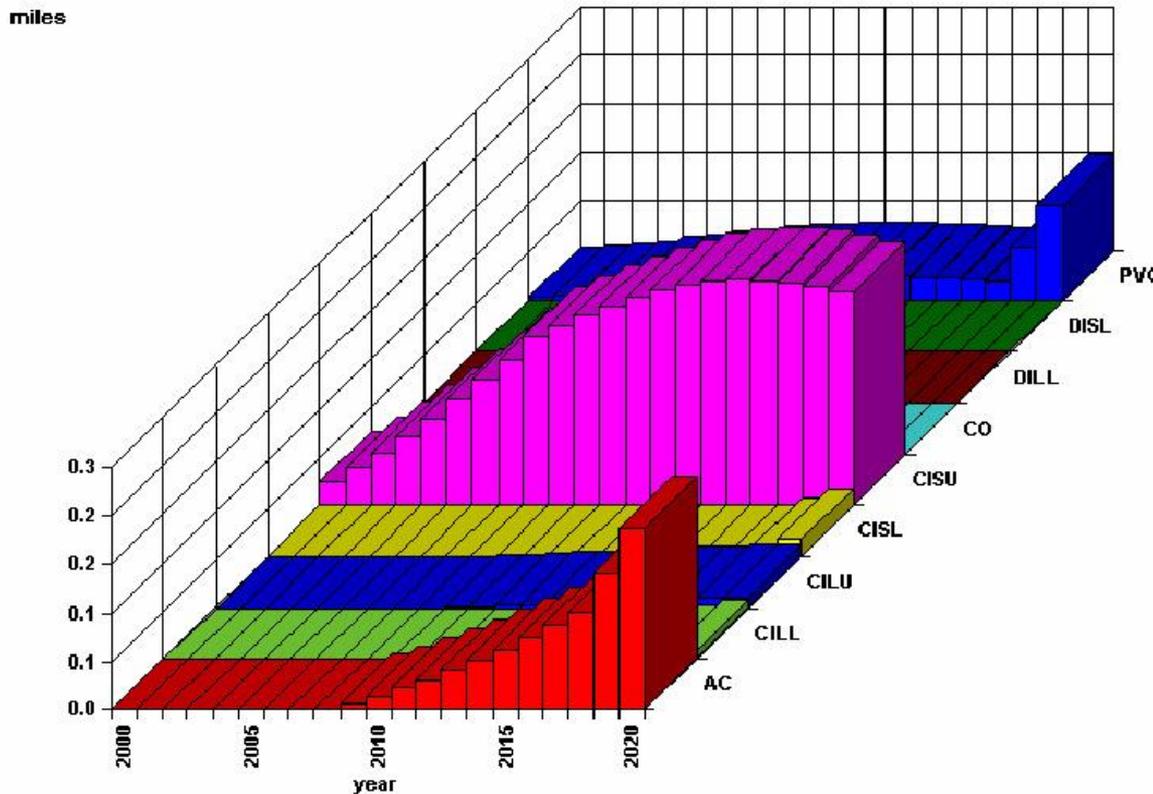
Likelihood Matrix

Likelihood Levels by Category	Category	Level 1	Level 2	Level 3	Level 4	Level 5
Frequency	Frequency of failure	Very Rare	Rare	Occasional	Frequent	Very Frequent
Duration	Duration of failure	Very Short	Short	Medium	Long	Very Long
Extent	Extent of failure	Very Limited	Limited	Medium	Extensive	Very Extensive
Impact	Impact of failure	Very Low	Low	Medium	High	Very High

Pipeline Renewal Decision Process

Length of water mains to be renewed
based on long life expectancies for categories of water mains

Your Town, USA
KANEW



SS
inventory and
condition data
review

Inventory
condition

Renewal
Options

Using hydraulic performance in conjunction with condition information strengthens decision making

- Innovyze The logo for CapPlan Water features the text "CapPlan" in green and "Water" in blue below it. To the right is a stylized globe with blue arrows forming a circular path around its base.
- Bentley Pipe Renewal Planner
- Can overlay your hydraulic results in a single interface and produce prioritized areas for focus

CapPlan (Innovyze) Setup Likelihood and Consequence of Failure

Edit Likelihood of Failure

Likelihood of Failure

- Analysis Results
- Pipe Attribute
- Soil
- Failure History Data
- Intersection
- Advanced GIS Field Calculation



Descriptions

Hydraulic model analysis results might indicate potential for failure and can be used for estimating likelihood of failure. (e.g. pressure)

OK Cancel

Edit Consequence

Consequence

- Analysis Results
- Population Density
- Critical Facilities
- Outage Analysis
- Isolation
- Fire Flow
- Street Paving
- Intersection
- Pipe Inventory Data
- Advanced GIS Field Calculation

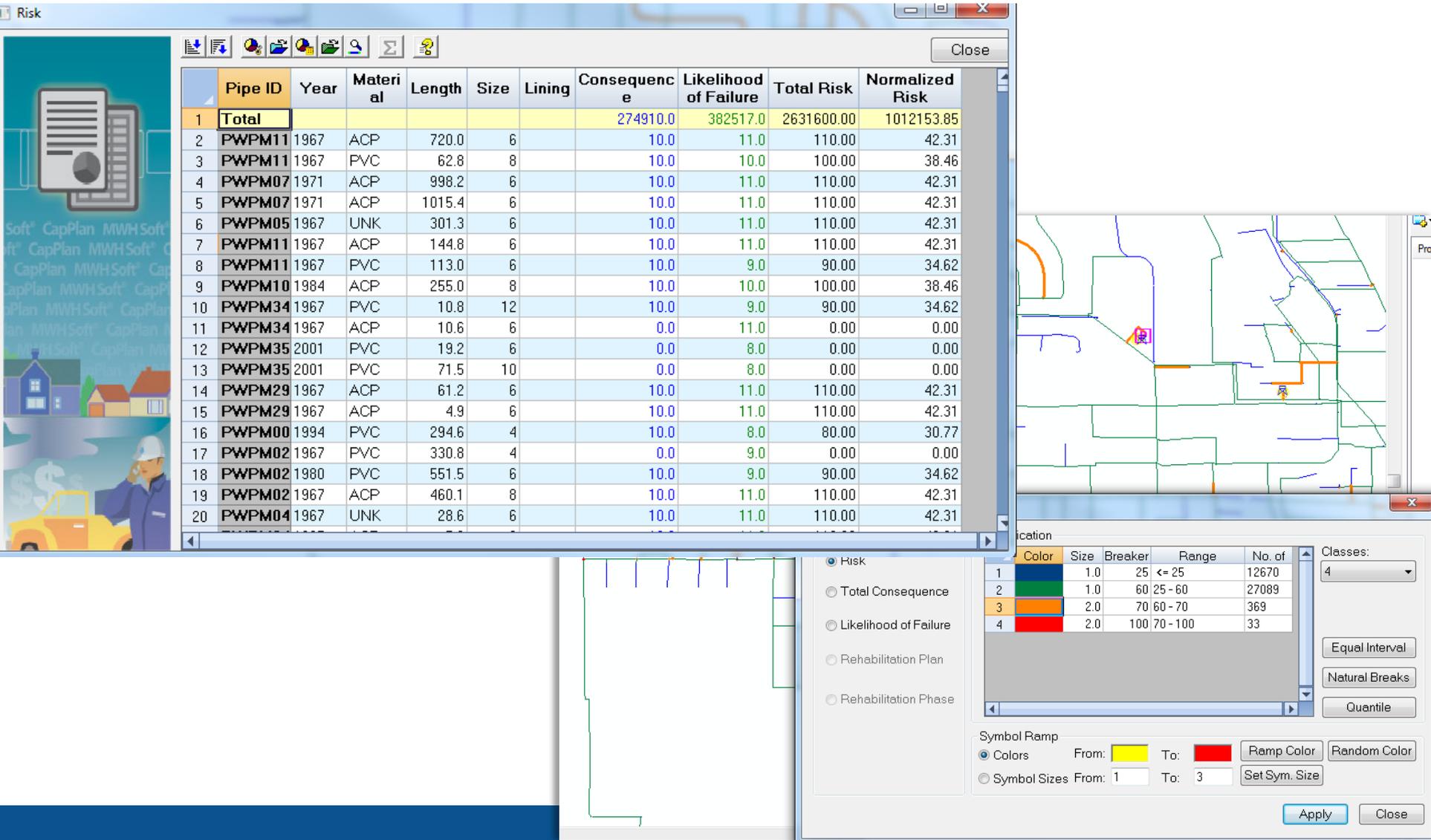


Descriptions

Use hydraulic and water quality analysis results such as flow or pressure to calculate consequences of failure for each pipe. (e.g. A pipe with higher flow might cause more erosion damage and more flooding upon failure)

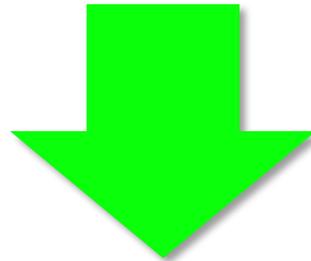
OK Cancel

CapPlan (Innovyze) Risk Results



Phase 1 Recap: Desktop Analysis

- Goal:
 - Prioritize pipelines for field study
 - Identify classes of pipeline with similar history of use and external factors to guide prioritization for evaluation



Pipe Cohorts

- If funding limited, use Phase 1 results to identify remaining life from available information and plan for future Phases as funding is available

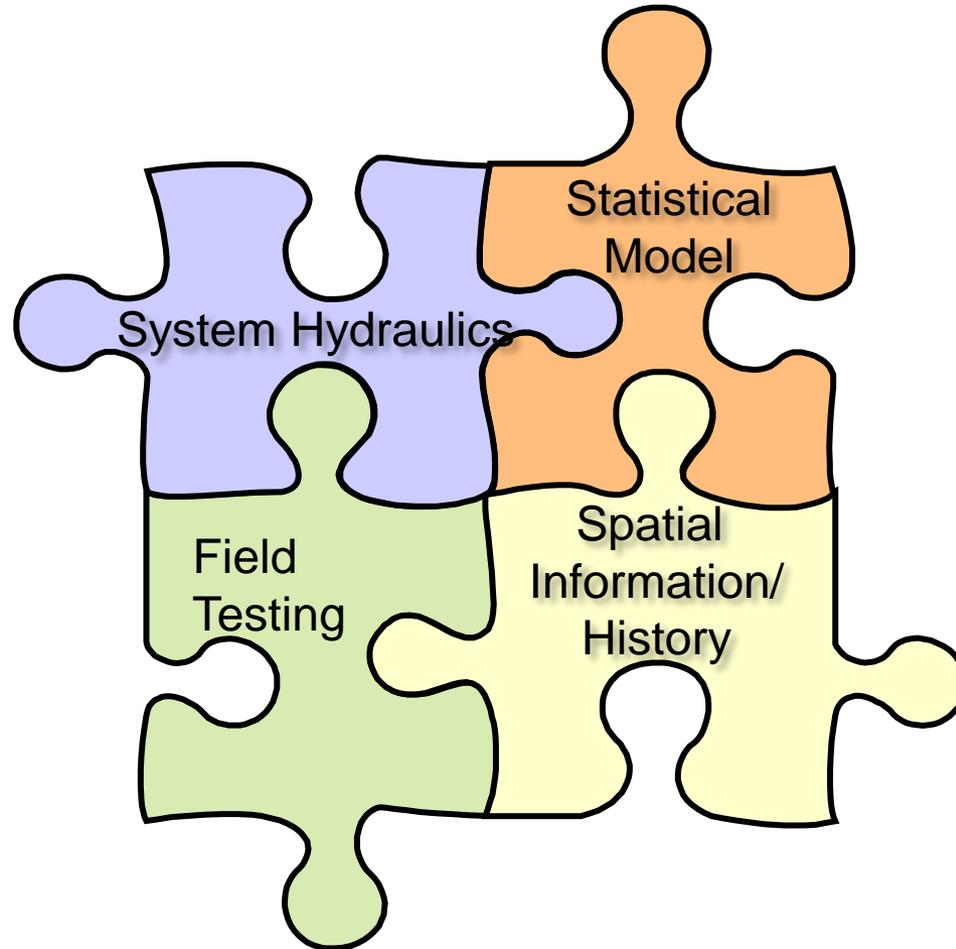
Phase 1 Recap: Field Screening

■ Goal:

- Screen a range of pipe segments and calibrate evaluation of field data
- Field studies may include leak detection or other acoustical methods for wall thickness information
- Develop segments to make average wall thickness calculations meaningful
- Identify pipelines with wall thickness reduction that directs additional evaluation to pinpoint defects



Phase 2: Combining Technologies



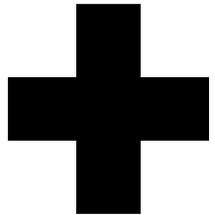
Phase 2 Recap: Assess Phase 1 Testing and Additional Field Evaluation

- Assess results of Phase 1 testing to identify if and where additional field tests should be focused
- Phase 2 Testing could include:
 - Internal acoustic swimming tools
 - Internal electromagnetic swimming tools
 - Coupons
- Goal:
 - Identify **location** of pipe defects along length of pipe
 - Leaks, anomalies, visualization of information available with some technologies
 - Quantify defect and if additional testing is required
 - (Additional Tier 2 or Tier 3)



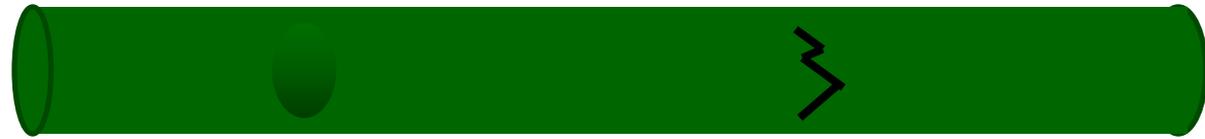
Smart Ball, Sahara®

PHASE 1

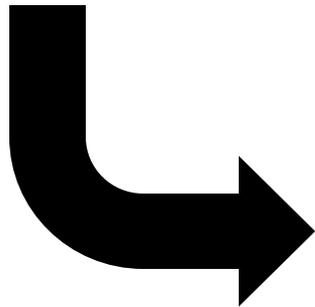


Average information along pipe segment

PHASE 2



More specific location of defect/anomaly



PHASE 3: Can remaining life be estimated with results?
Additional testing needed?

Phase 3: Assess Phase 2 Testing and Estimate Remaining Life

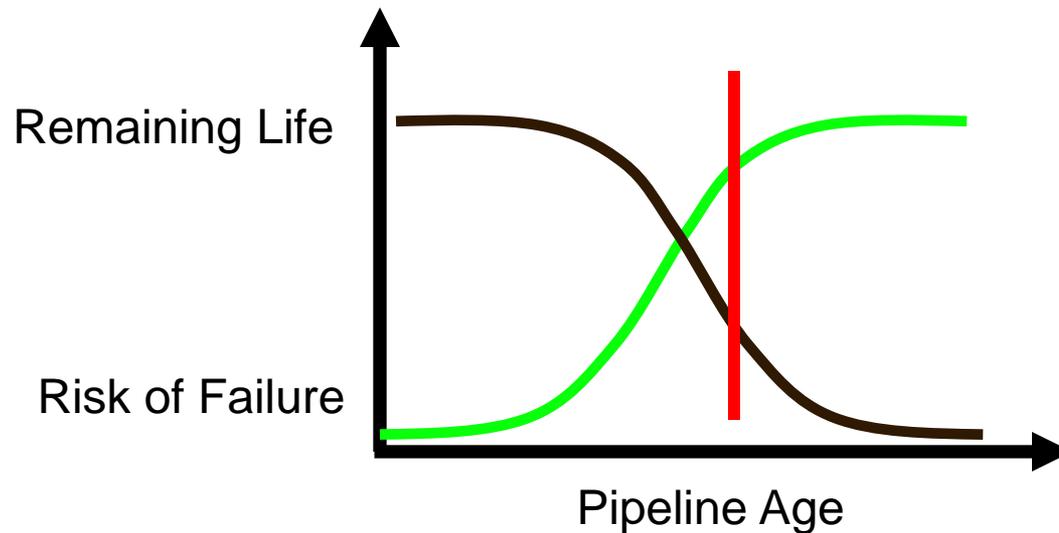
- Assess results of Phase 1 and Phase 2 testing
- Determine if additional segments should be brought forward into evaluation process before developing rehabilitation plan
- Determine if Phase 3 testing (fully intrusive) is needed

- Examples
 - Robotics – CCTV, laser profiling and scanning
 - In-line electromagnetic tools – Remote Field Eddy Current /Magnetic Flux Leakage (RFEC/MFL)
 - P-Wave / Remote Field Transfer Coupling (RFTC) PCCP only

Phase 3: Estimate Remaining Life

■ Goal:

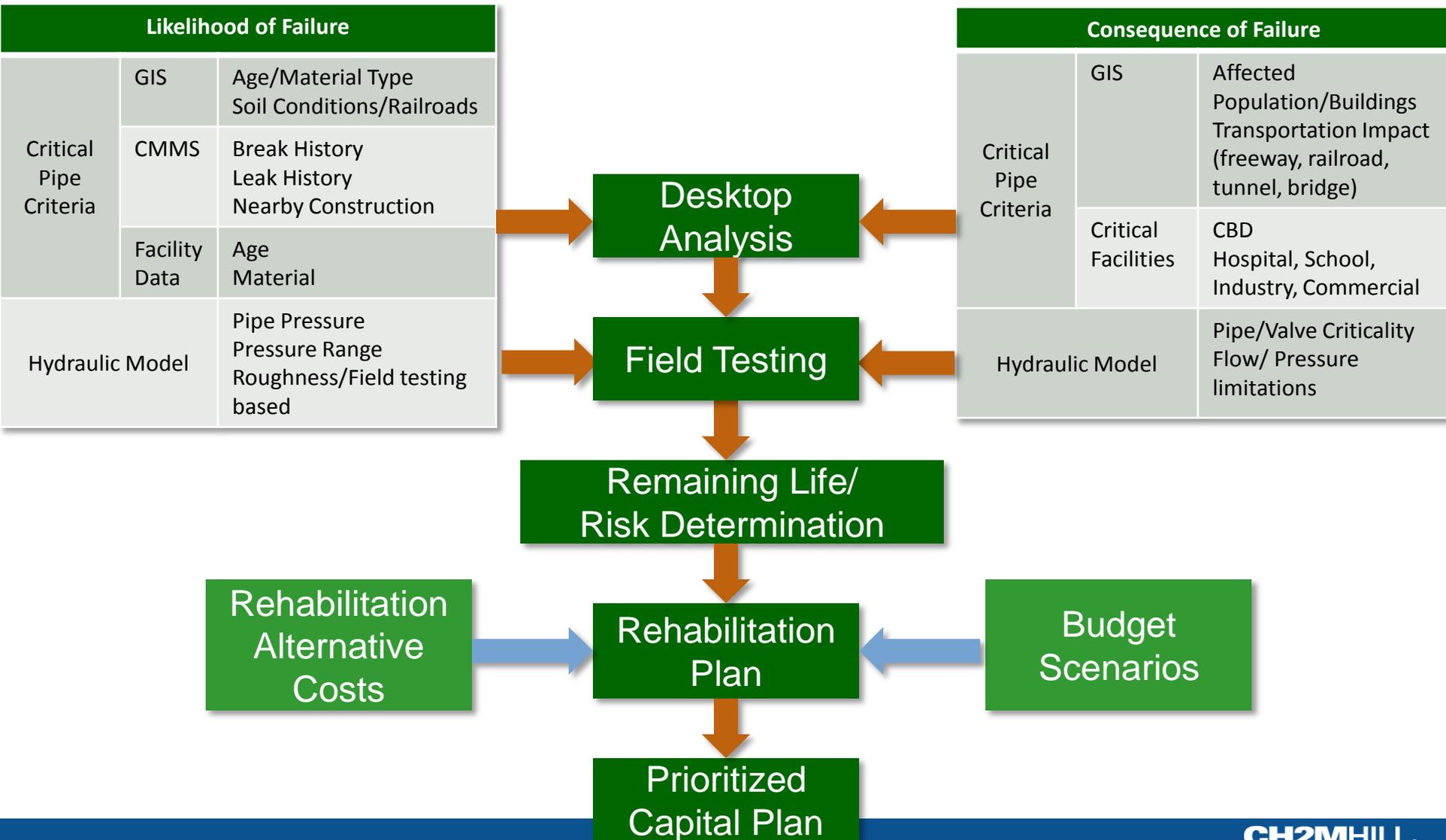
- Confirm collection of sufficient field data to estimate remaining life
 - Could be done after Phase 1 or Phase 2 if sufficient data available
- Remaining life supports identifying system improvements needs



Phase 4: Rehabilitate

- Develop and implement rehabilitation plan
 - Risk mitigation
 - Prioritization of focus from highest risk pipelines
 - Incorporate fiscal data
 - Rehabilitation Costs
 - Budget Scenarios
 - Develop Capital Plan

Phased approach provides step-wise process to make the best decisions about rehabilitation



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 - ***Field Technologies***
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Up Next Hour!!

Questions?